DRINKING WATER
SOURCE PROTECTION
ACT FOR CLEAN WATER

TRENT CONSERVATION COALITION
SOURCE PROTECTION REGION

Approved

Trent Assessment Report

Approved October 1, 2014
Effective January 1, 2015
Updated December 19, 2022

Volume 1 of 3

Trent Source Protection Areas:
Crowe Valley Source Protection Area
Kawartha-Haliburton Source Protection Area
Lower Trent Source Protection Area
Otonabee-Peterborough Source Protection Area

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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 2012), *Alderville First Nation*
Mae Whetung (Tracey Taylor to July 2008, Wanita Dokis to November 2008), *Curve Lake First Nation*

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

The Trent Conservation Coalition Source Protection Committee is a locally based committee comprised of 28 representatives from municipal government, First Nations, the commercial/industrial/agriculture sectors, and other interests. The committee's role is to develop source protection plans that establish policies for preventing, managing, or eliminating threats to sources of drinking water. In developing the plans, the committee members commit to the following:

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

<u>Current Membership (as of August 11, 2021)</u>

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, LTSPA *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*

ACKNOWLEDGEMENTS

The committee would like to thank staff of the following organizations for their contributions in preparing the Trent Source Protection Plan for the Trent source protection areas.

Conservation Authorities

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

Consultants & Others

- XCG Consultants Ltd.
- EarthFX Inc.
- GENIVAR (formerly Jagger Hims Ltd.)
- IBI Group
- AECOM Canada Ltd.
- 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
- Ontario Ministry of the Environment, Conservation and Parks
- Ontario Ministry of Natural Resources and Forestry
- Conservation Ontario

Municipalities

The following municipalities are located, either partially or entirely, within the Trent Conservation Coalition Source Protection Region. Ongoing communication has occurred with municipalities throughout the source protection planning process. Many have been involved with the development of the Trent Source Protection Plan.

- Township of Algonquin Highlands
- Township of Alnwick/Haldimand
- Township of Asphodel-Norwood
- Municipality of Brighton
- Township of Brock
- Township of Cavan Monaghan
- Municipality of Centre Hastings
- Municipality of Clarington
- Town of Cobourg
- Township of Cramahe
- Township of Douro-Dummer
- Regional Municipality of Durham
- Municipality of Dysart et al
- Township of Faraday
- Municipality of Trent Lakes (formerly Township of Galway-Cavendish & Harvey)
- County of Haliburton
- Township of Hamilton
- County of Hastings
- Township of Havelock-Belmont-Methuen
- Municipality of Highlands East
- City of Kawartha Lakes
- Township of Limerick
- Municipality of Marmora and Lake
- Township of Minden Hills
- Township of North Kawartha
- County of Northumberland
- Township of Otonabee-South Monaghan
- City of Peterborough
- County of Peterborough
- Municipality of Port Hope
- City of Quinte West
- Township of Scugog
- Township of Selwyn (formerly Township of Smith-Ennismore-Lakefield)
- Township of Stirling-Rawdon
- Municipality of Trent Hills
- Township of Tudor and Cashel
- Township of Wollaston

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 three volumes: Volume I (Text), Volume 2 (Appendices), and Volume 3 (Maps). While some figures have been included in the text for illustrative purposes, the complete map set is in Volume 3.

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

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

The Assessment Report was developed from a number of background reports (see Appendix F) prepared by Conservation Authorities, municipalities, and consultants that have been completed in accordance with the *Clean Water Act* using the best available data. 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 developed by the Ministry of the Environment and Climate Change.

Technical Rules

The Technical Rules sets out the requirements for the Assessment Report. These rules are referred to throughout this report. The Technical Rules is available on the Ministry of the Environment and Climate Change website: ***www.ene.gov.on.ca/en/water/cleanwater***

Public Consultation

The draft Proposed 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 Assessment Report was revised as appropriate. Following the revisions, the Proposed 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 Assessment Report to the Ministry of the Environment and Climate Change for review. The Proposed Trent Assessment Report was submitted on October 29, 2010.

During the winter of 2010-11, the document was updated to address data gaps and to reflect new information received since the October submission. Further, comments were received from the Ministry of the Environment and Climate Change in April 2011, which were addressed in the document. The Draft Amended Proposed Trent Assessment Report was submitted for public consultation from May 3 to June 4, 2011. Comments received were considered by the Source Protection Committee. The Amended Proposed Trent Assessment Report was submitted to the Source Protection Authorities for the Trent Source Protection Areas and then forwarded to the

Ministry of the Environment and Climate Change for review and consideration in June 2011. The Trent Assessment Report was approved by the Ministry of the Environment and Climate Change in October 2011.

In 2013, technical studies were carried out to update the wellhead protection area delineation, vulnerability assessment, and threats enumeration for the Keene Heights municipal drinking water system to account for the presence of a newly constructed municipal well. The Trent Assessment Report was updated to reflect the results of those technical studies and the updated document was submitted for public consultation from January 13 to February 14, 2014, including a public meeting in Keene Heights on January 30, 2014.

This Assessment Report will be used as a foundation for preparing the Trent Source Protection Plan. The purpose of the Trent Source Protection Plan is to eliminate or manage 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 Assessment Report is a summary of the technical studies undertaken in the Trent source protection areas – Crowe Valley, Kawartha-Haliburton, Lower Trent, and Otonabee-Peterborough – to meet the requirements of the *Clean Water Act, 2006* and associated *Technical Rules*.

The report includes the following elements:

- A watershed characterization for each source protection area that characterizes its human and physical geography, drinking water systems, terrestrial and aquatic characteristics, 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.

> ***Source Protection Area***
>
> *A source protection area is an area established under the Clean Water Act and generally is the same as the area over which a conservation authority has jurisdiction under the Conservation Authorities 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.*

The main findings of the Assessment Report are summarized below.

WATERSHED CHARACTERIZATION

The Trent source protection areas cover approximately 12,900 square kilometres (km^2) and encompass the entire Trent River watershed (except for about 114 km^2 of the Rice Lake watershed that is located in the Ganaraska Region Source Protection Area) and a small area that drains directly into Lake Ontario and the Bay of Quinte. Many of the major watercourses in the area form the navigation channel of the Trent-Severn Waterway.

The Trent source protection areas include a variety of physiographic regions that can generally be separated into two distinct areas based on the underlying bedrock. The north is covered with rocky landscapes associated with the Canadian Shield, and the south is underlain by limestone bedrock covered with various depths of overburden. The overburden was shaped by glacial activity into a variety of physiographic features including drumlins, eskers, and limestone plains. The largest physiographic regions in the watershed by area include (from north to south) the Algonquin Highlands, Georgian Bay Fringe, Dummer Moraines, and Peterborough Drumlin Field; together these four regions cover over 80% of the Trent source protection areas. Also of note is the presence of the Oak Ridges Moraine in the south; this is a unique physiographic feature that is the source of many streams in the watershed and is an important groundwater recharge area.

Natural vegetative cover in the Trent source protection areas includes about 7,500 km^2 of wetlands and 1,100 km^2 of woodlands. Vegetated riparian areas (including vegetated lands within 120 metres (m) of lakes, wetlands, and woodlands) cover about 5,300 km^2.

The total population of the Trent source protection areas is approximately 317,000. This total is made up of all or part of 36 municipalities and 7 First Nations reserves. The most populated settlements include Peterborough, Trenton, and Lindsay.

WATER BUDGET AND WATER QUANTITY STRESS ASSESSMENT

Water budget and water quantity stress assessment analyses were completed for the Trent River watershed. The results of this chapter provide insight into how water moves in the watershed and are useful for the management of water quantity. The study area included the four Trent source protection areas and the portion of the Ganaraska Source Protection Area that is located in the Trent River watershed.

Guidelines provided by the Province required a tiered approach to develop an understanding of groundwater and surface water quantities, flows, and stresses. This analysis included a Conceptual water budget, a Tier 1 water budget, and a Tier 2 water budget for selected subwatersheds. The Conceptual water budget provided an initial overview of water movement through the area at a broad scale and included a description of the physical setting of the area. The Tier 1 water budget expanded on the findings of the Conceptual water budget by calculating water budgets at a smaller scale and by evaluating the level of stress on water quantity in each subwatershed in the study area. The uncertainty associated with the Tier 1 water budget and water quantity stress levels was also evaluated.

> ***Water Budget***
>
> *A water budget quantifies the components of the hydrologic cycle including precipitation, evapotranspiration and human use of water. They are developed to evaluate the amount of water used versus the amount of water available in a watershed. If a detailed water budget indicates that a municipal system is stressed, risks to water quantity are identified.*

Most of the subwatersheds were found to have a low stress level in the Tier 1 water budget. The subwatersheds with municipal wells or intakes found to have a moderate or significant stress level were the following:

- Lindsay (includes all subwatersheds upstream of the Lindsay intake)
- Crowe 4 (subwatershed associated with Havelock municipal wells)
- Lake Ontario 1 (subwatershed associated with Colborne municipal wells)
- Lake Ontario 3 (subwatershed associated with Brighton municipal wells).

Tier 2 water budgets were prepared for these four subwatersheds using complex numerical models to confirm or negate the stress levels assigned in the Tier 1 analysis. All four of the subwatersheds were assigned a low stress level (with low uncertainty) in the Tier 2 analysis. As a result, no Tier 3 analyses are required and no water quantity threats are identified in the Trent River watershed.

VULNERABILITY ASSESSMENT

Groundwater Systems

There are 31 municipal well systems and 1 planned system in the Trent source protection areas:

- Crowe Valley Source Protection Area: 3 municipal well systems
- Kawartha-Haliburton Source Protection Area: 16 municipal well systems

- Lower Trent Source Protection Area: 4 municipal well systems
- Otonabee-Peterborough Source Protection Area: 8 municipal well systems and 1 planned system.

The wellhead protection area was delineated for each of the existing systems using a computer based three-dimensional groundwater flow model (MODFLOW). The wellhead protection area for the planned system was delineated using the uniform flow method. The vulnerability of the aquifers related to the municipal wells was assessed using index methods (Intrinsic Susceptibility Index and Aquifer Vulnerability Index) and advective transport methods. Vulnerability scores were assigned to each area in a wellhead protection area 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.

Wellhead Protection Area

A wellhead protection area is the surface and subsurface area surrounding a well that supplies a drinking water system. Contaminants can move through a wellhead protection area and eventually reach the well.

Surface Water Systems

There are 15 municipal surface water intakes in the Trent source protection areas:

- Crowe Valley Source Protection Area: 1 municipal surface water system
- Kawartha-Haliburton Source Protection Area: 6 municipal surface water systems
- Lower Trent Source Protection Area: 5 municipal surface water systems
- Otonabee-Peterborough Source Protection Area: 3 municipal surface water systems.

The surface water intakes in the Trent source protection areas are all located in inland rivers, streams, and lakes and were treated as Type C and Type D intakes (per the *Clean Water Act* definitions). Intake Protection Zones 1, 2, and 3 were delineated for each municipal surface water system. Intake Protection Zones 1 and 3 were delineated using linear calculations, and Intake Protection Zone 2 was delineated based on a 2-hour time of travel that was evaluated using a combination of dye studies, drogue studies, modeling, and extrapolation approaches.

Intake Protection Zone

An intake protection zone is an area in and adjacent to a lake or river, where contaminants can quickly reach a drinking water intake.

Since the Trent River watershed is so large and all of the municipal surface water intakes are located upstream or downstream of one or more of the other intakes, the Intake Protection Zone 3 for each system was truncated at the downstream boundary of the Intake Protection Zone 1 of the upstream intake. The Intake Protection Zone 3 for the Bayside intake includes all of the Intake Protection Zones and extends to the northernmost part of the watershed.

Vulnerability scores were assigned to each Intake Protection Zone based on the intake type and an area vulnerability factor that reflects the physical setting of the zone. Vulnerability scores are highest in Intake Protection Zones 1 and 2. Intake Protection Zones 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 in the Trent source protection areas. 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. 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 the 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.

> ***Aquifer***
> *An aquifer is a subsurface area of porous, permeable soil or rock – almost like a sponge – that can store and transmit significant amounts of groundwater.*

Significant Groundwater Recharge Areas

Significant groundwater recharge areas in the 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. Further, for subwatersheds subject to a Tier 2 water budget, the significant groundwater recharge areas were updated using a subwatershed-based threshold recharge method (using data from the computer models developed for the Tier 2). Significant groundwater recharge areas were assigned a vulnerability score of 6, 4, or 2 using the landscape-scale groundwater vulnerability analysis discussed above. A higher vulnerability score means that the aquifer is more susceptible to contamination. Maps of the significant groundwater recharge areas and vulnerability scores are provided in Volume 2.

> ***Significant Groundwater Recharge Area***
> *A Significant Groundwater Recharge Area is an area where a large amount of water moves downward from the surface to recharge an aquifer.*

DRINKING WATER ISSUES

Drinking water issues exist where the concentration of a contaminant at a surface water intake or well 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*. The following drinking water issue was identified in the Trent source protection areas:

- *E. coli* at the Stirling well system (Lower Trent Source Protection Area).

Issue contributing areas were identified for the Blackstock and Stirling systems. Activities in the contributing area that could contribute to the drinking water issue were identified as significant threats.

One additional concern was identified in the issues evaluation process: *Microcystin*-LR was identified as a potential issue at the Bayside surface water system (Lower Trent Source Protection Area), but additional water quality data is required to confirm that it is an issue. If confirmed, research would be required to determine the factors contributing to the issue.

DRINKING WATER THREATS

Areas in 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. The number of parcels at which a person is engaging in an activity that is or would be a significant drinking water threat at each municipal drinking water system is summarized in Table 1 for surface water threats and Table 2 for groundwater threats. In total, 1,662 prescribed drinking water threats have been identified on 1,006 parcels. A local threat, added by the Source Protection Committee with the approval of the Ministry of the Environment and Climate Change (see Appendix A), occurs on three additional properties. More specific details are provided in the table below.

Significant Drinking Water Threat

A drinking water threat is 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. Those activities that pose the greatest risk are termed "Significant Drinking Water Threats."

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

Table 1: Summary of Significant Drinking Water Threats for Surface Water Systems in the Trent Source Protection Areas

Drinking Water Threats		Source Protection Area				TOTAL
		Kawartha-Haliburton	Otonabee-Peterborough	Crowe Valley	Lower Trent	
No.	Prescribed Drinking Water Threats					
1	The establishment, operation or maintenance of a waste disposal site within the meaning of Part V of the *Environmental Protection Act*	1	3	0	3	**7**
2	The establishment, operation or maintenance of a system that collects, stores, transmits, treats or disposes of sewage	148	34	17	6	**205**
3	The application of agricultural source material to land	8	33	1	63	**105**
4	The storage of agricultural source material	2	11	0	28	**41**
5	The management of agricultural source material	0	0	0	0	**0**
6	The application of non-agricultural source material to land	0	0	0	0	**0**
7	The handling and storage of non-agricultural source material	0	0	0	0	**0**
8	The application of commercial fertilizer to land	0	0	0	0	**0**
9	The handling and storage of commercial fertilizer	0	0	0	0	**0**
10	The application of pesticide to land	8	14	0	42	**64**
11	The handling and storage of pesticide	1	5	0	8	**14**
12	The application of road salt	30	7	1	12	**50**
13	The handling and storage of road salt	0	0	0	0	**0**
14	The storage of snow	0	0	0	1	**1**
15	The handling and storage of fuel	3	3	0	6	**12**
16	The handling and storage of a dense non-aqueous phase liquid	0	0	0	0	**0**
17	The handling and storage of an organic solvent	0	0	0	0	**0**
18	The management of runoff that contains chemicals used in the de-icing of aircraft	0	0	0	0	**0**
21	The use of land as livestock grazing or pasturing land, an outdoor confinement area, or a farm-animal yard	3	32	1	60	**96**
	Total No. Significant Prescribed Drinking Water Threats	204	142	20	229	**595**
	Total No. Parcels Affected by Significant Prescribed Drinking Water Threats	167	83	18	108	**374**
Local Drinking Water Threats						
Maintaining open areas of mown grass for recreational activities that promote the congregation of waterfowl within or near surface water bodies		0	3	0	0	**3**
	Total No. Significant Local Drinking Water Threats	0	3	0	0	**3**
	Total No. Parcels Affected by Significant Local Drinking Water Threats	0	3	0	0	**3**
TOTAL (All Significant Drinking Water Threats)						
	Total No. Significant Drinking Water Threats	**204**	**145**	**20**	**211**	**598**
	Total No. Parcels Affected by Significant Drinking Water Threats	**167**	**86**	**17**	**108**	**377**

*Note: The total number of affected parcels is less than the total number of drinking water threats because more than one threat occurs on some parcels.

Table 2: Summary of Significant Drinking Water Threats for Groundwater Systems in the Trent Source Protection Areas

Drinking Water Threats		Source Protection Area				TOTAL
		Kawartha-Haliburton	Otonabee-Peterborough	Crowe Valley	Lower Trent	
No.	Prescribed Drinking Water Threats					
1	The establishment, operation or maintenance of a waste disposal site within the meaning of Part V of the *Environmental Protection Act*	1	0	1	0	**2**
2	The establishment, operation or maintenance of a system that collects, stores, transmits, treats or disposes of sewage	274	166	23	7	**470**
3	The application of agricultural source material to land	26	7	1	41	**75**
4	The storage of agricultural source material	6	1	0	7	**14**
5	The management of agricultural source material	0	0	0	0	**0**
6	The application of non-agricultural source material to land	1	0	0	0	**1**
7	The handling and storage of non-agricultural source material	0	0	0	0	**0**
8	The application of commercial fertilizer to land	72	0	0	0	**72**
9	The handling and storage of commercial fertilizer	4	0	0	0	**4**
10	The application of pesticide to land	20	6	2	3	**31**
11	The handling and storage of pesticide	3	0	0	0	**3**
12	The application of road salt	0	0	0	0	**0**
13	The handling and storage of road salt	0	0	0	0	**0**
14	The storage of snow	0	0	0	0	**0**
15	The handling and storage of fuel	195	93	22	23	**333**
16	The handling and storage of a dense non-aqueous phase liquid	3	0	9	0	**12**
17	The handling and storage of an organic solvent	1	0	0	0	**1**
18	The management of runoff that contains chemicals used in the de-icing of aircraft	0	0	0	0	**0**
21	The use of land as livestock grazing or pasturing land, an outdoor confinement area, or a farm-animal yard	8	3	0	35	**46**
Total No. Significant Prescribed Drinking Water Threats		614	276	58	116	**1064**
Total No. Parcels Affected by Significant Prescribed Drinking Water Threats		325	196	37	71	**629**
Local Drinking Water Threats						
None						**0**
TOTAL (All Significant Drinking Water Threats)						
Total No. Significant Drinking Water Threats		614	276	58	116	**1064**
Total No. Parcels Affected by Significant Drinking Water Threats		325	196	37	71	**629**

*Note: The total number of affected parcels is less than the total number of drinking water threats because more than one threat occurs on some parcels.

ADDITIONAL CONTENT

Great Lakes Considerations

A discussion is included on how the 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 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 this 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 this Assessment Report in the next 25 years include increases in the size 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 Assessment Report identifies a number of matters that affect other source protection areas and regions. These include wellhead protection areas that are located in both the Lake Simcoe Source Protection Area and the Kawartha-Haliburton Source Protection Area, and Intake Protection Zones that are located in both the Lower Trent Source Protection Area and the Quinte Source Protection Region. In addition, regional mapping of areas such as significant groundwater recharge areas and highly vulnerable aquifers are matters that need to be considered in consultation with the neighbouring source protection regions.

NEXT STEPS

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

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

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CHAPTER 10: Conclusions and Next Steps

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CHAPTER 1: INTRODUCTION

This Assessment Report has been prepared as a component of the source protection planning process for 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 (Figure 1-1) 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 prevent, 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 regulations 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 that 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 area 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 adjacent source protection areas 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

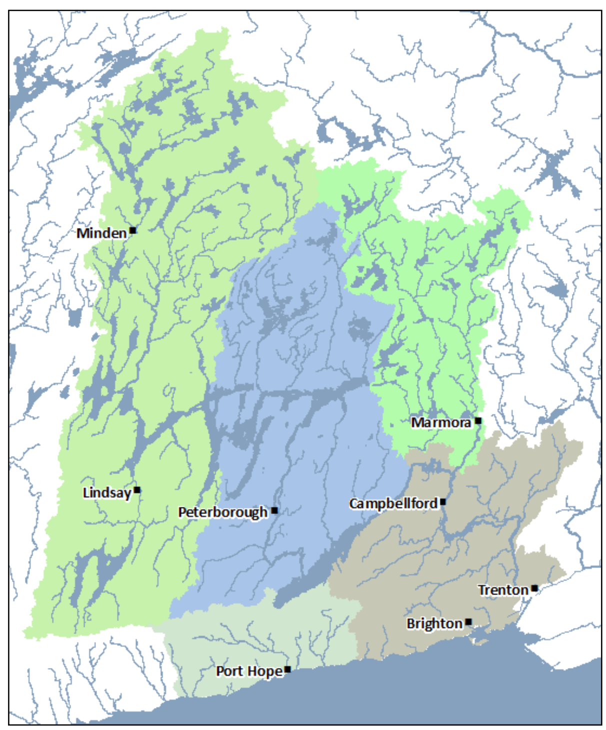
The Trent Conservation Coalition Source Protection Region (hereafter, the Region) has been established in accordance with the Act as a partnership among the Kawartha-Haliburton, Otonabee-Peterborough, Crowe Valley, and Ganaraska Region Source Protection Authorities, with the Lower Trent as the lead Source 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, which 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, which 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 shown on Map 1-1.

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; others act as reservoirs helping to regulate water supply. The waterway is owned and operated by Parks Canada and their management decisions can have a significant impact on water flows and levels throughout the Region.



The five Source Protection Areas that make up the Trent Conservation Coalition Source Protection Region (see also Map 1-1)

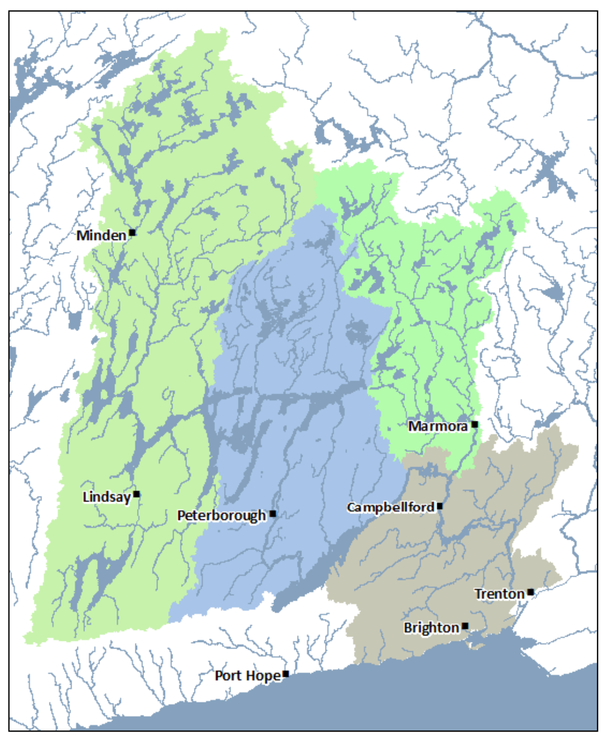
1.3 OVERVIEW OF SOURCE PROTECTION PLANNING PROCESS

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 been completed, publicly reviewed, approved by the Minister of the Environment and Climate Change, and is available on the Trent Conservation Coalition website. The Assessment Report is a technical document developed in accordance with the Terms of Reference 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 quantity and will identify who is responsible to take action, set timelines, and establish 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 Kawartha-Haliburton, Otonabee-Peterborough, Crowe Valley, and Lower Trent source protection areas. These source protection areas have been grouped into a single Assessment Report to maintain a focus on the Trent River watershed and to preserve linkages to the Trent-Severn Waterway. A separate Assessment Report has been developed for the Ganaraska Region Source Protection Area. Where technical studies performed in fulfillment of the Act have considered all five source protection areas, the Ganaraska Assessment Report will be cross-referenced as appropriate. The source protection areas that are the subject of this report are illustrated on Map 1-2.



The four source protection areas that are the subject of this Assessment Report (see also 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 and Climate Change, and the *Terms of Reference* for each of the four applicable source protection areas. 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 the *Technical Rules,* including watershed characterizations, water budgets, vulnerability assessments, issues identification, and threats assessments; it will provide a scientific basis for the development of policies in a Source Protection Plan.

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 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 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 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 Trent Assessment Report occurred between June 2 and July 9, 2010 upon the completion of the Draft Proposed Trent Assessment Report and again in September and October 2010 when the Proposed Trent Assessment Report was submitted to the source protection authorities. Public consultation on the Draft Amended Proposed Trent Assessment Report occurred in May and June 2011 prior to submission to the source protection authorities and the Ministry of the Environment and Climate Change in June 2011.

Further public consultation occurred between January 13 and February 14, 2014 regarding updates to the Trent Assessment Report to include a newly drilled well for the Keene Heights drinking water system.

1.6 PROJECT TIMELINE

The Act establishes timelines for the source protection planning process. The Assessment Report is 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 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 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 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.

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, 2006								

CHAPTER 2: WATERSHED CHARACTERIZATION

2.1 INTRODUCTION

A watershed is the area of land that drains to a waterbody. A watershed characterization is an overview of a watershed that includes a description of its geography and natural features, a summary of the drinking water systems, and a characterization of its water quality (based on the available data). This chapter includes the water characterizations for the four Trent source protection areas.

2.1.1 OVERVIEW

This section describes the main headings used in the watershed characterizations for the four Trent source protection areas and summarizes the watershed characterization for the Trent River watershed and the portions of the Lower Trent Source Protection Area that flow directly into Lake Ontario and the Bay of Quinte. The detailed watershed characterizations for each of the four source protection areas are provided in Sections 2.2 to 2.5.

1.0 Overview of Source Protection Area [Technical Rules 16(1) & 16(2a)]

This section describes the watershed and subwatershed boundaries and provides a general overview of the source protection area. Maps are provided for watershed and subwatershed boundaries.

Summary for the Trent River Watershed

The Trent source protection areas include the Crowe Valley, Otonabee-Peterborough, Kawartha-Haliburton, and Lower Trent Source Protection Areas. Together these areas cover a total of about 12,900 km^2 and they encompass the entire Trent River watershed (except for about 114 km^2 of the Rice Lake watershed that is located in the Ganaraska Region Source Protection Area). Many of the major watercourses in the area form the navigation channel of the Trent-Severn Waterway.

2.0 Human and Physical Geography [Technical Rules 16(2a-e); 16(9)-16(11); 17; O. Reg. 287/07 S.13(1)(1)]

This section addresses the *Technical Rules* related to human geography (areas of settlement and the boundaries and populations of municipalities and First Nations reserves) and physical geography. Maps are provided for all of these features.

Summary for the Trent River Watershed

The Trent source protection areas include a variety of physiographic regions that can generally be separated into two distinct areas based on the underlying bedrock: the north is covered with rocky landscapes associated with the Canadian Shield and the south is underlain by limestone bedrock covered with various depths of overburden. The overburden was shaped by glacial activity into a variety of physiographic features (including drumlins, eskers, and limestone plains). The largest physiographic regions in the watershed by area include (from north to south) the Algonquin Highlands, Georgian Bay Fringe, Dummer Moraines, and Peterborough Drumlin Field; together these four regions cover over 80% of the Trent source protection areas. Also of note is the presence of the Oak Ridges Moraine in the south; this unique physiographic feature is the source of many streams in the watershed and is an important area for groundwater functions. The coverage of physiographic regions in the Trent source protection areas is summarized in Table 2.1-1.

Table 2.1-1: Physiographic Regions in the Trent Source Protection Areas

Physiographic Region	Area (km^2)	% Total
Algonquin Highlands	3387	26.3
Peterborough Drumlin Field	3230	25.1
Georgian Bay Fringe	2390	18.6
Dummer Moraines	1583	12.3
Iroquois Plain	1069	8.3
Schomberg Clay Plains	418	3.2
Oak Ridges Moraine	261	2.0
Carden Plain	232	1.8
South Slope	208	1.6
Napanee Plain	79	0.6
Prince Edward Peninsula	9	0.1

The total population of the Trent source protection areas is approximately 317,000. This total is made up of all or part of 36 municipalities and seven First Nations reserves. The most populated settlements include Peterborough, Trenton, and Lindsay. An estimate of the population in each source protection area is listed in Table 2.1-2. Federal lands in the Trent source protection areas include Canadian Forces Base Trenton and lands along the Trent-Severn Waterway.

Table 2.1-2: Approximate Population of the Trent Source Protection Areas

Source Protection Area	Approximate Population	% Total
Otonabee-Peterborough	129,299	40.8
Kawartha-Haliburton	99,021	31.2
Lower Trent	78,457	24.7
Crowe Valley	10,490	3.3

3.0 Overview of Drinking Water Systems [Technical Rules 16(3)(a-e)]

This section of the watershed characterization identifies the drinking water systems in the source protection area, their classifications in accordance with the *Drinking Water Systems Regulation* (*O. Reg. 170/03)*, their average pumping rates, and the location of monitoring wells related to these systems. Maps are provided for municipal residential drinking water systems and for other drinking water systems.

Summary for the Trent River Watershed

Drinking water systems in the Trent source protection areas 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 *Safe Drinking Water Act, 2002* based on ownership, number of users, flow rate, annual operating period, and type of facility served. The number of drinking water systems of each classification is listed by source protection area in Table 2.1-3. About 43% of the population of the Trent source protection areas are served by 47 municipal residential drinking water systems (including the "large municipal residential" and "small municipal residential" classifications); this includes 31 groundwater systems and 16 surface water systems.

Table 2.1-3: Drinking Water Systems in the Trent Source Protection Areas

Safe Drinking Water Act Classification	Number of Drinking Water Systems				
	ORCA	LTSPA	KHSPA	CVSPA	Total
Large municipal residential	10	10	16	3	39
Small municipal residential	1	0	6	1	8
Large municipal non-residential*	1	0	0	0	1
Small municipal non-residential*	33	0	39	11	83
Non-municipal year-round residential*	12	18	18	3	51
Non-municipal seasonal residential*	30	29	29	6	94
Large non-municipal non-residential*	1	0	0	0	1
Small non-municipal non-residential*	98	130	130	12	370

*Estimated from Ministry of the Environment and Climate Change Drinking Water Information System database

4.0 Terrestrial and Aquatic Characteristics [Technical Rules 16(4)-16(7)]

This section of the watershed characterization describes the natural vegetative cover (including wetlands, woodlands, and vegetated riparian areas) and aquatic habitats (including the fisheries and macroinvertebrate communities) in the source protection area. Maps are provided for wetlands and woodlands, vegetated riparian areas, stream temperature, Simpson's species diversity index, and Hilsenhoff water quality index.

Summary for the Trent River Watershed

Natural vegetative cover in the Trent source protection areas includes about 7,500 km^2 of wetlands and 1,100 km^2 of woodlands. Vegetated riparian areas (including vegetated lands within 120 metres (m) of lakes, wetlands, and woodlands) cover about 5,300 km^2. The coverage of wetlands, woodlands, and vegetated riparian areas is indicated in Table 2.1-4.

Table 2.1-4: Natural Vegetative Cover in the Trent Source Protection Areas

Natural Vegetative Cover Type	Area (km^2)				
	OPSPA	KHSPA	LTSPA	CVSPA	Total
Wetlands	346	343	217	192	1,098
Woodlands	1,674	3,537	715	1,548	7,474
Vegetated Riparian Areas	1,362	2,188	625	1,115	5,290

5.0 Surface Water and Groundwater Quality [Technical Rules 16(8)-16(9) & 18]

This section of the watershed characterization summarizes the available surface water and groundwater quality data in the source protection area. The most comprehensive sources of data are the Provincial Water Quality Monitoring Network (for surface water) and the Provincial Groundwater Quality Monitoring Network (for groundwater). Data tables are provided that summarize the data from both of these sources. Maps are provided for the locations of surface water and groundwater quality monitoring network stations. Other miscellaneous sources of data are also summarized, including the Drinking Water Information System database, sampling data from municipal water treatment plants, and regional groundwater quality studies.

2.1.2 INFORMATION TO SUPPORT CONTINUAL IMPROVEMENT

Available information was used to complete the characterization of the source protection areas as required by the *Technical Rules*. Improvements to the characterization could be made with more data.

Ecological Land Classification

Mapping of land cover could be improved if ecological land classification mapping was completed for all source protection areas in the region.

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 limited data available that indicate the locations and types of aquatic habitats in the source protection areas. Stream temperature, Simpson's Diversity Index, and Hilsenhoff's Water Quality Index were used as an indicator 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 of the source protection areas 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 for all source protection areas in the region.

Continuation of the benthic macroinvertebrate surveys conducted by Conservation Authorities 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.

2.2 KAWARTHA-HALIBURTON SOURCE PROTECTION AREA

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. This is the watershed characterization of the Kawartha-Haliburton Source Protection Area, and it has been prepared in accordance with the *Clean Water Act*, *2006*, *O. Reg. 287/07*, and Part II of the *Technical Rules*. This watershed characterization draws from earlier documents prepared before the publication of the *Technical Rules* and has expanded on them where required to satisfy the legislation. The reports were prepared in 2008 by Kawartha Conservation and are entitled:

- *Watershed Characterization Report: Kawartha-Haliburton Source Protection Area (Kawartha Conservation Watershed)*
- *Watershed Characterization Report: Kawartha-Haliburton Source Protection Area (Burnt & Gull River Watersheds).*

2.2.1 OVERVIEW OF SOURCE PROTECTION AREA

The Kawartha-Haliburton Source Protection Area covers an area of 5,406 km^2 and is located within the southcentral region of Ontario, fringing on the Greater Toronto Area to the south and Algonquin Park to the north. The west-east extent stretches from Lake Simcoe to Pigeon Lake. The source protection area is divided into two physically distinct areas by geologic features: the Precambrian Shield in the north and the Paleozoic limestone plateau in the south. The northern portion is characterized by Precambrian Shield features such as faults, dips, and complex folds that originated during a mountain building phase about 550 million years ago. The Precambrian bedrock that is visually apparent in this region disappears from view in the southwesterly direction and is overlain by younger sedimentary rocks in the south that were deposited by a large ocean that existed during the Ordovician period about 480-460 Million years ago (Turnstone Geological Services Ltd., 2008). The boundary between these two different bedrock formations is approximately marked by the northern shorelines of the Kawartha Lakes. The Kawartha-Haliburton Source Protection Area and its subwatersheds are shown on Maps 2-1(KH) and 2-2(KH), respectively.

2.2.2 GEOGRAPHY AND LAND USE

2.2.2.1 PHYSICAL GEOGRAPHY

The current landscape of the source protection area owes its character to approximately 800,000 years of glacial activity that occurred during the Pleistocene epoch; this glacial activity shaped a highly variable landscape. Massive ice sheets that covered the area and the meltwaters of retreating glaciers shaped many of the present surface features found in the Kawartha-Haliburton Source Protection Area. The recession of the most recent Wisconsinan glaciation, particularly the recession of the Lake Simcoe ice lobe, greatly affected the landscape of the source protection area by leaving behind moraines, eskers, drumlins, and other glacial features. The source protection area is divided into several different physiographic regions including the Oak Ridges Moraine, Peterborough Drumlin Field, Schomberg Clay Plain, Carden Plain, Dummer Moraine, Georgian Bay Fringe, and Algonquin Highlands. Physiographic regions in the source protection area are shown on Map 2-3(KH), and the percent coverage of each physiographic feature is identified in Table 2.2-1. Physical characteristics of subwatersheds are summarized in Table 2.2-2.

The Oak Ridges Moraine is one of the key landforms in the Kawartha-Haliburton Source Protection Area, supporting many of the best groundwater-fed headwater systems in the area that flow into streams in the southern portion of the source protection area. The Oak Ridges Moraine is classified as an interlobate moraine in which sediments were deposited between two oscillating ice sheets about 12,000 years ago. The moraine is composed of differing till deposits that vary in silt, sand, and clay content.

To the north of the Oak Ridges Moraine is the Peterborough Drumlin Field, where three to four thousand drumlins are present in the overall physiographic region (Chapman & Putman, 1984; Jalava et. al, 2001). Drumlins typical to this area are elongated, low-lying hills. They are composed of highly calcareous glacial till that consists of sands and gravels, and their general orientation is from northeast to southwest.

The Schomberg Clay Plain is a relatively flat, dish-shaped area, bound by the Peterborough Drumlin Field to the west, north, and east, and by the Oak Ridges Moraine to the south, that was created by the deposition of clay and silt sediments of glacial Lake Schomberg (Singer, S.N., Cheng, C., & Scafe, M., 2003). The majority of the clay and silt deposits measure an average depth of 5 metres in thickness, however in some locations, the thickness reaches up to 8 metres.

The Carden Plain is located between Lake Simcoe and Balsam Lake north of the Peterborough Drumlin Field. The Carden Plain supports an alvar community, which indicates an open habitat environment situated on a limestone plain with a thin layer of soil. The landscape is distinctly unique and is comprised primarily of grass, shrubs, and wildflowers that provide habitat for many species such as butterflies, dragonflies, and birds.

The Algonquin Highlands is a subdivision of the Precambrian Canadian Shield physiographic region. A thin layer of soil overlies the Precambrian bedrock that is fractured by several faults. These fracture lines are often covered by lakes and rivers. The Gull River, for example, runs along a fault line for most of its length.

The Georgian Bay Fringe physiographic region is located between the Algonquin Highlands and the Carden Plain. It is characterized by bare rock knobs, ridges, scanty drift coverings and shallow soil (Singer et al., 2003). Thin overburden (less than 10 metres in depth) was eroded during glaciations; this exposed the underlying limestone at various locations. The grinding and abrasive activity of the moving ice scoured depressions into the bedrock and resulted in the numerous lakes and wetlands that exist today (Adams, P. & Taylor, C., 1992). This physiographic region contains granites and gneisses that give a rugged appearance to the landscape associated with the Precambrian Shield. There are also some areas with limited amounts of fine sand, silt, and clay loams (Chapman & Putnam, 1984).

The Dummer Moraine occupies the southern portion of the Burnt River subwatershed between the Georgian Bay Fringe (to the north) and the Carden Plain (to the west). A limestone plain mostly overlain with shallow overburden characterizes this physiographic region. The Dummer Moraine is an area of jagged stony land running along the southern border of the Canadian Shield from the Kawartha Lakes eastward to Kingston (Chapman & Putman, 1984). The till is composed of coarse boulders and sandy materials, and several bedrock outcrops occur throughout the area north of the Kawartha Lakes. Both Paleozoic and Precambrian rock fragments are found in the till, and the area is generally characterized by rough topography with low moraine ridges that are comprised of stony soil.

Table 2.2-1: Physiographic Regions in the Kawartha-Haliburton Source Protection Area

Physiographic Region	Area (km^2)	Land Coverage (%)
Algonquin Highlands	2,100.8	38.9
Carden Plain	231.7	4.3
Dummer Moraine	321.5	5.9
Oak Ridges Moraine	102.0	1.9
Schomberg Clay Plain	417.8	7.7
Georgian Bay Fringe	742.8	13.7
Peterborough Drumlin Field	1,489.4	27.6

Data Source: Calculated using data supplied under license by members of the Ontario Geospatial Data Exchange

2.2.3 HUMAN GEOGRAPHY: POPULATION AND LAND USE

2.2.3.1 AREAS OF SETTLEMENT

The *Places to Grow Act, 2005* provides a legislative framework for the development of growth plans in designated growth areas. The Act provides the following definition for 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.*" Areas of settlement in the Kawartha-Haliburton Source Protection Area are shown on Map 2-4(KH).

2.2.3.2 MUNICIPALITIES

There are eleven municipalities located within or partially within the Kawartha-Haliburton Source Protection Area. The total population of these municipalities is 140,580 (Statistics Canada, 2006), and about 99,021 of them are located within the source protection area boundary. Population is typically concentrated in the larger urban developments in the southern part of the Kawartha-Haliburton Source Protection Area such as Port Perry, Lindsay, Fenelon Falls, and Bobcaygeon. The majority (2,826 km^2) of the source protection area has a population density of less than 25 people per square kilometre. There is a seasonal increase of population of about 50% in the portion of the source protection area located in Haliburton County during the summer months. Municipalities located in the source protection area, their total population and area, and the portion of their population and area located in the source protection area are listed in Table 2.2-3. Municipal boundaries, populations, and population densities in the source protection area are shown on Maps 2-5(KH), 2-6(KH), and 2-7(KH), respectively.

2.2.3.3 FIRST NATIONS

The Mississaugas of Scugog Island First Nation, located at the northern tip of Scugog Island, is the only First Nation reserve in the Kawartha-Haliburton Source Protection Area. The population of the reserve is 72 (Statistics Canada, 2006) and its population density is about 30 people per square kilometre. The reserve is shown on Map 2-8(KH).

Table 2.2-2: Physical Characteristics of Kawartha-Haliburton Source Protection Area Subwatersheds

Subwatershed Name	Drainage Area (km^2)	Channel Length (km)	Total Fall (m)	Channel Average Slope (%)	Percent Land Cover			Physiographic Region(s)
					Wetlands	Lakes	Woodland	
								Gull River
Upper Gull River	564.51	73.92	150.64	0.20	2.36	15.89	76.30	Algonquin Highlands
Redstone River	235.47	50.19	147.96	0.29	2.09	11.83	82.34	Algonquin Highlands
East Gull River	272.62	44.21	71.10	0.16	2.30	12.42	81.38	Algonquin Highlands
Lower Gull River	274.19	36.71	16.30	0.04	5.51	12.71	70.45	Georgian Bay Fringe
								Burnt River
Drag River	304.28	45.48	132.56	0.29	3.91	10.89	81.92	Algonquin Highlands
Burnt River	516.65	92.76	111.18	0.12	5.69	4.62	79.26	Algonquin Highlands
Irondale River	526.68	71.43	88.32	0.12	3.13	6.67	82.70	Algonquin Highlands; Georgian Bay Fringe
Union Creek	146.64	43.38	57.84	0.13	14.08	1.51	69.74	Georgian Bay Fringe; Dummer Moraine
Balsam Lake	157.85	N/A	N/A	N/A	5.62	30.42	32.52	Carden Plain
Staples River	48.24	18.47	16.27	0.09	7.61	0	14.84	Peterborough Drumlin Field
Corben Creek	68.38	23.54	36.44	0.15	6.81	11.52	56.61	Carden Plain
Cameron Lake	40.02	N/A	N/A	N/A	6.82	38.88	16.92	Peterborough Drumlin Field
Pearns Creek	43.84	17.77	23.5	0.13	6.20	0.41	23.43	Peterborough Drumlin Field
Martin Creek S.	41.87	12.41	1.63	0.01	14.90	0	29.42	Peterborough Drumlin Field
								Scugog River
Scugog River	61.98	13.44	2.51	0.02	5.47	2.31	4.73	Peterborough Drumlin Field
Mariposa Brook	233.20	39.89	22.61	0.06	8.99	0.39	13.67	Peterborough Drumlin Field; Schomberg Clay Plain
East Cross Creek	211.93	39.79	30.42	0.08	13.38	0.59	27.27	Peterborough Drumlin Field; Schomberg Clay Plain
Sturgeon Lake	375.42	N/A	N/A	N/A	8.18	12.51	32.22	Peterborough Drumlin Field
Emily Creek	160.63	27.13	14.9	0.05	17.80	2.20	15.74	Peterborough Drumlin Field
Pigeon Lake	102.06	N/A	N/A	N/A	8.68	23.92	23.72	Peterborough Drumlin Field
Pigeon River	296.50	53.65	58.05	0.11	10.08	1.64	27.27	Oak Ridges Moraine; Peterborough Drumlin Field
Nogies Creek	186.64	32.25	55.09	0.17	11.92	7.03	77.35	Dummer Moraine; Georgian Bay Fringe
Lake Scugog	340.59	N/A	N/A	N/A	10.65	19.99	15.32	Schomberg Clay Plain
Nonquon River	195.70	34.23	45.92	0.13	12.70	0.66	19.41	Oak Ridges Moraine;Peterborough Drumlin Field; Schomberg Clay Plain

Data Source: Calculated using data supplied under license by members of the Ontario Geospatial Data Exchange

Table 2.2-3: Municipal Populations in the Kawartha-Haliburton Source Protection Area

Municipality	Portion Within SPA		Entire Municipality	
	Area (km^2)	Population	Area (km^2)	Population
City of Kawartha Lakes	2,104	64,184	3,332	74,561
United Townships of Dysart et al	1,027	4,587	1,680	5,526
Township of Minden Hills	678	5,247	949	5,556
Municipality of Highlands East	469	1,689	758	3,089
Township of Scugog	443	20,133	519	21,439
Township of Galway-Cavendish and Harvey	346	1,153	970	5,284
Township of Algonquin Highlands	260	1,288	1,180	1,976
Township of Brock	36	609	421	11,979
Township of Cavan Monaghan	8	127	308	8,828
Township of North Kawartha*	2	4	844	2,342

*Located only marginally within the Source Protection Area
Data Source: Calculated from Statistics Canada, GeoSuite, 92-150-XCB, 2006 Census

2.2.3.4 INTERACTIONS BETWEEN HUMAN AND PHYSICAL GEOGRAPHY

The first signs of human activity in the Kawartha-Haliburton Source Protection Area can be traced back to about 2,100 years ago when the Hopewellian mound-builders, a semi-nomadic hunter-gatherer culture, occupied this area and engaged in agricultural practices on a small scale compared to current practices. The Hopewellians were displaced by the Iroquois about 1,000 years ago who in turn were driven south beyond Lake Ontario by the Algonquin and Huron peoples. By 1649, coinciding with the destruction of the Huron peoples, the area was largely vacated, and by the end of the century the Mississauga, a sub-tribe of the Ojibwa of the Algonquin people, began to move into the region (Edmison, 1978).

The Mississauga still occupied the area a century later when the first Europeans arrived (Francis, 1980). Early European interests in the area focused primarily on the fur trade. The Kawartha-Haliburton Source Protection Area, possessing over 250 rivers and lakes, was an ideal location for trapping beaver and trading with the First Nations communities in the area. These early explorers and fur traders paved the way for the settlers that were soon to follow. During the early 1800s, European settlers moved progressively north from Lake Ontario. Early settlement revolved around two activities: agriculture and forestry. Settlers, once having purchased land, were eager to clear the forests and begin agricultural practices. Clearing of the land for agriculture was often indiscriminate and wasteful of the timber resources. Clearing of lands was followed by an increased need for gristmills and timber mills. In 1825, William Cottingham built a mill on Pigeon River and founded the town that is now Omemee. In 1828, William Purdy dammed a rapid on the Scugog River and established Lindsay. Bobcaygeon resulted from the construction of a mill by Thomas Need in 1833, and in 1841 Messrs. Wallis and Jamieson erected a mill in Fenelon Falls (Kirkconnell, 1920). Thus began the era of timber harvesting and settlement that was to shape not only the communities but also the landscape of the Kawartha Region.

The increased demand for transportation of timber to mills and the markets beyond was the impetus behind the construction of the Trent-Severn Waterway and the building of railways. In 1857 the first railway from Port Hope to Lindsay was constructed and in 1871 it was extended to Beaverton. In 1872 the Victoria Railway was proposed, which was meant to run from Lindsay through Haliburton to join the Canada Pacific Railway (CPR) transcontinental railway at Mattawa, but the project was subject to the political and fiscal realities of the day and the terminus, completed in 1876, never extended beyond Haliburton. Railway construction continued in the latter half of the nineteenth century with the extension of the Whitby-Port Perry line through Manilla and into Lindsay in 1877. In 1886 the Irondale Bancroft Branch was constructed, and finally the Manilla-Whitby line was connected at Blackwater to the Toronto-Nipissing line creating, with the construction of a bridge over the Scugog River, a through service from Port Hope to Toronto via Lindsay and Blackwater (Kirkconnell, 2008).

The extension of rail service had the unexpected yet significant benefit of opening the Kawartha Lakes region to tourists, athletes, and summer vacationers. The Trent-Severn Waterway provided access to shoreline areas that became dotted with cottages and resort hotels that catered to the influx of summer vacationers.

Today, agriculture, urban development, recreation, and tourism are still the major activities in the Kawartha-Haliburton Source Protection Area. The rapid clearing of the forested landscape for agricultural land use practices resulted in a diminishment of forest areas and an increase in fragmentation that is especially evident in the southern part of the Kawartha-Haliburton Source Protection Area. Larger forested areas can still be found in the Precambrian Shield in the northern part of the watershed and in the Oak Ridges Moraine in the south.

2.2.3.5 FEDERAL LANDS

In the Kawartha-Haliburton Source Protection Area, lands that are under the jurisdiction of the Government of Canada include lands along the Trent-Severn Waterway (including lands located at the bottom of lakes on the waterway), managed by Parks Canada. Federal lands in the watershed are shown on Map 2-9(KH).

2.2.4 OVERVIEW OF DRINKING WATER SYSTEMS

Drinking water systems in the Kawartha-Haliburton 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 *Safe Drinking Water Act, 2002* 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. About half of the population of the source protection area relies 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.

2.2.4.1 MUNICIPAL RESIDENTIAL DRINKING WATER SYSTEMS

About 45% of the population in the Kawartha-Haliburton Source Protection Area (38,050 people) obtains their drinking water from 22 municipal residential drinking water systems. These systems are discussed in more detail below, and their locations and approximate service areas are shown on Map 2-10(KH).

2.2.4.1.1 Surface Water Systems

There are six existing municipal residential drinking water systems in the source protection area that obtain their water from surface water sources. These systems serve about 22,350 people. Under the *Drinking-Water Systems Regulation* (*O. Reg. 170/03)*, four of these systems are classified as large municipal residential systems and the remaining two are classified as small municipal residential systems. These systems are discussed in detail in Chapter 4.

2.2.4.1.2 Groundwater Systems

There are 16 existing municipal residential drinking water systems in the source protection area that obtain their water from groundwater sources. These systems serve about 15,700 people. Under the *Drinking-Water Systems Regulation (O. Reg. 170/03)*, half of these systems are classified as large municipal residential systems and the other half are classified as small municipal residential systems. These systems are discussed in detail in Chapter 5.

Four of these systems draw water from a total of eight wells that are considered to be groundwater under the direct influence (GUDI) of surface water. All three wells in the Canadiana Shores supply system and one well of the Sonya supply system have been identified as GUDI wells without effective in-situ filtration (i.e., soils do not adequately remove microorganisms) as a result of a GUDI assessment. Both wells of the Manorview supply system are considered GUDI as a result of a hydrological appraisal that suggested that minor pathways may exist between the system and a surface waterbody. The two Pleasant Point supply system wells have been classified as GUDI because of a lack of documentation of well sealing and grouting procedures.

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.

2.2.4.2 OTHER DRINKING WATER SYSTEMS

There are about 216 drinking water systems in the Kawartha-Haliburton Source Protection Area that are classified as non-municipal or non-residential systems under the *Drinking-Water Systems Regulation (O. Reg. 170/03)* (e.g., trailer parks, campgrounds, subdivisions, community centres, schools, and public buildings). Estimates of the number of systems of each non-municipal and non-residential classification is given in Table 2.2-4A. Details for many of these systems are given in Appendix B, and their locations are shown on Map 2-11(KH). (Note that these systems were identified from the Drinking Water Information System database, which 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.)

2.2.4.3 FIRST NATIONS SYSTEMS

All residents of the Mississaugas of Scugog Island First Nation are served by private wells. Systems that are owned and operated by the First Nation are listed in Table 2.2-4B; these are not classified under the Provincial *Drinking-Water Systems Regulation (O. Reg. 170/03*).

Table 2.2-4A: Other Drinking Water Systems in the Kawartha-Haliburton SPA

Safe Drinking Water Act Classification	Estimated No. Systems
Large municipal non-residential	0
Small municipal non-residential	39
Non-municipal year-round residential	18
Non-municipal seasonal residential	29
Large non-municipal non-residential	0
Small non-municipal non-residential	130

Data Sources: Ministry of the Environment and Climate Change Drinking Water Information System (March 19, 2009); Durham Region Water Bill Accounts (2008); Annual Drinking Water Reports (2008)

Table 2.2-4B: Mississaugas of Scugog Island First Nation Drinking Water Systems

System	Users Served (approximate)
Administration Building	18
Health & Resource Centre	10
Great Blue Heron Charity Casino – Staff and patrons	Average 1000 Max Cap 2500

2.2.5 TERRESTRIAL AND AQUATIC CHARACTERISTICS

2.2.5.1 NATURAL VEGETATIVE COVER

Healthy watersheds include a variety of vegetation types and communities that are well distributed across the landscape. Wetlands, wooded areas, and riparian areas can protect drinking water sources by trapping sediments and soils and altering or reducing contaminants, nutrients, and some pathogens, before contributing to surface and groundwater sources. 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 2.2-5. Wetlands and woodlands are shown on Map 2-12(KH) and vegetated riparian areas are shown on Map 2-13(KH).

Table 2.2-5: Natural Vegetative Cover in the Kawartha-Haliburton Source Protection Area

Physiographic Region	Area (km2)	% Total Area
Wetland	324.23	6
Woodland	2902.49	54
Vegetated Riparian Area[1]	2188.18	40

[1]Vegetated riparian areas include vegetated lands located within 120 m of lakes, wetlands, and watercourses
Data Sources: Ministry of Natural Resources and Forestry (MNRF); Ecological Land Classification data from Kawartha Region Conservation Authority (KRCA)

Wetlands

Wetlands found in the Kawartha-Haliburton Source Protection Area include a variety of swamps, bogs, and marshes. Wetlands perform a significant role in improving water quality by contributing to groundwater recharge and 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 6% of the source protection area (324 km^2), which includes 4.8% Provincially Significant Wetlands that cover 259.18 km^2. In the northern portion of the source protection area, a large number of small wetlands are interspersed along the length of most watercourses due to the rough topography of the Canadian Shield. As a result of the sluggish nature of watercourses, poor infiltration conditions, and high water tables, large wetlands still exist in the southern portion of the source protection area despite the employment of draining practices used to increase the land available for agricultural purposes. These wetlands typically occur among the Peterborough Drumlin Fields, Schomberg Clay Plain, and Dummer Moraine areas. Smaller, isolated wetlands are located in the headwaters of streams throughout the southern portion of the source protection area. Wetlands in the source protection area are shown on Map 2-12(KH).

Woodlands

Woodland cover in the Kawartha-Haliburton Source Protection Area includes successional and climax forests, such as coniferous or deciduous hardwood forests, hedgerows, and plantations. Woodland vegetation prevents erosion by stabilizing soils and acting as a natural shelterbelt. This protects water quality by preventing sedimentation of watercourses. Woodlands cover most (65.4%) of the Kawartha-Haliburton Source Protection Area. In the southern portion of the Kawartha-Haliburton Source Protection Area, much of the woodland cover is located in the low-lying, marginal lands adjacent to watercourses or on the steep slopes of the Oak Ridges Moraine. Similar to wetland drainage, woodlands were cleared in the past to facilitate agricultural activities; this resulted in their fragmentation into isolated patches of varying sizes and shapes. Due to the limited overburden in the Canadian Shield and, as a result, its limited agricultural capacity, the upper half of the source protection area is almost entirely covered by woodlands. Woodland cover in the source protection area is shown on Map 2-12(KH).

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 they 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. Healthy riparian areas provide multiple benefits with respect to surface water health and ecological diversity. Vegetated riparian areas in the watershed were delineated as vegetated lands located within 120 m of lakes, wetlands, and watercourses. Riparian areas in the watershed are shown on Map 2-13(KH).

2.2.5.2 AQUATIC HABITATS

Aquatic habitats are the areas 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. The location and types of aquatic habitats in the Kawartha-Haliburton Source Protection Area are discussed in the following sections.

2.2.5.2.1 Fisheries

Location of Habitats

There are limited data available that indicate the confirmed location of aquatic habitats in the watershed, however stream temperature can be used as an indicator to identify the potential locations of aquatic habitats. 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, 2009). Stream temperatures in the Kawartha-Haliburton Source Protection Area are shown on Map 2-14(KH).

Generally, lakes in the southern portion of the source protection area support warm water fish species whereas lakes located in the northern part support cool water or cold water fisheries. This is largely due to the fact that lakes to the south of the Canadian Shield are shallow (less than 10 m), and the development of distinct stratification is prevented as the wind sufficiently mixes the water. Warm water fish species such as Largemouth and Smallmouth Bass, Muskellunge, Walleye, Pumpkinseed, Minnows, Yellow perch, Bluegill, Common Carp, White Sucker, and Central Mudminnow are common to Lake Scugog, Pigeon Lake, Sturgeon Lake, Cameron Lake, and their connecting rivers. In contrast, lakes in the northern portion of the Kawartha-Haliburton Source Protection Area are often extremely deep and thus develop significant layering that provides cold temperatures throughout the year. Cold water habitats support species such as Brook Trout, Lake Trout, Rainbow Trout, Sculpin, Lake Whitefish, Burbot, and Smelt.

Cold water habitats in streams in the source protection area are localized to headwater streams originating on or in close proximity to the Oak Ridges Moraine or to small, isolated tributaries such as Martin, Potash, and Emily Creeks, where groundwater is the main contributor to stream flow.

Species such as Brook Trout and Mottled Sculpin are the dominant fish species within the small cold water tributaries. In contrast, warm water streams are ubiquitous and dominated by various species of Minnows (Ministry of Natural Resources and Forestry, 2005).

Impacts of Development on Fish Habitat

Land development can have a dramatic impact on aquatic habitats. Some of the changes that result from development include increased storm water runoff. This can lead to erosion, increased water temperatures, and entering of pollutants into waterways, all of which may result in habitat loss. Impacts on riparian cover, such as the removal of forest and plants, can compromise cold water fish habitats by increasing stream temperatures and runoff.

The northern portion of the Kawartha-Haliburton Source Protection Area experiences less pressure in regard to urbanization and agricultural activities, and much of the natural vegetative cover adjacent to rivers, lakes, and wetlands remains intact.

The southern portion of the Kawartha-Haliburton Source Water Protection Area contains larger urban centres, rural development, and large areas of intensive agriculture, which have resulted in the loss of lake-associated wetlands, important spawning areas, and riparian habitat. Increased boat traffic and fluctuating water levels and flows also have a negative impact on aquatic habitat due to increased pollution by boaters and disruption of the natural flow.

2.2.5.2.2 Aquatic Macroinvertebrates

Location of Habitats

Aquatic macroinvertebrates, commonly referred to as benthic macroinvertebrates, are the bugs 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 Index value for each location are shown on Map 2-15(KH). The Simpson's Diversity Index indicates the diversity of the benthic macroinvertebrate community. The location of benthic macroinvertebrate sampling sites and the Simpson's Diversity Index value at each site are shown on Map 2-16(KH).

Impacts of Development on Benthic Habitats

Analysis of benthic macroinvertebrate communities across the Kawartha-Haliburton 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 species diversity and abundance. Such sites are typically found in the northern portion of the watershed and in the vicinity of the Oak Ridges Moraine where development is limited and population density is very low. Sites with moderate water quality are dominated by the presence of pollution-tolerant benthic macroinvertebrates. Sites with poor water quality are dominated by pollution-tolerant species of the taxa Chironomidae, Simuliidae, and Isopoda, and show limited diversity and abundance.

2.2.6 SURFACE WATER QUALITY

This section is a summary of the available data that is suitable for a watershed-scale analysis of surface water quality in the Kawartha-Haliburton Source Protection Area. Surface water quality data specific to individual drinking water systems were analyzed during the evaluation of drinking water issues (see Section 4.3). Surface water quality data for the watershed are available from the Provincial Water Quality Monitoring Network, the Lake Partner Program operated by the Ministry of the Environment and Climate Change, the Lake Scugog Environmental Management Plan, and the Kawartha Water Watch program.

The Provincial Water Quality Monitoring Network has records from 11 monitoring stations across the watershed and has water quality records going back as far as 1966; most stations, however, have records going back to the 1970s. The Lake Partner Program monitors water quality at 25 sampling sites and, since 2004, phosphorus and nitrogen data are available for 14 stations in the Lake Scugog Environmental Management Plan monitoring network. In addition, Kawartha Water Watch samples water quality parameters at 26 stations. Each monitoring network has data on various water quality parameters. The data available from the provincial and non-provincial water quality networks are summarized in Tables 2.2-6 and 2.2-7, respectively. Surface water quality monitoring stations are shown on Map 2-17(KH).

Table 2.2-6: Provincial Water Quality Monitoring Network Stations and Available Data

Subwatershed	Station Name	Station ID	Data Record
Balsam Lake	Balsam Lake Outlet at Rosedale dam, Rosedale	17002105402	1971-2008
Burnt River	Burnt River at 11th Line Somerville, 5 km S of Kinmount	17002107502	1972-2008
Cameron Lake	Cameron Lake Outlet at Victoria Cnty Rd. 121, Fenelon Falls	17002102302	1966-2008
Lower Gull River	Gull River at Hwy. 35, Coboconk	17002102502	1966-2008
Mariposa Brook	Mariposa Brook at Valentia Rd., E of Little Britain	17002111902	1982-1990; 2004-2008
Nonquon River	Nonquon River at River St., Seagrave	17002113602	1970-1994; 2004-2008
Pigeon River	Pigeon River at Victoria Cnty Rd. 14, N of Omemee	17002107402	1972-2008
Scugog River	Scugog River downstream of Lindsay lagoons	17002104102	1970-2008
Scugog River	Scugog River at Hwy. 7/35, upstream of Lindsay	17002113002	1978-1990; 1996-2008
Sturgeon Lake	Sturgeon Lake Outlet at Hwy. 36, Bobcaygeon	17002102102	1966-2008
Lake Scugog	Blackstock Creek at R.Rd. 57, N of Blackstock	17002113702	2004-2008

Data Source: Provincial Water Quality Monitoring Network

Table 2.2-7: Kawartha-Haliburton Regional Water Quality Monitoring Network Stations and Available Data

Subwatershed	Program	No. Stations	Data Record
Balsam Lake	LPP	3	2002 - 2008
Burnt River	KWW	5	1998 – 2008
Cameron Lake	KWW, LPP	6, 1	1998 – 2008; 2002-2008
Lower Gull River	--	--	--
Mariposa Brook	KWW	5	1998 – 2008
Nonquon River	LSEMP	3	2004 - 2008
Pigeon River	--	--	--
Scugog River	KWW, LSEMP	4,1	1998 – 2008; 2004-2008
Sturgeon Lake	LPP	3	2002 - 2008
Lake Scugog	LPP, LSEMP	2,10	1998 – 2008; 2002-2008; 2004-2008
East Cross Creek	KWW	2	1998 – 2008
Pigeon Lake	LPP	7	2002 - 2008
Pearns Creek	KWW	1	1998 – 2008
Staples River	KWW	1	1998 – 2008
Corben Creek	LPP	1	2002 - 2008
Nogies Creek	LPP	1	2002 - 2008

Data Sources: Kawartha Region Water Quality Monitoring Network; Lake Scugog Environmental Management Program; Lake Partner Program

2.2.6.1 INDICATOR PARAMETERS

There are many water quality parameters that can be used to characterize the quality of a water source. A small group of parameters is often used to provide a representative overview of water quality in an area of interest. Eight indicator parameters have been selected for analysis. Indicator parameters reflect a range of land uses and aid in determining the relative watershed health. Indicator parameters and their associated standards or guidelines, sources, and potential health and environmental impacts are identified in Table 2.2-8.

2.2.6.2 SUMMARY OF PROVINCIAL WATER QUALITY MONITORING NETWORK DATA

The following subsections summarize the surface water quality data available from the Provincial Water Quality Monitoring Network stations in the Kawartha-Haliburton Source Protection Area. Each subsection includes a brief discussion of the sampling results for the indicator parameters identified above and provides a table that summarizes the historical exceedances and trends for all data on record. It also 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.

Analyzed parameters are listed with the corresponding Provincial Water Quality Objective (PWQO). If the PWQO is not available, the Canadian Environmental Quality Guidelines (CEQG) is used. PWQOs and CEQGs presented are based on raw water and toxicity levels to aquatic organisms. However, even though a limit of concentration is given, this does not mean that water quality should be allowed to degrade to the particular objective or guideline. It must also be noted that during data analysis *Ontario Drinking Water Quality Standards* is not used to describe or classify stream water quality characteristics.

Table 2.2-8: Surface Water Indicator Parameters

Parameter	Standards		Source	Effects
	PWQO[1]	CEQG[2]		
Chloride (Cl^-)		250 mg/L	Naturally occurring salts, 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		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).
Cadmium (Cd)	0.1 µg/L (<100 mg/L CaCO3) 0.5 µg/L (>100 mg/L CaCO3)		Naturally present in small quantities in air, water, and soil. Cadmium can be released into the air when household or industrial waste, coal, or oil is burned. Cadmium also can be released from car exhaust, metal processing industries, battery and paint manufacturing, and waste hauling and disposal activities. Higher levels of cadmium may be found in water near industrial areas or hazardous waste sites.	Toxic to aquatic organisms in very low concentrations. It can bio accumulate in mussels and fish.
Cobalt (Co)	0.9 µg/L		Naturally present in nickel-bearing laterite and nickel-copper sulphides deposits, and sedimentary copper deposits. Municipal and industrial wastes and effluents are primary sources of anthropogenic cobalt in the environment and are also associated with industrialized or mining areas.	Cause reproductive effects in some invertebrates; health effects on humans, especially children and the elderly when given to administer anemia (National Academy of Science, USA, 1977).
Lead (Pb)	5 µg/L (> 80mg/L CaCO3) 3 µg/L (30-80 mg/L) 1 µg/L (<30 mg/L CaCO3)		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)	20 µg/L		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		Incidental input or physical methods (e.g. erosion) (Sharpley et al., 1996). 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^-)		2.9 mg/L	Wastewater, septic systems, agricultural land use, and atmospheric deposition.	The most stable and usable form of nitrogen, but can be toxic in high concentrations and cause rapid growth of aquatic vegetation.

[1]Provincial Water Quality Objective
[2]Canadian Environmental Quality Guideline

2.2.6.2.1 Chloride

Chloride concentrations in the Kawartha-Haliburton Source Protection Area significantly increased in the majority of the streams that are monitored in the Provincial Water Quality Network program. Chloride concentration varied from as low as 4.1 milligrams per litre (mg/L) in the northern, more rural portion to as high as 73.8 mg/L in the more urbanized, southern portion of the watershed. Urbanization and the interrelationship with the application of road salts have been recognized in many studies (Howard, K. W. F. & Taylor, L. C., 1998; Environment Canada & Health Canada, 2001). At present the benchmark of 250 mg/L has not been reached, however, given the steady increase of chloride concentration since the 1970s, it may be fair to say that this parameter will be of concern in some of the surface water stations such as the Scugog River downstream, Mariposa Brook, and Blackstock Creek in the near future. The highest concentration was measured at the Scugog River downstream station with 73.8 mg/L. Mid-range or inter-quartile values at this station vary from 29.1 to 43.5 mg/L, resulting in the greatest dispersion of chloride concentrations compared to the lowest inter-quartile values at the Gull River station ranging from 4.7 to 5.8 mg/L. Chloride data from the Provincial Water Quality Monitoring Network are summarized in Table 2.2-9.

2.2.6.2.2 Metals

Cadmium and lead concentrations are the parameters of highest concern in the Kawartha-Haliburton Source Protection Area. The Provincial Water Quality Monitoring Network shows a significant increasing trend in cadmium concentrations at all stations. Almost half of the samples taken exceed the Provincial Water Quality Objective at Cameron Lake and Sturgeon Lake (47.5% and 45.8%, respectively). Although the highest concentration of cadmium was detected at the Pigeon River location (2.25 micrograms per litre (µg/L)), cadmium concentrations are least often exceeded at this sample location.

Increasing trends of lead concentrations are noticeable in nine of the eleven Provincial Water Quality Monitoring Network stations, while the remaining two stations show a significant decreasing trend. The highest concentration of lead was detected at Pigeon River with 11.8 µg/L followed closely by Mariposa Brook station with a concentration of 11.1 µg/L. Gull River station exceeded most often the suggested provincial guideline with 18.4% (48/261), out of all samples taken. Increased cadmium and lead concentrations in the northern part of the Kawartha-Haliburton Source Protection Area are likely a reflection of the natural weathering processes of the Precambrian rocks prevailing in this region. Increased trends of cadmium and lead in the southern portion of the watershed require more detailed sampling in order to prove or disprove the observed trends, but are likely related to human activities. Cadmium and lead data from the Provincial Water Quality Monitoring Network are summarized in Tables 2.2-10 and 2.2-11, respectively.

Other parameters that exceeded the corresponding guidelines include aluminum, cobalt, iron, and zinc (Tables 2.2-12 to 2.2-15). Generally aluminum concentrations across the watershed stay well below the Provincial Water Quality Objectives and display a decreasing trend. The only increasing trend could be observed at the Gull River station. The highest aluminum concentration was observed at Mariposa Brook station (262 µg/L).

Cobalt concentrations across the Kawartha-Haliburton Source Protection Area show an increasing trend and exceedances are observed at all provincial monitoring stations. The highest result was detected at Nonquon River station, however, concentrations exceeded the Provincial Water Quality Objective most often (13.5% of all samples) at Mariposa Brook.

Overall iron levels do not exceed the provincial guidelines on a regular basis across the watershed and show a declining trend, however they may be of concern at Burnt River. Almost half of all samples taken at this station (92/223) exceed the suggested provincial guideline of 300 µg/L. The Nonquon River station also displays elevated levels of iron and 35.4% of all samples taken from this location exceed the provincial objective. Mariposa Brook displays with a value of 1,690 µg/L show the highest iron concentration in the watershed.

Zinc concentrations are generally well below the Provincial Water Quality Objective and display a decrease in concentrations at most stations. Zinc concentrations are most frequently exceeded at Sturgeon Lake (11/266). However, samples taken during the period from 2004 to 2008 show no irregularities and are of no concern. Aluminum, cobalt, iron, and zinc sampling data at Provincial Water Quality Monitoring Network stations are summarized in Tables 2.2-12 to 2.2-15.

Table 2.2-9: Summary of Chloride Sampling Data at Provincial Water Quality Monitoring Network Stations

Station Name	Station ID	Years on Record	No. Samples on Record	GCDWQ Exceedances[1] (250mg/L)		Trend		Descriptive Statistics (mg/L)						
				%	#	Direction	p[2]	Years Analyzed	n	min	median	max	Percentiles 25th	Percentiles 75th
Balsam Lake Outlet	17002105402	71-79; 81-94; 96-08	337	0	0	↑	0.01	04-08	38	5.10	6.15	7.60	5.70	6.06
Burnt River at 11th Line	17002107502	72-93; 96-08	308	0	0	↑	0.01	04-08	38	4.60	6.90	9.10	6.40	7.50
Cameron Lake Outlet	17002102302	66-94; 96-08	405	0	0	↑	0.01	04-08	38	5.90	6.80	8.60	6.60	7.48
Gull River at Hwy. 35	17002102502	66-94; 96-08	412	0	0	↑	0.01	04-08	38	4.10	5.30	8.60	4.70	5.83
Mariposa Brook	17002111902	82-90; 04-08	122	0	0	↑	0.01	04-08	37	16.00	28.50	54.40	25.40	37.10
Nonquon River	17002113602	70-94; 04-08	274	0	0	↑	0.01	04-08	37	17.10	26.00	49.40	22.90	30.10
Pigeon River	17002107402	72-94; 96-08	314	0	0	↑	0.01	04-08	38	10.80	13.60	18.50	12.53	15.28
Scugog River downstream Lindsay	17002104102	70-94; 96-08	310	0	0	↑	0.01	04-08	38	17.80	31.80	73.80	29.10	43.50
Scugog River upstream Lindsay	17002113002	70-94; 96-08	314	0	0	↑	0.01	04-08	38	14.60	26.10	31.50	24.50	27.80
Sturgeon Lake Outlet	17002102102	66-94; 96-08	421	0	0	↑	0.01	04-08	38	8.60	11.95	20.60	10.35	13.08
Blackstock Creek	17002113702	04-08	37	0	0	↑	NS	04-08	38	25.10	35.90	46.00	31.00	38.80

[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 2.2-10: Summary of Cadmium Sampling Data at Provincial Water Quality Monitoring Network Stations

Station Name	Station ID	Years on Record	No. Samples on Record	PWQO Exceedances[1] (0.1/0.5µg/L)		Trend		Descriptive Statistics (µg/L)						
				%	#	Direction	p^2	Years Analyzed	n	min	median	max	Percentiles 25th	Percentiles 75th
Balsam Lake Outlet	17002105402	96-08	120	37.5*	45	↑	0.01	04-08	38	0.000	0.185	1.020	0.000	0.564
Burnt River at 11th Line	17002107502	96-08	106	38.7*	41	↑	0.01	04-08	38	0.000	0.305	1.230	0.000	0.568
Cameron Lake Outlet	17002102302	94; 96-08	118	47.5*	56	↑	0.01	04-08	38	0.000	0.271	1.020	0.000	0.539
Gull River at Hwy. 35	17002102502	96-08	107	40.2*	43	↑	0.01	04-08	38	0.000	0.341	1.140	0.000	0.648
Mariposa Brook	17002111902	04-08	37	29.7	11	↑	0.01	04-08	37	0.000	0.222	0.959	0.000	0.691
Nonquon River	17002113602	04-08	37	40.5	15	↑	0.05	04-08	37	0.000	0.185	1.320	0.005	0.856
Pigeon River	17002107402	94; 96-08	110	12.7	14	↑	0.01	04-08	38	0.000	0.377	2.250	0.000	0.642
Scugog River downstream Lindsay	17002104102	94; 96-08	98	18.4	18	↑	0.05	04-08	38	0.000	0.274	1.150	0.000	0.720
Scugog River upstream Lindsay	17002113002	96-08	118	14.4	17	↑	0.01	04-08	38	0.000	0.217	1.430	0.000	0.758
Sturgeon Lake Outlet	17002102102	94; 96-08	120	45.8*	55	↑	0.01	04-08	38	0.000	0.264	1.090	0.000	0.497
Blackstock Creek	17002113702	04-08	37	40.5	15	↑	0.05	04-08	38	0.000	0.248	1.320	0.096	0.706

[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 $p<0.05$)

*Indicates 0.1 µg/L benchmark

Table 2.2-11: Summary of Lead Sampling Data at Provincial Water Quality Monitoring Network Stations

Station Name	Station ID	Years on Record	No. Samples on Record	PWQO Exceedances[1] (5/3/1µg/L)		Trend		Descriptive Statistics (µg/L)						
				%	#	Direction	p^2	Years Analyzed	n	min	median	max	Percentiles 25th	Percentiles 75th
Balsam Lake Outlet	17002105402	81-94; 96-08	257	10.2	26	↑	0.01	04-08	38	0.00	0.00	6.92	0.00	0.24
Burnt River at 11th Line	17002107502	81-94; 96-08	224	5.8	13*	↑	0.01	04-08	38	0.00	0.00	8.50	0.00	1.84
Cameron Lake Outlet	17002102302	81-94; 96-08	261	8.04	21	↑	0.01	04-08	38	0.00	0.10	4.45	0.00	1.99
Gull River at Hwy. 35	17002102502	81-94; 96-08	261	18.4	48**	↑	NS	04-08	38	0.00	0.25	8.87	0.00	2.04
Mariposa Brook	17002111902	82-90; 04-08	122	8.2	10*	↑	0.01	04-08	37	0.00	1.05	11.10	0.00	3.22
Nonquon River	17002113602	81-94; 04-08	164	3.0	5	↓	0.01	04-08	37	0.00	0.00	9.76	0.00	1.06
Pigeon River	17002107402	81-94; 96-08	232	5.6	13	↑	0.01	04-08	38	0.00	0.04	11.80	0.00	1.33
Scugog River downstream Lindsay	17002104102	81-94; 96-08	232	2.2	5*	↓	0.01	04-08	38	0.00	0.00	7.49	0.00	1.49
Scugog River upstream Lindsay	17002113002	96-08	111	6.3	7*	↑	NS	04-08	38	0.00	0.00	6.77	0.00	1.85
Sturgeon Lake Outlet	17002102102	81-94; 96-08	267	3.4	9*	↑	0.01	04-08	38	0.00	0.00	5.85	0.00	2.13
Blackstock Creek	17002113702	04-08	37	13.5	5*	↑	NS	04-08	38	0.00	0.25	7.06	0.00	2.52

[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 $p<0.05$)

*Indicates 5 µg/L benchmark

** Indicates 1 µg/L benchmark

Table 2.2-12: Summary of Aluminum Sampling Data at Provincial Water Quality Monitoring Network Stations

Station Name	Station ID	Years on Record	No. Samples on Record	PWQO Exceedances[1] (75µg/L)		Trend[2]	Descriptive Statistics (µg/L)						
				%	#		Years Analyzed	n	min	median	max	Percentiles 25th	Percentiles 75th
Balsam Lake Outlet	17002105402	96-08	117	0.0	0	↓	04-08	38	0.00	7.29	18.10	4.11	10.82
Burnt River at 11th Line	17002107502	96-08	106	5.7	6	↓	04-08	38	9.52	22.85	207.00	16.25	31.70
Cameron Lake Outlet	17002102302	96-08	115	0.0	0	↓	04-08	38	0.00	8.52	59.10	4.23	14.03
Gull River at Hwy. 35	17002102502	96-08	114	0.0	0	↑	04-08	38	2.76	9.64	41.90	5.95	15.18
Mariposa Brook	17002111902	04-08	37	43.2	16	↓	04-08	37	16.60	63.00	262.00	38.8	100.00
Nonquon River	17002113602	04-08	38	2.6	1	↓	04-08	37	2.95	28.30	106.00	16.10	49.50
Pigeon River	17002107402	96-08	106	0.0	0	↓	04-08	38	0.00	6.25	59.20	3.31	8.38
Scugog River downstream Lindsay	17002104102	96-08	98	34.7	34	↓	04-08	38	7.70	35.60	162.00	23.80	47.50
Scugog River upstream Lindsay	17002113002	96-08	111	3.6	4	↓	04-08	38	2.04	18.25	43.10	12.28	27.13
Sturgeon Lake Outlet	17002102102	96-08	116	1.7	2	↓	04-08	38	0.63	9.65	80.40	5.90	15.00
Blackstock Creek	17002113702	04-08	37	2.7	1	↓	04-08	38	4.20	18.40	143.00	11.50	30.60

[1]Indicates the quantity of all samples on record that exceeded the Provincial Water Quality Objective

[2]Trend observed but not statistically validated

Table 2.2-13: Summary of Cobalt Sampling Data at Provincial Water Quality Monitoring Network Stations

Station Name	Station ID	Years on Record	No. Samples on Record	PWQO Exceedances[1] (0.9µg/L)		Trend[2]	Descriptive Statistics (µg/L)						
				%	#		Years Analyzed	n	min	median	max	Percentiles 25th	Percentiles 75th
Balsam Lake Outlet	17002105402	96-08	117	6.0	7	↑	04-08	38	0.000	0.214	1.260	0.005	0.452
Burnt River at 11th Line	17002107502	96-08	106	7.5	8	↑	04-08	38	0.000	0.131	1.340	0.000	0.537
Cameron Lake Outlet	17002102302	96-08	115	2.6	3	↑	04-08	38	0.000	0.000	1.710	0.000	0.493
Gull River at Hwy. 35	17002102502	96-08	114	3.5	4	↑	04-08	38	0.000	0.330	1.300	0.000	0.650
Mariposa Brook	17002111902	04-08	37	13.5	5	↑	04-08	37	0.000	0.349	2.190	0.000	0.731
Nonquon River	17002113602	94; 04-08	37	5.4	2	↑	04-08	37	0.000	0.357	7.290	0.000	0.519
Pigeon River	17002107402	96-08	106	4.7	5	↑	04-08	38	0.000	0.065	1.810	0.000	0.267
Scugog River downstream Lindsay	17002104102	96-08	98	8.2	8	↑	04-08	38	0.000	0.334	2.060	0.005	0.797
Scugog River upstream Lindsay	17002113002	96-08	111	8.1	9	↑	04-08	38	0.000	0.151	1.660	0.000	0.585
Sturgeon Lake Outlet	17002102102	96-08	116	4.3	5	↑	04-08	38	0.000	0.184	1.440	0.000	0.673
Blackstock Creek	17002113702	04-08	37	10.8	4	↑	04-08	38	0.000	0.250	2.140	0.000	0.590

[1]Indicates the quantity of all samples on record that exceeded the Provincial Water Quality Objective

[2]Trend observed but not statistically validated

Table 2.2-14: Summary of Iron Sampling Data at Provincial Water Quality Monitoring Network Stations

Station Name	Station ID	Years on Record	No. Samples on Record	PWQO Exceedances[1] (300µg/L)		Trend[2]	Descriptive Statistics (µg/L)						
				%	#		Years Analyzed	n	min	median	max	Percentiles 25th	Percentiles 75th
Balsam Lake Outlet	17002105402	71-72; 81-94; 96-08	287	1.0	3	↓	04-08	38	19.30	31.60	61.10	27.77	40.37
Burnt River at 11th Line	17002107502	72; 81–93; 96-08	223	41.3	92	↓	04-08	38	130.00	302.50	643.00	238.50	372.50
Cameron Lake Outlet	17002102302	66-72; 81-94; 96-08	258	0.4	1	↓	04-08	38	24.10	66.60	168.00	44.90	85.40
Gull River at Hwy. 35	17002102502	66-94; 96-08	307	1.6	5	↓	04-08	38	29.40	66.45	150.00	54.95	79.65
Mariposa Brook	17002111902	04-08	37	2.7	1	↓	04-08	37	40.50	124.00	1690.00	91.00	172.00
Nonquon River	17002113602	70-72; 94; 04-08	48	35.4	17	↓	04-08	37	73.40	205.00	707.00	154.00	260.00
Pigeon River	17002107402	72;86; 94; 96-08	113	0.0	0	↓	04-08	38	8.41	19.35	93.20	14.20	24.88
Scugog River downstream Lindsay	17002104102	70-08	110	1.8	2	↓	04-08	38	5.10	39.60	122.00	30.20	55.50
Scugog River upstream Lindsay	17002113002	96-08	111	0.0	0	↓	04-08	38	15.70	40.90	88.20	34.35	53.98
Sturgeon Lake Outlet	17002102102	66-72; 81-08	312	1.3	4	↓	04-08	38	16.50	26.60	117.00	24.03	39.58
Blackstock Creek	17002113702	04-08	37	5.4	2	↑	04-08	38	50.70	129.00	366.00	89.30	180.00

[1]Indicates the quantity of all samples on record that exceeded the Provincial Water Quality Objective

[2]Trend observed but not statistically validated

Table 2.2-15: Summary of Zinc Sampling Data at Provincial Water Quality Monitoring Network Stations

Station Name	Station ID	Years on Record	No. Samples on Record	PWQO Exceedances[1] (20µg/L)		Trend[2]	Descriptive Statistics (µg/L)						
				%	#		Years Analyzed	n	min	median	max	Percentiles 25th	Percentiles 75th
Balsam Lake Outlet	17002105402	81-94; 96-08	257	1.6	4	↓	04-08	38	0.00	1.07	9.89	0.40	1.67
Burnt River at 11th Line	17002107502	81-93; 96-08	224	0.9	2	↓	04-08	38	0.15	1.73	7.08	1.07	2.77
Cameron Lake Outlet	17002102302	81-94; 96-08	259	3.5	9	↓	04-08	38	0.00	0.61	1.87	0.36	1.07
Gull River at Hwy. 35	17002102502	81-94; 96-08	261	2.3	6	↓	04-08	38	0.30	1.48	9.91	0.76	2.17
Mariposa Brook	17002111902	82-90; 04-08	122	3.3	4	↓	04-08	37	0.00	2.98	42.80	1.19	4.82
Nonquon River	17002113602	81-94; 04-08	161	1.9	3	↓	04-08	37	0.00	0.87	13.10	0.35	2.18
Pigeon River	17002107402	81-94; 96-08	232	3.4	8	↑	04-08	38	0.00	0.65	72.50	0.16	2.46
Scugog River downstream Lindsay	17002104102	81-94; 96-08	208	2.4	5	↓	04-08	38	0.00	1.07	6.25	0.60	1.69
Scugog River upstream Lindsay	17002113002	96-08	111	1.8	2	↓	04-08	38	0.00	1.37	17.40	0.00	2.81
Sturgeon Lake Outlet	17002102102	81-94; 96-08	266	4.1	11	↑	04-08	38	0.00	0.48	40.60	0.28	1.12
Blackstock Creek	17002113702	04-08	37	0.0	0	↑	04-08	38	0.00	0.55	4.63	0.15	1.10

[1]Indicates the quantity of all samples on record that exceeded the Provincial Water Quality Objective

[2]Trend observed but not statistically validated

2.2.6.2.3 Nutrients

Total Phosphorus

Total phosphorus is a measure of all forms of phosphorus present in water. Total phosphorus concentrations in the watershed frequently exceed the Provincial Water Quality Objective at all Provincial Water Quality Monitoring Network stations with the exception of Gull River station. The stations showing the most frequent exceedances of total phosphorus are Scugog River (downstream of Lindsay) and Nonquon River (74.5% and 70.6%, respectively). The high concentrations of phosphorus observed at these stations may be a result of intensive agricultural land use in this area. Significant trends in total phosphorus concentrations are detected at eight Provincial Water Quality Monitoring Network stations. These stations show a decline in total phosphorus concentrations since the beginning of the sampling period in the 1970s and 1980s. In contrast, Gull River station displays an increasing trend in phosphorus concentrations, which may be related to growing cottage development. Total phosphorus data from the Provincial Water Quality Monitoring Network are summarized in Table 2.2-16.

Nitrate Nitrogen

Nitrate nitrogen is the concentration of nitrogen present in water in the form of the nitrate ion (NO_3^-). Nitrate nitrogen concentrations in the watershed have been increasing at three Provincial Water Quality Monitoring Network stations: Gull River, Scugog River downstream of Lindsay, and Mariposa Brook. Because there is no Provincial Water Quality Objective for nitrate nitrogen, this analysis employs the Canadian Environmental Quality Guidelines as a standard for nitrate nitrogen exceedances. Provincial Water Quality Monitoring Network data indicate that nitrate nitrogen has exceeded the Canadian Environmental Quality Guideline at Mariposa Brook (8.1%) and Blackstock Creek (5.3 %). Nitrate nitrogen data from the Provincial Water Quality Monitoring Network are summarized in Table 2.2-17.

Table 2.2-16: Summary of Phosphorus Sampling Data at Provincial Water Quality Monitoring Network Stations

Station Name	Station ID	Years on Record	No. Samples on Record	PWQO Exceedances[1] (0.03/0.02mg/L)		Trend		Descriptive Statistics (mg/L)						
				%	#	Direction	p[2]	Years Analyzed	n	min	median	max	Percentiles 25th	Percentiles 75th
Balsam Lake Outlet	17002105402	71-93; 96-08	377	9.5	36	↓	0.01	04-08	38	0.006	0.009	0.064	0.008	0.011
Burnt River at 11th Line	17002107502	72-93; 96-08	311	9.3	29	↓	0.01	04-08	38	0.005	0.009	0.046	0.007	0.013
Cameron Lake Outlet	17002102302	66-94; 96-08	429	14.2	61	↓	0.01	04-08	38	0.005	0.009	0.046	0.007	0.012
Gull River at Hwy. 35	17002102502	96-08	44	0	0	↑	NS	04-08	38	0.004	0.008	0.018	0.006	0.011
Mariposa Brook	17002111902	82-90; 04-08	122	45.1	55	↓	0.05	04-08	37	0.026	0.026	0.150	0.019	0.032
Nonquon River	17002113602	70-94; 04-08	279	70.6	197	↓	0.01	04-08	37	0.009	0.034	0.870	0.025	0.049
Pigeon River	17002107402	72-94; 96-08	320	36.3	116	↓	0.01	04-08	38	0.005	0.015	0.041	0.012	0.017
Scugog River downstream Lindsay	17002104102	70-94; 96-08	318	74.5	237	↓	0.01	04-08	38	0.013	0.021	0.055	0.018	0.029
Scugog River upstream Lindsay	17002113002	96-08	111	33.3	37	↓	NS	04-08	38	0.011	0.024	0.050	0.018	0.030
Sturgeon Lake Outlet	17002102102	66-93; 96-88	442	46.6	206	↓	0.01	04-08	38	0.008	0.014	0.024	0.011	0.019
Blackstock Creek	17002113702	04-08	38	68.4	26	↓	NS	04-08	38	0.016	0.044	0.111	0.025	0.080

[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 2.2-17: Summary of Nitrate Nitrogen Sampling Data at Provincial Water Quality Monitoring Network Stations

Station Name	Station ID	Years on Record	No. Samples on Record	CEQG Exceedances[1] (2.9mg/L)		Trend		Descriptive Statistics (mg/L)						
				%	#	Direction	p[2]	Years Analyzed	n	min	median	max	Percentiles 25th	Percentiles 75th
Balsam Lake Outlet	17002105402	96-08	118	0	0	↓	0.01	04-08	38	0.005	0.005	0.064	0.005	0.013
Burnt River at 11th Line	17002107502	96-08	108	0	0	↓	0.05	04-08	38	0.005	0.033	0.521	0.018	0.050
Cameron Lake Outlet	17002102302	96-08	116	0	0	↓	0.01	04-08	38	0.005	0.008	0.521	0.005	0.024
Gull River at Hwy. 35	17002102502	96-08	79	0	0	↑	0.05	04-08	38	0.005	0.007	0.532	0.005	0.030
Mariposa Brook	17002111902	04-08	37	8.1	3	↑	NS	04-08	37	0.015	1.500	3.760	0.997	2.260
Nonquon River	17002113602	81-94; 96-08	166	0	0	↓	NS	04-08	37	0.005	0.162	1.260	0.036	0.390
Pigeon River	17002107402	96-08	107	0	0	↓	NS	04-08	38	0.005	0.007	0.223	0.005	0.025
Scugog River downstream Lindsay	17002104102	96-08	101	0	0	↑	NS	04-08	38	0.005	0.251	2.490	0.072	0.660
Scugog River upstream Lindsay	17002113002	96-08	111	0	0	↓	0.01	04-08	38	0.005	0.061	1.760	0.014	0.291
Sturgeon Lake Outlet	17002102102	96-08	117	0	0	↓	0.05	04-08	38	0.005	0.021	0.578	0.010	0.111
Blackstock Creek	17002113702	04-08	38	5.3	2	↓	NS	04-08	38	0.175	0.863	3.680	0.490	1.390

[1]Indicates the quantity of all samples on record that exceeded the Canadian Environmental 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 $p<0.05$)

2.2.7 GROUNDWATER QUALITY

This section is a summary of the available data that are suitable for a watershed-scale analysis of groundwater quality in the Kawartha-Haliburton Source Protection Area. Groundwater quality data specific to individual drinking water systems were analyzed during the evaluation of drinking water issues (see Section 5.3). The available data include limited groundwater quality data from the Provincial Groundwater Monitoring Network, the Drinking Water Surveillance Program, Ministry of the Environment and Climate Change Water Well Records Database, sampling data from municipalities and Health Units, and several regional groundwater studies. Monitoring programs associated with municipal groundwater drinking water supply systems include data on microbiological indicators, metals, and other parameters. Generally, there are limited groundwater quality data available to allow for comprehensive analysis across the source protection area.

2.2.7.1 SUMMARY OF GROUNDWATER QUALITY

Overall, groundwater in the southern portion of the Kawartha-Haliburton Source Protection Area is characterized by low chloride, sulphate, and heavy metal concentrations. Similar to the north, water quality concerns are mainly associated with elevated hardness, iron, and manganese concentrations. Periodically other parameters, such as sodium, exceed the *Ontario Drinking Water Quality Standards*. Concurrently, elevated levels of nitrates are a widespread problem across the southern part of the Kawartha-Haliburton Source Protection Area as these concentrations are likely related to intensive agricultural land use. Wells in the Oak Ridges Moraine generally show good water quality.

Groundwater in the northern part of the Kawartha-Haliburton Source Protection Area is characterized by low chloride, nitrate, and heavy metal concentrations. Iron and manganese occasionally exceed the Ontario Drinking Water Quality Standards, because of weathering processes in the bedrock and soils, and are thus naturally occurring. Water quality concerns in the northern portion of the source protection area are usually associated with elevated hardness, iron, and manganese concentrations. In general, these common constituents are not considered harmful to human health although some components can affect the taste, smell, or clarity of water. Overall, deeper wells tend to have better water quality.

2.2.7.2 INDICATOR PARAMETERS

There are many water quality 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. Parameters normally analyzed for groundwater quality include general chemical parameters such as pH, conductivity, hardness, alkalinity, total organic carbon, anions such as chloride and sulphate, nutrients such as ammonia and nitrate, microbiology, pesticides, herbicides, and metals such as cadmium, lead, and iron. Indicator parameters used in the analysis of Provincial Groundwater Monitoring Network data are described in Table 2.2-18.

2.2.7.3 PROVINCIAL GROUNDWATER MONITORING NETWORK

The Provincial Groundwater Monitoring Network was established in 2002 to provide data to characterize groundwater quantity and quality across the province. Ten monitoring wells were established in the Kawartha-Haliburton Source Protection Area as part of the overall network; these wells generally represent the regional aquifers across the watershed. Provincial Groundwater Monitoring Network wells in the Kawartha-Haliburton Source Protection Area are described in Table 2.2-19 and their locations are shown on Map 2-18(KH).

Provincial Groundwater Quality Monitoring Network wells in the Kawartha-Haliburton Source Protection Area watersheds were sampled in 2002, 2004, 2006, 2007, and 2008 and tested for most parameters in the *Ontario Drinking Water Quality Standards (O. Reg. 169/03*). The number of samples analyzed at each monitoring station and the range of sampling results up to 2008 are listed in Table 2.2-20. Since sampling through this network started recently (2002), there are insufficient data to make observations regarding trends in groundwater quality.

2.2.7.4 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.

2.2.7.5 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 map the groundwater resources and delineate wellhead protection areas in municipalities across the province. 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 Durham Region.

Results from this study indicate that regional groundwater quality in both the overburden and the bedrock is reportedly good in the Kawartha-Haliburton Source Protection Area. Some areas, generally along the Paleozoic/Precambrian contact, showed salty, sulphurous, and mineralized water (particularly in the area west of Pigeon Lake). The occurrence of sulphurous water may be attributed to the high organic content of the rock not the presence of evaporates (Morrison Environmental Ltd., 2004).

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, which underlies the southern portion of the Kawartha-Haliburton 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, and hardness, or they may contain gas.

Table 2.2-18: 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. Sources include rocks, 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 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.	80-100 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-})	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. Natural sources include decomposing vegetation and rock or soil containing gypsum, barite, or other minerals.	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 (MAC)[2]	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 numbers 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 a 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, 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) values and Aesthetic Objective (AO) / Operational Guideline (OG) values as per Ontario's Regulation 169/03 made under *Safe Drinking Water Act* (amended to O. Reg. 327/08)

[2]The aesthetic objective for sodium in drinking water is 200 mg/L. As per the Ontario Drinking Water Standards, Objectives and Guidelines (June 2006), the local Medical Officer of Health should be notified when the sodium concentration exceeds 20 mg/L so that this information may be communicated to local physicians for their use with patients on sodium restricted diets.

Table 2.2-19: Provincial Groundwater Monitoring Wells in the Kawartha-Haliburton Source Protection Area

Well Identification Numbers		Subwatershed	Casing Inside Diameter (in)	Well Depth (m)	Static Water Level (m)	Aquifer (relative location)	Number of Water Quality Sampling Events
MOECC[1] ID	Well ID						
BH00-2B	W115-2	Mariposa Brook	1.25	6.36	2.72	Shallow	5
BH00-2A	W115-3	Mariposa Brook	2	15	2.14	Shallow	5
6414902	W117-2	Pigeon River	2	54.34	42.59	Deep	5
262146	W386	Nonquon River	3	27.92	11.75	Middle	5
262144	W387	Lake Scugog Tributary	3	33.7	17.92	Middle	5
A004265	W432	Sturgeon River	6.25	11.51	3.72	Shallow	5
A004272	W433*	Sturgeon Lake	6.25	14.89	4.09	Shallow	2
A069874	W483	East Cross Creek	4.00	45.00	31.6	Deep	1
A069873	W484	East Cross Creek	4.00	16.52	6.18	Shallow	1
W0000310[2]	GA310	Irondale River	6.1	18.9	4.9	Shallow	0

Data source: Kawartha Region Conservation Authority
[1]Ministry of the Environment and Climate Change
[2]Well is located in the Kawartha-Haliburton Source Protection Area but is monitored by Crowe Valley Conservation
*Decommissioned Dec. 21, 2006

Table 2.2-20: Summary of Provincial Groundwater Monitoring Network data in the Kawartha-Haliburton Source Protection Area

Well ID	No. Samples	Years on Record	Range of Water Quality Sampling Results								
			Hardness (mg/L)	Sodium (mg/L)	Iron (ug/L)	Sulfate (mg/L)	Chloride (mg/L)	Nitrate (mg/L)	Organic Nitrogen (mg/L)	DOC (mg/L)	TDS (mg/L)
W115-2	5	02; 06-08	455.0-961.0	205.0-330.0	3030.0-15000.0	11.0-21.0	420.0-760.0	<0.008-0.557	0.19-0.31	1.6-3.8	1080.0
W115-3	5	02; 06-08	294.0-382.0	169.0 - >300.0	6.0-86.0	1.2-16.0	296.0-584.0	<0.008-1.29	0.06-0.44	0.6-0.8	1260.0
W386	5	04; 06-08	247.0-366.0	5.96-24.6	6.0-20.0	11.0-13.3	7.9-131.0	0.04-0.845	0.03-0.07	0.9-1.2	359.0
W387	5	04; 06-08	164.0-188.0	3.4-4.4	96.0-140.0	24.0-28.4	1.8-2.3	<0.008-0.05	0.00-0.04	0.2-1.3	219.0
W388	5	04; 06-08	327.0-362.4	>90.0-124.0	2880.0-3840.0	0.5-0.6	54.0-160.0	<0.008-0.718	0.61-1.08	11.1-13.4	723.0
W432	5	04; 06-08	242.0-281.5	66.0- >115.0	15.0-221.0	20.5-21.0	82.0 -190.0	<0.008-0.05	0.03-0.26	0.09- <1.0	272.0
W433*	2	04; 06	355.0-475.9	17.2-33.0	210.0-770.0	15.9-26.0	52.3-121.0	<0.008-0.05	0.07-0.19	1.6-1.8	433.0
ECF-Parking Lot	1	08	178.0	3.71	<0.01	19.0	1.9	0.1	0.08	no reading	no reading
ECF-North	1	08	216.0	2.2	<0.01	12.0	1.4	2.7	<0.04	no reading	no reading

*Decommissioned Dec. 21, 2006

2.2.8 REFERENCES

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2.3 OTONABEE-PETERBOROUGH SOURCE PROTECTION AREA

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. This is a watershed characterization of the Otonabee-Peterborough Source Protection Area prepared in accordance with the *Clean Water Act*, *2006*, *O. Reg. 287/07*, and Part II of the *Technical Rules*.

This watershed characterization draws from an earlier document prepared before the publication of the *Technical Rules* and has expanded on it where required to satisfy the legislation. The report was prepared in 2008 by Otonabee Conservation and is entitled: *Watershed Characterization Report: Otonabee-Peterborough Source Protection Area.*

2.3.1 OVERVIEW OF SOURCE PROTECTION AREA

The Otonabee-Peterborough Source Protection Area covers an area of approximately 3,365 km^2 and includes the jurisdiction of the Otonabee Region Conservation Authority as well as portions of Haliburton and northern portions of Peterborough County. The source protection area boundary and its subwatersheds are shown on Maps 2-1(OP) and 2-2(OP), respectively.

The source protection area is comprised of two major physiographic regions that divide the area approximately equally between north and south. The division between these two areas runs predominately through the middle of the Kawartha Lakes, which include Pigeon, Buckhorn, Lower Buckhorn, Lovesick, and Stony Lakes. These lakes also represent a portion of the Trent-Severn Waterway that links Lake Ontario with Georgian Bay via a 386-km inland waterway system. Water levels along the waterway are regulated by a series of dams and weirs for purposes of flood control and recreation; navigation through the waterway is made possible by a series of locks and canals. The population of the source protection area is approximately 129,299. Approximately 58% of the population lives in the City of Peterborough, which is located south of the Kawartha Lakes and is the largest population centre in the source protection area.

The southern portion of the source protection area (1,951 km^2) lies south of the northern Kawartha Lakes and within the jurisdiction of the Otonabee Region Conservation Authority. This area lies within the Great Lakes-St. Lawrence Lowlands, an area that is characterized by limestone bedrock and areas of deep overburden and glacial till deposits that support agricultural land uses and settlement areas. A combination of mixed successional forests and wetlands are also found in this area. The Oak Ridges Moraine and Peterborough Drumlin Field are the predominant physiographic features in this area, and karst topography is present in the Indian and Ouse watersheds.

The northern portion of the source protection area (1,415 km^2) is located north of the Kawartha Lakes on the Canadian Shield and includes portions of Peterborough and Haliburton Counties. This area is characterized by granite bedrock, shallow overburden, mixed climax forests, and wetlands. It is largely undeveloped and supports limited human settlement.

2.3.2 GEOGRAPHY AND LAND USE

2.3.2.1 PHYSICAL GEOGRAPHY

Physiographic features in the Otonabee-Peterborough Source Protection Area include the Peterborough Drumlin Field, Georgian Bay Fringe, Dummer Moraine, and to a lesser extent, the Oak Ridges Moraine, Algonquin Highlands, and Iroquois Plain. Physiographic regions in the source protection area are shown on Map 2-3(OP), and the area and percent coverage of each physiographic feature are identified in Table 2.3-1. Physical characteristics of each subwatershed in the source protection area are summarized in Table 2.3-2.

The Peterborough Drumlin Field is the largest physiographic feature in the source protection area, and it lies south of the Dummer Moraine and north of the Oak Ridges Moraine. The Peterborough Drumlin Field consists of thousands of drumlins that are closely spaced and average six to eight per square kilometre. Due to the high density of drumlins, some of the drumlins are compound; compound drumlins have double crests, double tails, or distinct secondary ridges and flutings along their sides. The drumlins are separated by low-lying, poorly drained, or swampy areas.

The City of Peterborough was originally built on seven drumlins and thus termed the “City of Seven Hills”, however, the city has since expanded and now occupies numerous surrounding drumlins.

A small portion of the source protection area is occupied by the Iroquois Plain (east of the Village of Norwood). This area is gently rolling to flat and contains deposits of sand, fine sand, and silt.

The Oak Ridges Moraine occupies a small portion of the source protection area in the extreme southwest and is the headwaters region for numerous cold water streams. It is characterized by high relief, hummocky terrain, beds of stratified fine sands and clays, and a virtual absence of streams.

The Dummer Moraine extends east to west through the central portion of the source protection area and is characterized by angular fragments and blocks of limestone, a variety of Precambrian rocks, and an extremely rough stony surface.

The Algonquin Highlands are located in the northernmost portion of the source protection area and are predominately underlain by granite and other hard Precambrian bedrock. The relief is rugged and exhibits rounded knobs and ridges, and the occasional ridge reaches over 150 m. The Algonquin Highlands also include sand and gravel deposits that have taken the form of hills.

The Dummer Moraine is a landform of low and hummocky relief that extends across the source protection area, south of the natural division between the northern and southern portion of the source protection area. The surface is rough and littered with angular fragments and large blocks of limestone with many Precambrian Shield rocks also present. The main characteristics are its low stony knobs, relatively straight ridges, and many low, swampy areas. Most of the morainic ridges are relatively low as compared to those found in the Peterborough Drumlin Field.

The Georgian Bay Fringe encompasses most of the northern portion of the source protection area and exhibits a broad expanse of low relief and irregular, barren gneissic bedrock ridges that are interspersed with numerous linear, shallow-water wetlands and peat-filled depressions. Blocked drainage from beaver activity has contributed to the formation of sphagnum dominated wetlands. This area exhibits a discontinuous layer of till forming a ground moraine that has developed shallow, nutrient poor, sandy till soils.

Table 2.3-1: Physiographic Regions in the Otonabee-Peterborough Source Protection Area

Physiographic Region	Area (km^2)	Land Coverage (%)
Peterborough Drumlin Field	1,329	39.5
Iroquois Plain	6	0.2
Oak Ridges Moraine	72	2.1
Dummer Moraine	717	21.3
Algonquin Highlands	253	7.5
Georgian Bay Fringe	987	29.4

Data Source: Calculated using data supplied under license by members of the Ontario Geospatial Data Exchange

Table 2.3-2: Physical Characteristics of Otonabee-Peterborough Source Protection Area Subwatersheds

Subwatershed Name	Drainage Area[1] (km^2)	Channel Length[1] (km)	Total Fall[1] (m)	Channel Average Slope[1] (m/km)	Land Coverage (km^2)			Physiographic Region(s)
					Wetlands	Lakes	Woodland	
Otonabee River	936	45	NA	NA	103	25	208	Peterborough Drumlin Field; Dummer Moraine
Indian River	210	43	93	2.2	26	4	55	Peterborough Drumlin Field; Dummer Moraine
Ouse River	285	52	40	0.1	47	0.2	93	Peterborough Drumlin Field; Dummer Moraine
Miskwaa Ziibi River	202	53	156	3.0	30	13	140	Georgian Bay Fringe; Dummer Moraine
Mississauga River	372	58	160	2.8	35	54	253	Georgian Bay Fringe; Dummer Moraine
Kawartha Lakes Tributaries	719	NA	NA	NA	59	150	300	Georgian Bay Fringe; Dummer Moraine; Peterborough Drumlin Field
Rice Lake	159	NA	NA	NA	18	33	21	Peterborough Drumlin Field; Iroquois Plain
Eel's Creek	279	63	184	2.9	27	23	258	Georgian Bay Fringe; Algonquin Highlands
Jack's Creek	201	32	112	3.5	9	19	110	Georgian Bay Fringe; Algonquin Highlands

Data Source: Calculated using data supplied under license by members of the Ontario Geospatial Data Exchange

[1]Drainage Areas, Channel Length, Total Fall, and Channel Slope calculated using Ontario Flow Assessment Techniques (OFAT) (as a result, the drainage areas used to calculate these values are slightly different than those shown on Map 2-2(OP).

2.3.3 HUMAN GEOGRAPHY: POPULATION AND LAND USE

2.3.3.1 AREAS OF SETTLEMENT

The *Places to Grow Act, 2005* provides a legislative framework for the development of growth plans in designated growth areas. The *Places to Grow Act* provides the following definition for 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."*

In the Otonabee-Peterborough Source Protection Area, settlement areas are primarily located south of the Kawartha Lakes. The largest concentration of settlement areas is located in and near the City of Peterborough, the core of existing urban development in the source protection area. Smaller areas of settlement are scattered throughout the source protection area and include the villages and hamlets of Lakefield, Bridgenorth, Ennismore, Norwood, Millbrook, Keene, Young's Point, and Apsley. In addition, settlement areas have also been identified along the shorelines of the Kawartha Lakes, particularly Chemong, Pigeon, and Buckhorn Lakes. Areas of settlement in the source protection area are shown on Map 2-4(OP).

2.3.3.2 MUNICIPALITIES

There are 15 municipalities located within or partially within the Otonabee-Peterborough Source Protection Area. The total population of these municipalities is 326,616 (Statistics Canada, 2006). The estimated population of the source protection area is approximately 129,299.

Population density is highest in the southern portion of the source protection area, particularly so in urban areas such as the City of Peterborough (1,228 people/km^2) and the Village of Hastings in the Municipality of Trent Hills (127 people/km^2). The population density for the remainder of the southern portion of the source protection area ranges from 9 people/km^2 to 45 people/km^2. In the northern portion of the source protection area, population density is less than 8 people/km^2. Municipal boundaries in the source protection area are shown on Map 2-5(OP). Municipal populations are listed in Table 2.3-3, and population and population density are shown on Maps 2-6(OP) and 2-7(OP), respectively.

Table 2.3-3: Municipal Populations in the Otonabee-Peterborough Source Protection Area

Municipality	Portion within SPA		Entire Municipality	
	Area (km^2)	Population	Area (km^2)	Population
Township of North Kawartha	674	1,774	844	2,342
Township of Galway-Cavendish and Harvey	624	4,131	970	5,284
Township of Douro-Dummer	472	6,891	484	6,954
Township of Otonabee-South Monaghan	390	6,831	399	6,934
Township of Smith-Ennismore-Lakefield	384	17,399	384	17,413
Township of Cavan Monaghan	293	8,622	308	8,828
Township of Asphodel-Norwood	165	4,236	166	4,247
City of Kawartha Lakes	103	3,404	3,332	74,561
Township of Havelock-Belmont-Methuen	95	235	594	4,637
Municipality of Highlands East	84	186	758	3,089
City of Peterborough	61	74,898	61	74,898
Municipality of Port Hope*	8	100	279	16,390
Municipality of Trent Hills	4	509	538	12,247
Municipality of Clarington*	3	26	613	77,820
Township of Hamilton*	3	57	294	10,972

*Located only marginally within the source protection area
Data Source: Calculated from Statistics Canada, GeoSuite, 92-150-XCB, 2006 Census

2.3.3.3 FIRST NATIONS

The Otonabee-Peterborough Source Protection Area includes two populated First Nations Reserves that have a combined population of 1,543 (Statistics Canada, 2006). The Curve Lake First Nation straddles Buckhorn and

Chemong Lakes northwest of the City of Peterborough. The Hiawatha First Nation is located along the Otonabee River and the north shore of Rice Lake near the southern boundary of the source protection area. A third Reserve, Islands in the Trent Waters, includes various unpopulated islands located throughout the Kawartha Lakes. First Nations Reserves in the source protection area are shown on Map 2-8(OP), and their population, area, and population density are listed in Table 2.3-4.

Table 2.3-4: Population and Population Density by First Nation

First Nation	Area (km^2)	Population	Population Density (people/km^2)
Curve Lake	160	1,060	6.6
Hiawatha	8	483	59.9
Islands in the Trent Waters	0.4	0	0

Data Source: Calculated from Statistics Canada, GeoSuite, 92-150-XCB, 2006 Census

2.3.3.4 INTERACTIONS BETWEEN HUMAN AND PHYSICAL GEOGRAPHY

The primary land uses in the Otonabee-Peterborough Source Protection Area are agriculture, forestry, recreation, and urban development. The distribution and extent of land uses and human settlement is distinctly different between the northern and southern portions of the source protection area, primarily due to differences in physiography and access to water and transportation corridors. The presence of the Kawartha Lakes, many of which are part of the Trent-Severn Waterway, and numerous lakes, rivers, streams, and wetlands provide the area with a variety of recreational activities throughout the year.

The southern portion of the source protection area is dominated by agriculture, woodlands, and urban areas. The relatively deep glacial till soils found south of the Kawartha Lakes support widespread agricultural land use that includes cultivated fields and pasturelands. Urban areas are characterized by higher population density and higher proportions of impervious surfaces; these factors result in a greater demand on water resources. The City of Peterborough, located in the approximate center of this southern area, is the largest urban centre in the area followed by the Lakefield Ward, formerly the Village of Lakefield, located to the north of the City of Peterborough. Other smaller urban areas are also scattered throughout the area and provide a variety of goods and services to the surrounding, largely agricultural communities.

The northern portion of the source protection area is less densely populated and significantly less developed than the southern portion and is an important recreation centre for boating, swimming, seasonal residences, fishing, and outdoor winter sports. The granite bedrock and shallow overburden that characterize this area are not well suited for agricultural use and much of the area remains in its natural, forested state. While there are some areas of permanent residential development and small communities north of the Kawartha Lakes, new development is largely limited to seasonal, residential waterfront properties.

2.3.3.5 FEDERAL LANDS

Lands in the Otonabee-Peterborough Source Protection Area that are under the jurisdiction of the Government of Canada include those lands located along the Trent-Severn Waterway (including lands located at the bottom of lakes on the waterway) that are managed by Parks Canada. Federal lands in the source protection area are shown on Map 2-9(OP).

2.3.4 OVERVIEW OF DRINKING WATER SYSTEMS

Drinking water systems in the Otonabee-Peterborough 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 *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 that include the "large municipal residential" and "small municipal residential" classifications. The remaining six classifications include non-municipal and non-residential drinking water systems. Approximately half of the population of the source protection area relies on private wells and lake sources that 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.

2.3.4.1 MUNICIPAL RESIDENTIAL DRINKING WATER SYSTEMS

Approximately 67% of the population of the Otonabee-Peterborough Source Protection Area obtains their drinking water from 11 municipal residential drinking water systems (including the "large municipal residential" and "small municipal residential" classifications). Approximately 33% of the population relies on private wells and lake sources. These systems are discussed in more detail below, and their locations and approximate service areas are shown on Map 2-10(OP).

2.3.4.1.1 Surface Water Systems

There are three existing municipal residential drinking water systems in the Otonabee-Peterborough Source Protection Area that obtain their water from surface water sources. These systems serve approximately 86,579 people in Peterborough, Lakefield, and Hastings. Under the *Drinking-Water Systems Regulation* (*O. Reg. 170/03)*, all of these systems are classified as large municipal residential systems. These systems are discussed in more detail in Chapter 4.

2.3.4.1.2 Groundwater Systems

There are eight existing municipal residential groundwater supply systems in the Otonabee-Peterborough Source Protection Area that obtain their water from groundwater sources. These systems serve approximately 4,929 people in the communities of Alpine/Pirates Glen, Birchpoint Estates, Buckhorn Lake Estates, Elgeti/Crystal Springs Subdivision, Keene Heights Subdivision, Millbrook, Norwood, and Pinewood. Under the Drinking-Water Systems Regulation (O. Reg. 170/03), seven 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 more detail in Chapter 5.

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.

Three municipal residential drinking water systems in the source protection area are considered to be groundwater under the direct influence (GUDI) of surface water (Ministry of the Environment, 2008). These are the Buckhorn Lake Estates Well System, Crystal Springs Well System and the Norwood Well System.

2.3.4.2 OTHER DRINKING WATER SYSTEMS

There are approximately 154 drinking water systems in the source protection area that are classified as non-municipal or non-residential systems under the *Drinking-Water Systems Regulation (O. Reg. 170/03)* (e.g., 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 2.3-5A. Details for many of these systems are given in Appendix B, and their locations are shown on Map 2-11(OP). (Note that these systems were identified from the Drinking Water Information System database, which 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 2.3-5A: Other Drinking Water Systems in the Otonabee-Peterborough Source Protection Area

Safe Drinking Water Act Classification	Estimated No. Systems
Large municipal non-residential	1
Small municipal non-residential	27
Non-municipal year-round residential	11
Non-municipal seasonal residential	28
Large non-municipal non-residential	1
Small non-municipal non-residential	86

Data Source: Ministry of the Environment and Climate Change Drinking Water Information System, 2009

2.3.4.3 FIRST NATIONS SYSTEMS

The drinking water systems that serve the First Nations in the Otonabee-Peterborough Source Protection Area are discussed below.

2.3.4.3.1 Curve Lake First Nation

Approximately 87% of the residents of Curve Lake First Nation are served by private wells. The Nishnawbeke Subdivision Water System is owned and operated by the Curve Lake First Nation. It is the only truly communal water system in the community and serves approximately 13% of the population. Three wells currently service 51 homes (and potentially 55 homes) in the subdivision with an estimated 138 people. Systems that are owned and operated by the First Nation and serve the public are listed in Table 2.3-5B; these are not classified under the provincial *Drinking-Water Systems Regulation (O. Reg. 170/03)*. A new community water system (community wells) is in the planning stages. This will be constructed in three phases over a number of years.

2.3.4.3.2 Hiawatha First Nation

Most residents of Hiawatha First Nation are served by private wells. Systems that are owned and operated by the First Nation are listed in Table 2.3-5C; these are not classified under the provincial *Drinking-Water Systems Regulation (O. Reg. 170/03)*.

Table 2.3-5B: Curve Lake First Nation Drinking Water Systems

Drinking Water System	Users Served (approximate)
Nishnawbeke Subdivision Water System	138
Day Care (main building, church, toddler program building)	111
Church	350 (max)
School	200 (max)
Seniors Home/Centre	16
Small Business Centre	50
Health Centre	50
Band Office	50
Community Centre	660 (max)
Youth Drop-In Centre	20

Data Source: Curve Lake First Nation Source Protection Pre-Screening Survey, 2009

Table 2.3-5C: Hiawatha First Nation Drinking Water Systems

Drinking Water System	Users Served (approximate)
Hiawatha Church/Administration Building/Youth Centre/Community Centre Well System	75
Hiawatha Health Services Well System	30
Hiawatha Apartment Building Well System	7

Data Source: Darla Blodgett, Hiawatha First Nation Council Secretary (personal communication, March 22, 2010)

2.3.5 TERRESTRIAL AND AQUATIC CHARACTERISTICS

2.3.5.1 NATURAL VEGETATIVE COVER

Natural vegetative cover in the Otonabee-Peterborough Source Protection Area includes wetlands, woodlands, and vegetated riparian areas. Natural vegetative cover plays a critical role in protecting drinking water sources by trapping sediments and soils, and 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 2.3-6.

Wetlands

Wetlands found in the Otonabee-Peterborough Source Protection Area include swamps, fens, bogs, and marshes. Wetlands perform a significant role in improving water quality by contributing to groundwater recharge and 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 approximately 10% of the source protection area (353 km^2), which includes 66 Provincially Significant Wetlands that cover 181 km^2. Wetlands in the source protection area are shown on Map 2-12(OP).

Woodlands

Woodland cover in the Otonabee-Peterborough Source Protection Area includes successional and climax forests, hedgerows, and plantations. Woodland vegetation prevents erosion by stabilizing soils and acting as a natural shelterbelt. This protects water quality by preventing sedimentation of watercourses and provides wildlife habitat. Woodlands cover approximately 43% of the source protection area (1,438 km^2) and are shown on Map 2-12(OP).

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 in the Otonabee-Peterborough Source Protection Area were delineated as vegetated lands located within 120 m of lakes, wetlands, and watercourses. Vegetated riparian areas cover approximately 45% of the source protection area (1,362 km^2) and are shown on Map 2-13(OP).

Table 2.3-6: Natural Vegetative Cover in the Otonabee-Peterborough Source Protection Area

Natural Vegetative Cover Type		Area (km^2)	Land Coverage (%)
Wetlands	Provincially Significant	181	5
	Other Wetlands	172	5
Woodlands		1,438	43
Vegetated Riparian Areas[1]		1,362	45

[1]Vegetated riparian areas include vegetated lands located within 120 m of lakes, wetlands, and watercourses
Data Source: Calculated using data supplied under license by members of the Ontario Geospatial Data Exchange

2.3.6 AQUATIC HABITATS

Aquatic habitats are the areas inhabited by aquatic species. The health and composition of aquatic communities depend on the availability of adequate food, shelter, water, and space to provide the habitat required by the individual species utilizing the area. 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 Otonabee-Peterborough Source Protection Area, including fisheries and aquatic macroinvertebrates, and discusses the impacts of development on these aquatic communities. There are insufficient data to compare aquatic communities in the source protection area to unimpacted reference sites.

The Kawartha Lakes naturally divide the source protection area into distinct areas: the north that is largely undeveloped, sparsely populated, and continues to support extensive natural vegetative cover, and the south that supports intensive agricultural and urban land uses, has a significantly higher population density, and has lost most of its original natural vegetative cover.

2.3.6.1 FISHERIES

Location of Habitats

The Otonabee-Peterborough Source Protection Area includes many lakes, rivers, and streams that provide habitat for a variety of cold, cool, and warm water fish species. The lakes located north of the Kawartha Lakes generally support populations of Lake Trout and cool water sport fish and are generally deeper and colder than those found south of the Kawartha Lakes. In the southwest portion of the source protection area, cold water fish species are present only in the headwaters that originate from the Oak Ridges Moraine, namely, in Jackson, Cavan, Baxter, and Squirrel Creeks. Suitable cold water fish habitat also exists in the Ouse River in the northeast portion of the Ouse River subwatershed. Warm water streams and rivers are also found throughout the source protection area and support a variety of fish species. The warmer, shallower lakes, such as Chemong Lake and Rice Lake, are highly productive and support populations of Small and Largemouth Bass, Muskellunge, and a variety of pan fish.

Stream temperature can be used as an indicator to identify the potential locations of aquatic habitats. 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 is 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, 2009). Stream temperatures in the source protection area are shown on Map 2-14(OP).

Impacts of Development

Impacts of development on fish habitat in the Otonabee-Peterborough Source Protection Area include a reduction in the number of cold water streams and a loss of riparian vegetation. These impacts are particularly evident in the City of Peterborough where urbanization has resulted in the channelization of many watercourses, hardening of shorelines, and loss of riparian vegetation. Storm water outfalls also have a significant impact on water quality in the City of Peterborough, demonstrated by a high number of beach closures following rain events. Intensive development along lake shorelines, particularly for seasonal use, has resulted in the loss of lake-associated wetlands, important spawning areas, and riparian habitat. Increased boat traffic and fluctuating water levels and flows also have a negative impact on aquatic habitat.

2.3.6.2 AQUATIC MACROINVERTEBRATES

Location of Habitats

Aquatic macroinvertebrates, commonly referred to as benthic macroinvertebrates, are the 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 Index value for each location are shown on Map 2-15(OP). The Simpson’s

Diversity Index indicates the diversity of the benthic macroinvertebrate community. The location of benthic macroinvertebrate sampling sites and the Simpson's Diversity Index value at each site are shown on Map 2-16(OP).

Impacts of Development

Analysis of benthic macroinvertebrate communities across the Otonabee-Peterborough Source Protection Area indicated a range of water quality conditions, and species diversity and abundance. Sites with good water quality are dominated by pollution-intolerant species of the taxa Ephemeroptera, Trichoptera, and Plecoptera, and demonstrate species diversity and abundance. Such sites are typically found in the northern portion of the source protection area where development is limited and population density is very low. Sites with moderate water quality are dominated by the presence of pollution-tolerant benthic macroinvertebrates such as Worms and Diptera. Areas in the east central portion of the source protection area exhibit moderate water quality, particularly where agriculture is the dominant land use or where there is some level of urbanization. Sites with poor water quality, such as those located in the City of Peterborough and other urban areas subject to the impacts of intensive development, are dominated by pollution-tolerant species of the taxa Chironomidae, Simuliidae, and Isopoda, and show limited species diversity and abundance.

2.3.7 SURFACE WATER QUALITY

This section is a summary of the available data that is suitable for a watershed-scale analysis of surface water quality in the Otonabee-Peterborough Source Protection Area. Surface water quality data specific to individual drinking water systems were analysed during the evaluation of drinking water issues (see Section 4.3). Surface water quality data for the source protection area are available from a variety of monitoring programs, the most extensive and long-standing of which is the Provincial Water Quality Monitoring Network; this monitoring network has records from 37 monitoring stations across the source protection area, although not all remain active. As of 2009, 16 Provincial Water Quality Monitoring Network sites were actively being monitored, and the remaining 21 stations were discontinued. Provincial Water Quality Monitoring Network stations in the source protection area are listed in Table 2.3-7 and are shown on Map 2-17(OP). Data from the following programs were considered in this assessment of surface water quality in the source protection area:

- Ministry of the Environment and Climate Change Provincial Water Quality Monitoring Network: 1964 to present
- Ministry of the Environment and Climate Change Lake Partners Program: 2002 to 2005.

2.3.7.1 INDICATOR PARAMETERS

There are many water quality parameters that can be used to characterize the quality of a water source. A small group of parameters is often used to provide a representative overview of water quality in an area of interest. Six indicator parameters have been selected to represent the water quality conditions that reflect the natural features and land uses in the Otonabee-Peterborough Source Protection Area. These indicator parameters and their associated standards or guidelines, sources, and potential health and environmental impacts are identified in Table 2.3-8.

Table 2.3-7: Provincial Water Quality Monitoring Network Stations in the Otonabee-Peterborough SPA

Station Name	Station ID	First Year Sampled	Last Year Sampled	Total Years Sampled
Baxter Creek at Cedar Valley Road	17002101002	1965	1971	7
Baxter Creek at Hutchinson Drive	17002106902	1972	1990	19
Baxter Creek at Zion 4th Line	**17002107702**	**1977**	**2009**	**27**
Buckhorn Lake Outlet at County Road 23	**17002101802**	**1966**	**2009**	**41**
Cavan Creek at Airport Road	17002103002	1966	1977	12
Cavan Creek at Highway 7	**17002114002**	**2007**	**2009**	**1**
Clear Lake Outlet at Young's Point	**17002101602**	**1966**	**2009**	**41**
Eels Creek at Northey's Bay Road	17002105002	1971	1989	4
Indian River at County Road 2, Keene	17002100602	1965	2006	41
Indian River at David Fife Line	**17002114102**	**2007**	**2009**	**1**
Indian River at South Street, Warsaw	17002100902	1965	1987	8
Jack's Creek at Northey's Bay Road	17002105102	1971	1973	3
Jackson Creek at Dalhousie Street	**17002103802**	**1969**	**2009**	**37**
Jackson Creek at Parkhill Road West	17002101402	1965	1971	7
Lovesick Lake Outlet at Burleigh Falls	**17002101702**	**1966**	**2009**	**41**
Mississauga River at County Road 36	**17002105202**	**1971**	**2009**	**32**
Otonabee River at Bridge Street, Lakefield	17002101502	1965	2000	6
Otonabee River at County Road 2	**17002100802**	**1965**	**2009**	**42**
Otonabee River at Government dock, W. of Hwy 134, Lakefield	17002103102	1968	1972	5
Otonabee River at Highway 115 bridge	17002101202	1965	1999	8
Otonabee River at Highway 115 bridge	17002101102	1964	2006	28
Otonabee River at Lansdowne Street W	17002101183	1972	1991	18
Otonabee River at Lock 19	**17002107002**	**1972**	**2009**	**28**
Otonabee River at Lock 25	**17002106502**	**1972**	**2009**	**32**
Otonabee River at Matchett Line	**17002114402**	**2007**	**2009**	**1**
Otonabee River at Nassau Mills Road	17002101302	1965	2006	38
Ouse River at County Road 2	17002104902	1971	1999	4
Ouse River at River Road	17002112002	1983	2006	23
Ouse River Tributary at Dam of tributary pond, E of Hwy 7, Norwood	17002108002	1973	1977	5
Ouse River East at Center Line	**17002114302**	**2007**	**2009**	**3**
Ouse River East at Asphodel 8th Line	17002106602	1972	2006	29
Ouse River East at County Road 45, Norwood	**17002100702**	**1964**	**2009**	**38**
Ouse River East at Highway 7, Norwood	17002107902	1973	1986	6
Ouse River West at Asphodel 3rd Line	**17002114202**	**2007**	**2009**	**1**
Trent River at County Road 30	17002111083	1977	1990	14
Trent River at County Road 45, Hastings	**17002106702**	**1972**	**2009**	**32**
Trent River at Dents Cottage Dock, 137 m E of Bridge St, Hastings	17002100502	1965	1993	24
Trent River at Wellington Street, Hastings	17002100402	1965	1998	24

Data Source: Provincial Water Quality Monitoring Network
Active stations as of 2009 are shown in bold font

2.3.7.2 SUMMARY OF PROVINCIAL WATER QUALITY MONITORING NETWORK DATA

The following subsections summarize the surface water quality data available from the Provincial Water Quality Monitoring Network stations in the Otonabee-Peterborough Source Protection Area. Each subsection includes a brief discussion of the sampling results for the indicator parameters identified above and provides a table that summarizes the historical exceedances and trends for all data on record. It also 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.

Table 2.3-8: Surface Water Indicator Parameters

Parameter	Standards		Source	Effects
	PWQO[1]	CEQG[2]		
Chloride (Cl)	Not applicable	250 mg/L	Naturally occurring salts, 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).
Copper (Cu)	0.001 – 0.005 mg/L (hardness dependent)	1 mg/L	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)	0.001 – 0.005 mg/L (hardness dependent)	0.01 mg/L	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)	0.03 mg/L	5 mg/L	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 (rivers) 0.02 mg/L (lakes)	n/a	Incidental input or physical methods (e.g., erosion) (Sharpley et al., 1996). 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)	n/a	2.9 mg/L	Wastewater, septic systems, agricultural land use, and atmospheric deposition.	The most stable and usable form of nitrogen, but can be toxic in high concentrations and cause rapid growth of aquatic vegetation.

[1]Provincial Water Quality Objective

[2]Canadian Environmental Quality Guideline for the Protection of Aquatic Health

2.3.7.2.1 Chloride

Chloride concentrations recorded across the various monitoring locations are generally well below the Guidelines for Canadian Drinking Water Quality (250 mg/L), however concentrations at the majority of the sampling locations have been increasing over time. An expanding road network and increased traffic have likely increased road salt usage in the Otonabee-Peterborough Source Protection Area and resulted in an increase in chloride loadings to waterways.

The sampling location in Jackson Creek at Dalhousie Street in downtown Peterborough is the only active monitoring station in the source protection area where exceedances of the Guideline for chloride have been recorded since 1989. Jackson Creek flows directly through the downtown area and is highly channelized upstream of the sampling location, where little to no riparian vegetation is present. Chloride concentrations from the 35 samples collected at this location from 2004 through 2008 demonstrated an increase over this time period, although all remained considerably below the Guideline. The relatively high chloride concentrations observed at this location may be attributed to its urban surroundings. Chloride data from the Provincial Water Quality Monitoring Network are summarized in Table 2.3-9.

2.3.7.2.2 Metals

Copper

While copper concentrations in the Otonabee-Peterborough Source Protection Area have exceeded the Provincial Water Quality Objective (0.005 mg/L) at almost all sampling locations, an overall trend of declining copper levels has been observed across the source protection area. The highest rate of exceedance has historically occurred at the Jackson Creek at Dalhousie Street sampling location in downtown Peterborough, where 23.7% of the 228 samples analysed since 1981 exceeded the Provincial Water Quality Objective. Of the 35 samples analysed from this location between 2004 and 2008, only two exceeded the Objective. Copper data from the Provincial Water Quality Monitoring Network are summarized in Table 2.3-10.

Lead

Lead concentrations have historically exceeded the Provincial Water Quality Objective (0.005 mg/L) at many sampling locations throughout the Otonabee-Peterborough Source Protection Area with three of the thirteen sampling locations exhibiting trends of increasing lead concentrations, whereas the balance of locations demonstrate a declining trend with the exception of two sampling locations where there were insufficient data to identify trends. The highest rates of exceedance of the Objective occur at the following locations: Jackson Creek at Dalhousie Street in downtown Peterborough (52.6%), Lovesick Lake at Burleigh Falls (43.7%), Buckhorn Lake at County Road 23 (42.5%), Otonabee River at Lock 19 (42.3%), and Baxter Creek at Zion 4^{th} Line (39.4%). Lead data from the Provincial Water Quality Monitoring Network are summarized in Table 2.3-11.

Zinc

The Provincial Water Quality Monitoring network shows a general declining trend in zinc concentrations at all sampling locations in the Otonabee-Peterborough Source Protection Area, where sufficient data exist to identify trends. Various sampling locations have exhibited occasional exceedances of the Provincial Water Quality Objective (0.03 mg/L), although most samples yielded concentrations well below the Objective. One exceedance was recorded in 2007 at the Jackson Creek at Dalhousie Street sampling location in downtown Peterborough, however, zinc levels recorded prior to and subsequent to this singular sampling event yielded zinc concentrations that were well below the Objective, suggesting that the recorded exceedance is an anomaly and as such is not necessarily indicative of ongoing water quality at this location. Zinc data from the Provincial Water Quality Monitoring Network are summarized in Table 2.3-12.

Table 2.3-9: Summary of Chloride Sampling Data at Provincial Water Quality Monitoring Network Stations in the Otonabee-Peterborough SPA

Station Name	Station ID	Years on Record	No. Samples on Record	Trend[1]	GCDWQ Exceedances[2] (250 mg/L)		Descriptive Statistics (mg/L)						
					%	#	Years Analysed	n	min	median	max	Percentiles 25th	Percentiles 75th
Baxter Creek at Zion 4th Line	17002107702	77-97; 99-08	269	↑	0.0	0	04-08	35	4.7	5.6	14.3	5.3	6.2
Buckhorn Lake Outlet at County Road 23	17002101802	66-79; 81-97; 99-08	360	↑	0.0	0	04-08	35	10.4	12.9	17.3	11.3	14.2
Cavan Creek at Highway 7	17002114002	07-08	17	n/a	0.0	0	07-08	17	19.0	27.0	50.1	22.3	28.1
Clear Lake Outlet at Young's Point	17002101602	66-79; 81-97; 99-08	352	↑	0.0	0	04-08	35	9.6	11.9	16.1	10.7	12.5
Indian River at David Fife Line	17002114102	07-08	17	n/a	0.0	0	07-08	17	12.4	13.4	28.1	13.1	17.2
Jackson Creek at Dalhousie Street	17002103802	69-97; 99-08	362	↓	1.38	5	04-08	35	11.4	27.8	61.1	24.0	31.5
Lovesick Lake Outlet at Burleigh Falls	17002101702	66-79; 81-97; 99-08	354	↑	0.0	0	04-08	35	9.6	11.7	16.8	10.9	12.8
Mississauga River at County Road 36	17002105202	71-97; 99-08	321	↑	0.0	0	04-08	35	1.9	2.4	12.7	2.3	2.5
Otonabee River at County Road 2	17002100802	65-97; 99-08	378	↑	0.0	0	04-08	35	12.5	14.7	27.8	13.6	15.5
Otonabee River at Lock 19	17002107002	72, 77-97; 99-08	282	↑	0.0	0	04-08	35	3.7	12.5	18.2	11.6	13.4
Otonabee River at Lock 25	17002106502	72-97; 99-08	317	↑	0.0	0	04-08	35	10.1	12.3	16.8	11.2	12.9
Otonabee River at Matchett Line	17002114402	07-08	17	n/a	0.0	0	07-08	17	12.6	14.7	22.4	13.3	16.3
Ouse River East at Center Line	17002114302	07-08	17	n/a	0.0	0	07-08	17	13.6	23.1	49.0	18.5	25.6
Ouse River East at County Road 45	17002100702	65-71; 77-97; 99-08	349	↑	0.0	0	04-08	35	8.2	14.4	39.6	12.1	18.1
Ouse River West at Asphodel 3rd Line	17002114202	07-08	17	n/a	0.0	0	07-08	17	9.3	17.8	35.8	14.2	21.7
Trent River at County Road 45	17002106702	72-97; 99-08	328	↑	0.0	0	04-08	35	12.6	14.5	22.2	13.5	15.9

n/a indicates that there are insufficient data available to identify a trend

[1]Trend observed but not statistically validated

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

Table 2.3-10: Summary of Copper Sampling Data at Provincial Water Quality Monitoring Network Stations in the Otonabee-Peterborough SPA

Station Name	Station ID	Years on Record	No. Samples on Record	Trend[1]	PWQO Exceedances[2] (5 μg/L)		Descriptive Statistics (μg/L)						
					%	#	Years Analysed	n	min	median	max	Percentiles 25th	Percentiles 75th
Baxter Creek at Zion 4th Line	17002107702	81-97; 99-08	226	↓	7.5	17	04-08	35	0.0	0.5	2.0	0.3	0.9
Buckhorn Lake Outlet at County Road 23	17002101802	81-97; 99-07	214	↓	7.9	17	04-07	18	0.1	0.6	2.3	0.5	0.9
Cavan Creek at Highway 7	17002114002	07-08	17	n/a	0.0	0	07-08	17	0.4	0.9	1.3	0.6	1.0
Clear Lake Outlet at Young's Point	17002101602	81-97; 99-07	213	↓	6.6	14	04-07	18	0.2	0.5	1.5	0.4	0.6
Indian River at David Fife Line	17002114102	07-08	17	n/a	0.0	0	07-08	17	0.1	0.7	1.2	0.3	1.0
Jackson Creek at Dalhousie Street	17002103802	81-97; 99-08	228	↓	23.7	54	04-08	35	0.1	1.2	9.3	0.7	2.0
Lovesick Lake Outlet at Burleigh Falls	17002101702	81-97; 99-07	213	↓	9.4	20	04-07	18	0.0	0.6	2.0	0.3	0.8
Mississauga River at County Road 36	17002105202	71	233	↓	7.7	18	04-08	35	0.0	0.7	1.5	0.4	0.9
Otonabee River at County Road 2	17002100802	81-97; 99-08	205	↓	8.8	18	04-08	34	0.1	0.9	2.1	0.6	1.1
Otonabee River at Lock 19	17002107002	81-97; 99-07	213	↓	6.6	14	04-07	18	0.3	0.8	1.7	0.6	1.1
Otonabee River at Lock 25	17002106502	81-97; 99-08	226	↓	3.5	8	04-08	35	0.0	0.5	1.5	0.3	0.7
Ouse River East at County Road 45	17002100702	81-97; 99-08	229	↓	7.4	17	04-08	35	0.0	0.5	1.7	0.4	0.8
Trent River at County Road 45	17002106702	81-97; 99-07	211	↓	4.3	9	04-07	18	0.1	0.7	1.5	0.5	1.2

n/a indicates that there are insufficient data available to identify a trend

[1]Trend observed but not statistically validated

[2]Indicates the quantity of all samples on record that exceeded the Provincial Water Quality Objective

Table 2.3-11: Summary of Lead Sampling Data at Provincial Water Quality Monitoring Network Stations in the Otonabee-Peterborough SPA

Station Name	Station ID	Years on Record	No. Samples on Record	Trend[1]	PWQO Exceedances[2] (5 µg/L)		Descriptive Statistics (µg/L)						
					%	#	Years Analysed	n	min	median	max	Percentiles 25th	Percentiles 75th
Baxter Creek at Zion 4th Line	17002107702	81-97; 99-08	226	↓	39.4	89	04-08	35	0.0	0.0	15.0	0.0	1.9
Buckhorn Lake Outlet at County Road 23	17002101802	81-97; 99-07	214	↑	42.5	91	04-07	18	0.0	0.0	10.7	0.0	1.0
Cavan Creek at Highway 7	17002114002	07-08	17	n/a	5.9	1	07-08	17	0.0	0.0	5.1	0.0	0.0
Clear Lake Outlet at Young's Point	17002101602	81-97; 99-07	212	↓	3.3	7	04-07	18	0.0	0.0	7.9	0.0	0.7
Indian River at David Fife Line	17002114102	07-08	17	n/a	0.0	0	07-08	17	0.0	0.0	4.0	0.0	2.6
Jackson Creek at Dalhousie Street	17002103802	81-97; 99-08	228	↓	52.6	120	04-08	35	0.0	0.2	9.4	0.0	2.0
Lovesick Lake Outlet at Burleigh Falls	17002101702	81-97; 99-07	213	↑	43.7	93	04-07	18	0.0	0.2	9.4	0.0	2.2
Mississauga River at County Road 36	17002105202	80-97; 99-08	233	↓	39.1	91	04-08	35	0.0	0.0	12.6	0.0	2.5
Otonabee River at County Road 2	17002100802	81-97; 99-08	205	↓	4.9	10	04-08	34	0.0	0.0	11.5	0.0	2.5
Otonabee River at Lock 19	17002107002	81-97; 99-07	213	↑	42.3	90	04-07	18	0.0	0.0	15.9	0.0	1.7
Otonabee River at Lock 25	17002106502	81-97; 99-08	226	↓	4.9	11	04-08	35	0.0	0.6	9.5	0.0	3.0
Ouse River East at County Road 45	17002100702	81-97; 99-08	229	↓	5.2	12	04-08	35	0.0	0.0	5.7	0.0	1.7
Trent River at County Road 45	17002106702	81-97; 99-08	211	↓	3.3	7	04-08	18	0.0	0.1	14.2	0.0	2.7

n/a indicates that there are insufficient data available to identify a trend

[1]Trend observed but not statistically validated

[2]Indicates the quantity of all samples on record that exceeded the Provincial Water Quality Objective

Table 2.3-12: Summary of Zinc Sampling Data at Provincial Water Quality Monitoring Network Stations in the Otonabee-Peterborough SPA

Station Name	Station ID	Years on Record	No. Samples on Record	Trend[1]	PWQO Exceedances (30 µg/L)[2]		Descriptive Statistics (µg/L)						
					%	#	Years Analysed	n	min	median	max	Percentiles 25th	Percentiles 75th
Baxter Creek at Zion 4th Line	17002107702	81-97; 99-08	226	↓	0.0	0	04-08	35	0.0	1.0	12.1	0.6	1.9
Buckhorn Lake Outlet at County Road 23	17002101802	81-97; 99-07	213	↓	0.9	2	04-07	18	0.1	2.3	5.3	0.8	3.0
Cavan Creek at Highway 7	17002114002	07-08	17	n/a	0.0	0	07-08	17	0.0	1.5	8.1	0.6	3.3
Clear Lake Outlet at Young's Point	17002101602	81-97; 99-07	213	↓	1.4	3	04-07	18	0.2	1.0	3.5	0.7	2.1
Indian River at David Fife Line	17002114102	07-08	17	n/a	0.0	0	07-08	17	0.0	1.8	22.0	1.0	2.2
Jackson Creek at Dalhousie Street	17002103802	81-97; 99-08	227	↓	3.5	8	04-08	34	0.1	2.4	44.7	1.5	3.2
Lovesick Lake Outlet at Burleigh Falls	17002101702	81-97; 99-07	213	↓	0.9	2	04-07	18	0.1	1.3	8.2	0.3	1.6
Mississauga River at County Road 36	17002105202	80-97; 99-08	232	↓	0.9	2	04-08	35	0.4	1.8	3.5	1.1	2.4
Otonabee River at County Road 2	17002100802	81-97; 99-08	205	↓	0.5	1	04-08	34	0.0	1.9	10.8	1.3	3.1
Otonabee River at Lock 19	17002107002	81-97; 99-08	213	↓	0.0	0	04-07	18	0.4	1.5	3.8	0.9	2.3
Otonabee River at Lock 25	17002106502	81-97; 99-08	226	↓	0.9	2	04-08	35	0.0	1.2	9.5	0.8	1.6
Ouse River East at County Road 45	17002100702	81-97; 99-08	229	↓	0.4	1	04-08	35	0.0	1.9	13.5	0.9	2.9
Trent River at County Road 45	17002106702	81-97; 99-07	211	↓	0.0	0	04-07	18	0.1	1.7	8.1	0.5	3.0

n/a indicates that there are insufficient data available to identify a trend

[1]Trend observed but not statistically validated

[2]Indicates the quantity of all samples on record that exceeded the Provincial Water Quality Objective

2.3.7.2.3 Nutrients

Total Phosphorus

Total phosphorus is a measure of all forms of phosphorus present in water. Exceedances of the Provincial Water Quality Objective (0.03 mg/L) are common throughout the Otonabee-Peterborough Source Protection Area. While total phosphorus concentrations have been shown to fluctuate over time at all locations, there is an overall declining trend across the source protection area. Total phosphorus data from the Provincial Water Quality Monitoring Network are summarized in Table 2.3-13.

In addition to data from the Provincial Water Quality Monitoring Program, the Lake Partners Association, a volunteer-based water quality monitoring program supported by the Ministry of the Environment and Climate Change, has collected water samples for phosphorus analysis in various Peterborough County lakes across the source protection area and beyond. There are insufficient data available through this program to identify trends, however the following observations have been noted.

Rice Lake, located along the southern boundary of the source protection area and to which the entire source protection area ultimately drains, yielded the highest percentage of exceedances of the Provincial Water Quality Objective, with 88% of water samples collected from 2004 to 2005 yielding phosphorus levels above the Objective (Ministry of the Environment and Climate Change, 2002 to 2005). All three lakes sampled in the Township of Smith-Ennismore-Lakefield from 2002 to 2005 (Buckhorn, Chemong, and Lower Buckhorn Lakes) demonstrated exceedances of the Objective, from 19% to 33% of the samples collected. Six of the sixteen lakes (38%) sampled in the Township of Galway-Cavendish and Harvey exceeded the Objective, with the highest percentage recorded in Lovesick and Pigeon Lakes (30% and 24% of samples collected, respectively). Four of the five lakes sampled in the Township of Douro-Dummer (Clear, Katchewanooka, Stoney, Upper Stoney, and White Lakes) between 2002 and 2005 exceeded the Objective in as many as 39% of the samples. Two of nine lakes sampled in the Township of North Kawartha (Loon Call and Big Cedar Lakes) also yielded exceedances of the Objective, ranging from 10% to 15% of all samples collected from 2002 to 2005.

Nitrate Nitrogen

Nitrate nitrogen is the concentration of nitrogen present in water in the form of the nitrate ion (NO_3^-). No exceedances of the Canadian Environmental Quality Guideline (2.9 mg/L) for nitrate nitrogen have been recorded in the Otonabee-Peterborough Source Protection Area since such analysis was initiated by the Provincial Water Quality Monitoring Network in 1995. Levels of nitrate nitrogen recorded in surface water samples collected throughout the source protection area have been well below the Guideline. There is a general declining trend in nitrate nitrogen concentrations at all but one station (Baxter Creek at Zion 4th Line). Nitrate nitrogen data from the Provincial Water Quality Monitoring Network are summarized in Table 2.3-14.

Table 2.3-13: Summary of Total Phosphorus Data at Provincial Water Quality Monitoring Network Stations in the Otonabee-Peterborough SPA

Station Name	Station ID	Years on Record	No. Samples on Record	Trend[1]	PWQO Exceedances (0.03 mg/L)[2]		Descriptive Statistics (mg/L)					Percentiles	
					%	#	Years Analysed	n	min	median	max	25th	75th
Baxter Creek at Zion 4th Line	17002107702	77-97; 99-08	273	↓	22.0	60	04-08	35	0.010	0.020	0.260	0.010	0.030
Buckhorn Lake Outlet at County Road 23	17002101802	66-97; 99-08	390	↓	8.7	34	04-08	34	0.010	0.020	0.030	0.010	0.020
Cavan Creek at Highway 7	17002114002	07-08	17	n/a	5.9	1	07-08	17	0.010	0.020	0.040	0.010	0.020
Clear Lake Outlet at Young's Point	17002101602	66-97; 99-08	383	↓	9.9	38	04-08	34	0.006	0.015	0.025	0.011	0.017
Indian River at David Fife Line	17002114102	07-08	17	n/a	0.0	0	07-08	17	0.010	0.020	0.020	0.010	0.020
Jackson Creek at Dalhousie Street	17002103802	69-97; 99-08	374	↓	56.1	210	04-08	35	0.010	0.040	0.280	0.030	0.050
Lovesick Lake Outlet at Burleigh Falls	17002101702	66-97; 99-08	383	↓	7.0	27	04-08	34	0.010	0.020	0.030	0.010	0.020
Mississauga River at County Road 36	17002105202	71-97; 99-08	346	↓	2.6	9	04-08	34	0.000	0.010	0.020	0.000	0.010
Otonabee River at County Road 2	17002100802	65-97; 99-08	393	↓	42.0	165	04-08	35	0.007	0.019	0.047	0.016	0.023
Otonabee River at Lock 19	17002107002	72, 77-97; 99-08	283	↓	9.5	27	04-08	35	0.010	0.020	0.030	0.010	0.020
Otonabee River at Lock 25	17002106502	72-97; 99-08	321	↓	5.6	18	04-08	34	0.006	0.014	0.025	0.011	0.016
Otonabee River at Matchett Line	17002114402	07-08	17	n/a	5.9	1	07-08	17	0.010	0.020	0.040	0.020	0.020
Ouse River East at Center Line	17002114302	07-08	17	n/a	5.9	1	07-08	17	0.01	0.020	0.040	0.018	0.023
Ouse River East at County Road 45	17002100702	65-71; 77-97; 99-08	355	↓	16.6	59	04-08	35	0.006	0.014	0.048	0.011	0.020
Ouse River West at Asphodel 3rd Line	17002114202	07-08	17	n/a	5.9	1	07-08	17	0.010	0.020	0.040	0.010	0.020
Trent River at County Road 45	17002106702	72-97; 99-08	340	↓	32.1	109	04-08	35	0.007	0.022	0.033	0.017	0.026

n/a indicates that there are insufficient data available to identify a trend

[1]Trend observed but not statistically validated

[2]Indicates the quantity of all samples on record that exceeded the Provincial Water Quality Objective

Table 2.3-14: Summary of Nitrate Nitrogen Data at Provincial Water Quality Monitoring Network Stations in the Otonabee-Peterborough SPA

Station Name	Station ID	Years on Record	No. Samples on Record	Trend[1]	CEQG Exceedances (2.9 mg/L)[2]		Descriptive Statistics (Recent Data)					Percentiles	
					%	#	Years Analysed	n	min	median	max	25th	75th
Baxter Creek at Zion 4th Line	17002107702	95-97; 99-08	80	↑	0.0	0	04-08	33	0.11	0.75	0.88	0.68	0.77
Buckhorn Lake Outlet at County Road 23	17002101802	95-97; 99-08	79	↓	0.0	0	04-08	33	0.01	0.01	0.40	0.01	0.05
Cavan Creek at Highway 7	17002114002	07-08	17	n/a	0.0	0	07-08	17	0.24	0.36	0.76	0.31	0.43
Indian River at David Fife Line	17002114102	07-08	17	n/a	0.0	0	07-08	17	0.01	0.01	0.26	0.01	0.03
Jackson Creek at Dalhousie Street	17002103802	95-97; 99-08	78	↓	0.0	0	04-08	34	0.04	0.20	0.64	0.09	0.32
Lovesick Lake Outlet at Burleigh Falls	17002101702	95-97; 99-08	79	↓	0.0	0	04-08	33	0.01	0.02	0.40	0.01	0.07
Mississauga River at County Road 36	17002105202	95-97; 99-08	80	↓	0.0	0	04-08	33	0.01	0.03	0.13	0.01	0.06
Otonabee River at Lock 19	17002107002	95-97; 99-08	80	↓	0.0	0	04-08	34	0.01	0.03	0.46	0.02	0.13
Otonabee River at Lock 25	17002106502	95-97; 99-08	77	↓	0.0	0	04-08	33	0.01	0.02	0.34	0.01	0.11
Otonabee River at Matchett Line	17002114402	07-08	17	n/a	0.0	0	07-08	17	0.01	0.21	0.58	0.18	0.27
Ouse River East at Center Line	17002106602	07-08	17	n/a	0.0	0	07-08	17	0.25	0.72	2.01	0.66	1.15
Ouse River West at Asphodel 3rd Line	17002114202	07-08	17	n/a	0.0	0	07-08	17	0.01	0.02	0.27	0.01	0.09
Trent River at County Road 45	17002106702	95-97; 99-08	79	↓	0.0	0	04-08	33	0.01	0.03	0.38	0.02	0.06

n/a indicates that there are insufficient data available to identify a trend

[1]Trend observed but not statistically validated

[2]Indicates the quantity of all samples on record that exceeded the Provincial Water Quality Objective

2.3.8 GROUNDWATER QUALITY

This section is a summary of the available data that are suitable for a watershed-scale analysis of groundwater in the Otonabee-Peterborough Source Protection Area. Groundwater quality data specific to individual drinking water systems were analysed during the evaluation of drinking water issues (see Section 5.3). The available data include limited groundwater quality data from the Provincial Groundwater Monitoring Network and a variety of groundwater quality studies performed at local and regional scales.

2.3.8.1 INDICATOR PARAMETERS

There are many water quality 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. The data sources and groundwater quality studies identified in this characterization of groundwater quality use indicator parameters that reflect the natural features and land uses in the Otonabee-Peterborough Source Protection Area. The indicator parameters used in the analysis of Provincial Groundwater Monitoring Network data are described in Table 2.3-15.

2.3.8.2 PROVINCIAL GROUNDWATER MONITORING NETWORK

The Provincial Groundwater Monitoring Network in the Otonabee-Peterborough Source Protection Area was established in 2002/2003 by the Ministry of the Environment and Climate Change to provide data to characterize groundwater quantity and quality across the province. As part of the Provincial Groundwater Monitoring Network, 15 monitoring wells were established in the southern portion of the source protection area. These wells are described in Table 2.3-16 and their locations are shown on Map 2-18(OP).

Selected Provincial Groundwater Quality Monitoring Network wells in the source protection area were sampled and analysed from 2002 through to 2008 for various parameters listed in the *Ontario Drinking Water Quality Standards (O. Reg. 169/03)*. The number of samples and the range of sampling (for the period of time for which data are available for the indicator parameters described in Table 2.3-15) are listed in Table 2.3-17. There are insufficient groundwater quality data to identify trends in groundwater quality.

All of the wells exhibited exceedances of the Operational Guideline for hardness (80-100 mg/L), however the observed concentrations are not associated with health effects and remain below the level that is considered unacceptable for domestic purposes. All five samples collected at one of these wells exceeded the Maximum Acceptable Concentration for barium (1 mg/L), a common constituent in sedimentary rocks such as limestone and dolomite. (These are present throughout the source protection area.) Hard water often naturally contains concentrations of barium that are typically below the Maximum Acceptable Concentration, and most treatment methods used for water softening are effective for barium removal. Seven monitoring wells yielded iron concentrations that exceeded the Aesthetic Objective (0.3 mg/L), four of which also exhibited concentrations of manganese that exceeded the Aesthetic Objective (0.05 mg/L). Iron and manganese can be present in groundwater due to natural processes, and at excessive levels can cause discoloration of laundry and plumbing fixtures and an undesirable taste in drinking water. Four monitoring wells yielded water samples with sodium concentrations that exceeded the Aesthetic Objective. Sodium is not toxic, but elevated levels in drinking water may be of concern to persons that require a sodium restricted diet, particularly in combination with a domestic water softener, which typically increases the sodium content in treated water.

Table 2.3-15: 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. Sources include rocks, 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 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.	80-100 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-})	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. Natural sources include decomposing vegetation and rock or soil containing gypsum, barite, or other minerals.	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 500mg/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 a 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 the 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 Source: Ministry of the Environment and Climate Change (2003)

(1) Maximum Acceptable Concentration (MAC) and Aesthetic Objective (AO) / Operational Guideline (OG) values as per Ontario Regulation 169/03 made under *Safe Drinking Water Act* (amended to O. Reg. 327/08).

(2) The aesthetic objective for sodium in drinking water is 200 mg/L. As per the Ontario Drinking Water Standards, Objectives and Guidelines (June 2006), the local Medical Officer of Health should be notified when the sodium concentration exceeds 20 mg/L so that this information may be communicated to local physicians for their use with patients on sodium restricted diets.

Table 2.3-16: Provincial Groundwater Quality Monitoring Network Wells in the Otonabee-Peterborough SPA

Well Identification Numbers		Subwatershed	Casing Inside Diameter (in)	Well Depth[1] (m)	Static Water Level (m)	Aquifer (relative location)	Number of Water Quality Sampling Events
MOECC ID	Casing ID						
4502540	W0000192	Squirrel Creek	6.250	20.70	11.55	Middle	4
5116850	W0000193	Unknown	6.250	51.73	19.50	Deep	1
5117680	W0000195	Indian River	6.250	15.85	4.83	Shallow	4
5101076	W0000196	Indian River	6.250	15.85	5.56	Shallow	4
5104019	W0000197	Unknown	6.250	12.12	1.38	Shallow	1
5108692	W0000198	Indian River	6.250	43.82	5.95	Deep	4
5108009	W0000206	Indian River	6.250	12.89	1.31	Shallow	1
5109005	W0000225	Squirrel Creek	6.250	23.40	3.00	Middle	4
n/a	W0000253	Meade Creek	2.000	9.91	4.83	Shallow	1
5119203	W0000254	Ouse River	3.250	6.24	2.86	Shallow	1
5119205	W0000255-2	Squirrel Creek	2.000	7.21	2.30	Shallow	4
4502540	W0000255-3	Squirrel Creek	2.000	18.75	1.67	Middle	1
BH00-1A	W388	Pigeon River	2	182	48.78	Very deep	5
W0000389	W389-2a	Pigeon River	1.25	52.96	30.72	Deep	0
W0000389	W389-2b	Pigeon River	1.25	82.6	31.02	Very deep	0

Data source: Provincial Groundwater Quality Monitoring Network; Otonabee Region Conservation Authority
[1]Depth of screen in casing

Table 2.3-17: Summary of Provincial Groundwater Monitoring Network data in the Otonabee-Peterborough Source Protection Area

Well ID	Year Sampled[1]	Hardness		Sodium		Iron		Sulfate		Chloride		Nitrate		Organic N		DOC		TDS		Barium		Manganese		Fluoride	
		Range of Results (mg/L)	No. Samples	Range of Results (mg/L)	No. Samples	Range of Results (µg/L)	No. Samples	Range of Results (mg/L)	No. Samples	Range of Results (mg/L)	No. Samples	Range of Results (mg/L)	No. Samples	Range of Results (mg/L)	No. Samples	Range of Results (mg/L)	No. Samples	Range of Results (mg/L)	No. Samples	Range of Results (µg/L)	No. Samples	Range of Results (µg/L)	No. Samples	Range of Results (mg/L)	No. Samples
MAC/ AO/OG*		80-100 mg/L		20 mg/L		300 µg/L		500 mg/L		250 mg/L		10 mg/L		0.15 mg/L		5 mg/L		500 mg/L		1000 µg/L		50 µg/L		1.5 mg/L	
4502540	03; 06-08	159-163	2	5.0-7.9	4	1130-6230	4	0.6-24.2	4	15.1-21.0	4	0.05-1.80	4	0.05-2.00	4	1.4-2.0	2	134-303	4	20.8-72.6	4	66.4-176.0	4	0.01-0.09	4
5116850	03; 07-08	148-176	2	3.5-28.2	3	7-92	2	73.0-103.0	3	5.5-6.8	3	0.042-0.087	3	0.05-0.88	3	0.8-1.5	2	340-425	3	50.3-85.2	3	17.8-34.0	3	0.85-1.15	3
5117680	03; 06-08	281-283	2	5.4-6.4	4	6-260	4	38.1-53.9	4	9.0-10.8	4	0.366-0.450	4	0.36-0.45	4	1.3-1.5	2	334-357	4	112.0-142.0	4	2.0-29.8	4	0.05-0.13	4
5101076	03 06 07 08	273-361	2	1.2-8.0	4	1-2460	4	7.6-16.0	4	1.7-29.0	3	0.450-0.640	4	0.05-0.64	4	1.5-1.6	2	295-453	4	25.4-39.6	4	0.2-30.6	4	0.01-0.06	4
5104019	02	202	1	18.0	1	6880	1	1.2	1	18.0	2	no data		no data		1.3	1	273	1	99.9	1	253	1	0.40	1
5108692	02; 05-08	139-166	3	66.3-85.6	5	0-880	5	8.5-45.6	5	26.9-28.0	5	0.050-0.100	4	0.05-0.06	4	0.6-0.7	2	354-409	5	1180-2220	5	2.0-5.7	5	1.40-1.66	4
5108009	02	284	1	3.2	1	238	1	29	1	15.8	2	no data		no data		1.8	1	357	1	36.2	1	7.5	1	0.26	1
5109005	03;06-08	229-238	2	3.8-10.7	4	53-1530	4	21.0-30.2	4	4.0-14.0	4	0.005-0.060	4	0.05-0.06	4	0.9-1.2	2	280-320	4	136.0-311.0	4	4.4-44.3	4	0.06-0.19	4
N/A	03	202	1	17.2	1	0	1	43	1	6.6	1	0.044	1	0.05	1	1.2	1	398	1	57.7	1	5.38	1	0.07	1
5119203	03	279	1	36.2	1	1090	1	15.1	1	45.7	1	0.045	1	0.05	1	3.0	1	402	1	54.7	1	56.1	1	0.46	1
5119205	03; 06-07-08	223-276	3	3.8-21.3	5	4-3340	5	23.0-38.8	5	2.4-110.0	5	0.045-0.050	4	0.05-0.10	5	1.0-1.8	3	272-363	5	149.0-297.0	5	7.3-86.6	5	0.03-1.30	5

Data source: Provincial Groundwater Quality Monitoring Network
*MAC/AO/OG = Maximum Acceptable Concentration/ Aesthetic Objective/ Operational Guideline as per Regulation 169/03 made under *Safe Drinking Water Act* (amended to O. Reg. 327/08)
[1]Selected parameters analysed each year

2.3.8.3 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.

2.3.8.4 REGIONAL GROUNDWATER STUDIES

2.3.8.4.1 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 map the groundwater resources and delineate wellhead protection areas in municipalities across the province. The Trent Conservation Coalition Municipal Groundwater Study was completed by Morrison Environmental Ltd. The Aquifer Characterization component of the study (Volume 1) evaluated groundwater quality in bedrock and overburden wells across most of the Trent Conservation Coalition Source Protection Region.

In the Paleozoic Area the study observed that the vast majority of bedrock wells yield fresh water though they may require treatment to meet Ontario Drinking Water Standards (Morrison Environmental Ltd., 2004). There are some occurrences of sulphurous water where Paleozoic and Precambrian meet; this is attributed to the high organic content of the rock. The study also noted that salty and sulphurous water had been reported in bedrock wells north of the City of Peterborough and east of Chemong Lake.

In the Precambrian Area, the vast majority of bedrock wells yield fresh water although treatment to decrease the hardness and remove iron may be required to meet Ontario Drinking Water Standards (Morrison Environmental Ltd., 2003). Hardness and sulphates in the water were reported primarily along the Paleozoic-Precambrian contact. In addition, salty water was noted as having been reported and the study states that this may be due to anthropogenic activities such as road salting/stockpiling, dust control activities, and landfills.

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

Singer et al. (2003) provided information related to the quality of groundwater in the Precambrian and Simcoe Group hydrogeologic units, which encompass the northern and southern portions of the Otonabee-Peterborough Source Protection Area, respectively. 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 in the southern portion of the source protection area yield fresh water, but they occasionally yield water with natural water quality problems such as high levels of sulphate, hardness, or chloride. Most bedrock wells in the northern portion of the source protection area yield fresh water.

The report also indicated that the majority of the wells constructed in overburden, which are concentrated in the southern portion of the source protection area, yield fresh water with a very few exhibiting elevated chloride, sulphate, and hardness levels.

2.3.9 REFERENCES

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2.4 CROWE VALLEY SOURCE PROTECTION AREA

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. This is a watershed characterization of the Crowe Valley Source Protection Area prepared in accordance with the *Clean Water Act*, *2006*, *O. Reg. 287/07*, and Part II of the *Technical Rules*. This watershed characterization draws from an earlier document prepared before the publication of the *Technical Rules* and has expanded on it where required to satisfy the legislation. The report was prepared in 2008 by Crowe Valley Conservation Authority and is entitled: *Watershed Characterization Report: Crowe Valley Source Protection Area*.

2.4.1 OVERVIEW OF SOURCE PROTECTION AREA

The Crowe Valley Source Protection Area covers an area of approximately 2,006 km^2 and includes the entire Crowe River watershed. The source protection area boundary and its subwatersheds are shown on Maps 2-1(CV) and 2-2(CV), respectively.

The headwaters of the Crowe River are located in the northwest corner of the source protection area near Paudash Lake and flow in a southerly direction. The main channel of the Crowe River flows through a number of smaller waterbodies and empties into Belmont Lake. The Crowe River has two major tributaries: North River and Beaver Creek. The North River headwaters are above the Kasshabog Lake area in the northeastern corner of Havelock-Belmont-Methuen. It flows south through the southwestern portion of the source protection area, through Round Lake, and then joins the Crowe River subwatershed at Belmont Lake. The Beaver Creek tributary originates in the northeast corner of the source protection area and its subwatershed includes Cashel, Limerick, and Steenburg Lakes. Beaver Creek empties into Crowe Lake where the Crowe River and its tributaries flow into the Trent River.

The natural flows in the source protection area are regulated by a system of dams and weirs for purposes of flood control, recreation, and fish habitat requirements. The source protection area lies predominantly in the rugged Canadian Shield where outcrops of granite and other Precambrian rocks are located at or near the surface; only the southern portion (south of Highway 7) is located in the Paleozoic area. Because of the rough terrain (particularly in the north), woodland coverage is high. Some agriculture occurs in the south where soil conditions permit. There are also numerous wetlands and small lakes in the source protection area that increase its value for recreational use.

2.4.2 GEOGRAPHY AND LAND USE

2.4.2.1 PHYSICAL GEOGRAPHY

The prominent physiographic features in the Crowe Valley Source Protection Area include moraines, tills, eskers, and limestone plains. Physiographic regions in the source protection area are shown on Map 2-3(CV) and the percent coverage of each physiographic region is identified in Table 2.4-1. Physical characteristics of subwatersheds are summarized in Table 2.4-2.

The source protection area is divided near its southern tip by the Precambrian/Paleozoic geologic divide. The prominent physiographic regions north of the divide are the Algonquin Highlands and the Georgian Bay Fringe. This northern section is dominated by knobs and ridges of granite rocks, bare rock outcrops, and rough terrain typical of the Canadian Shield. The southern section is occupied by the Dummer Moraine and the Lake Iroquois Plain. This section consists of hummocky terrain and blocks of limestone mixed with Precambrian boulders of the Paleozoic age. It is characterized by rolling topography, smooth slopes, and marginal to good farmland (Chapman & Putman, 1984).

Throughout the source protection area there are numerous swamps, lakes, and marshes that generally occupy bedrock basins.

Table 2.4-1: Physiographic Regions in the Crowe Valley Source Protection Area

Physiographic Region	Area (km^2)	Land Coverage (%)
Algonquin Highlands	1031.36	51.41
Dummer Moraines	307.92	15.35
Georgian Bay Fringe	658.22	32.81
Iroquois Plain	7.89	0.39
Peterborough Drumlin Field	0.71	0.04

Data Source: Watershed Characterization Report: Crowe Valley Source Protection Area (2008)

Table 2.4-2: Physical Characteristics of Crowe Valley Source Protection Area Subwatersheds

Subwatershed	Drainage Area (km^2)	Channel Length (km)	Total Fall (m)	Channel Average Slope (%)	Percent Land Cover			Physiographic Region(s)
					Wetlands	Lakes	Woodland	
Crowe River	1259.93	105.3	175	0.3	6	10	77	Georgian Bay Fringe, Algonquin Highlands, Dummer Moraines
Beaver Creek	569.52	62.5	131	0.2	4	8	87	Georgian Bay Fringe, Algonquin Highlands
North River	178.54	26.4	63	0.2	5	14	76	Georgian Bay Fringe

Data Sources: Calculated using data supplied under license by members of the Ontario Geospatial Data Exchange

2.4.3 HUMAN GEOGRAPHY: POPULATION AND LAND USE

2.4.3.1 AREAS OF SETTLEMENT

The *Places to Grow Act, 2005* provides a legislative framework for the development of growth plans in designated growth areas. The *Places to Grow Act* provides the following definition for 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."* The *Places to Grow Act* does not apply to settlements in the Crowe Valley Source Protection Area, however in accordance with the *Technical Rules*, this definition has been used to define areas of settlement.

Areas of settlement in the source protection area are generally found along its southern boundary and near major lakes. Settlement is rural and in the form of small towns and hamlets. The largest settlement areas in the watershed are the villages of Havelock and Marmora and the hamlet of Coe Hill. There are also scattered pockets of settlement throughout the watershed with direct links to major roads and waterbodies. Additional settlements are increasing in more northern locations surrounding many of the hamlets and Highways 28, 620, and 46. There is a high seasonal fluctuation in population in the rural areas due to tourism, recreation, and seasonal residents of waterfront properties. Areas of settlement in the Crowe Valley Source Protection Area are shown on Map 2-4(CV).

2.4.3.2 MUNICIPALITIES

There are 11 municipalities located within or partially within the Crowe Valley Source Protection Area. The total population of these municipalities is 41,441 (Statistics Canada, 2006), and about 10,490 of them are located within the source protection area boundary. Population density is typically low; most of the source protection area has less than 10 people/km^2. Population density is highest in the southern portion of the source protection area; in this area population density exceeds 40 people/km^2. There is a seasonal increase of population in some parts of the source protection area during the summer months. Municipal boundaries, populations, and population densities in the source protection area are shown on Maps 2-5(CV), 2-6(CV), and 2-7(CV), respectively. Municipalities located in the source protection area, their total population and area, and the portion of their population and area located within the source protection area are listed in Table 2.4-3.

Table 2.4-3: Municipal Populations in the Crowe Valley Source Protection Area

Municipality	Source Protection Area		Entire Municipality	
	Area (km^2)	Population	Area (km^2)	Population
Township of Havelock-Belmont-Methuen	471	3,782	594	4,637
Municipality of Marmora and Lake	453	2,612	588	3,912
Township of Wollaston	218	695	227	730
Township of Tudor and Cashel	172	259	458	682
Township of North Kawartha	171	564	844	2,342
Township of Limerick	168	274	233	364
Municipality of Highlands East	166	952	758	3,089
Township of Faraday	125	787	237	1,578
Municipality of Trent Hills	27	355	568	12,247
Township of Stirling-Rawdon	18	147	285	4,906
Township of Douro-Dummer*	13	63	484	6,954

*Located only marginally within the source protection area
Data Source: Calculated from Statistics Canada, GeoSuite, 92-1500XCB, 2006 Census

2.4.3.3 FIRST NATIONS

There are no First Nations communities in the Crowe Valley Source Protection Area.

2.4.3.4 INTERACTIONS BETWEEN HUMAN AND PHYSICAL GEOGRAPHY

Physiography and access to water and transportation corridors had the most significant influence on human settlement in the Crowe Valley Source Protection Area.

The Iroquois Plain and the Dummer Moraines are the most densely populated physiographic regions in the Crowe Valley Source Protection Area, and they are where the largest urban centres and the most productive farmlands are found.

During early settlement days, agriculture was, next to forestry, the primary industrial activity in the source protection area. However in the present day, agriculture is limited due to poor soil quality and quantity; poor soil quality is attributed to the rock-based areas in the majority of the watershed that are part of the natural physiographic characteristics of the Canadian Shield. Only a small percentage of the source protection area is now used for agriculture.

2.4.3.5 FEDERAL LANDS

Lands in the Crowe Valley Source Protection Area that are under the jurisdiction of the Government of Canada include two aircraft navigation beacons. These are located on County Road 46 northeast of Kasshabog Lake in the Municipality of Havelock-Belmont-Methuen and in the southeast portion of the Crowe Valley Source Protection Area watershed along 11th Line East in the Municipality of Trent Hills. The locations of these sites are shown on Map 2-8(CV).

2.4.4 OVERVIEW OF DRINKING WATER SYSTEMS

Drinking water systems in the Crowe Valley 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 *Safe Drinking Water Act, 2002* 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. About half of the population of the source protection area relies on private wells and lake sources that 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.

2.4.4.1 MUNICIPAL RESIDENTIAL DRINKING WATER SYSTEMS

About 46% of the population in the Crowe Valley Source Protection Area (approximately 4,825 people) obtains their drinking water from four 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(CV).

2.4.4.1.1 Surface Water Systems

There is one existing municipal residential surface water supply system in the source protection area that obtains water from a surface water source. This system serves about 1,500 people in the community of Marmora and, under the *Drinking-Water Systems Regulation* (*O. Reg. 170/03)*, it is classified as a large municipal residential system. This system is discussed in detail in Chapter 4.

2.4.4.1.2 Groundwater Systems

There are three existing municipal residential groundwater supply systems in the source protection area that obtain their water from groundwater sources. These systems serve about 1,730 people. Under the *Drinking-Water Systems Regulation (O. Reg. 170/03)*, two of these systems are classified as large municipal residential systems and the third is classified as a small municipal residential system. These systems are discussed in detail in Chapter 5.

There are two municipal residential drinking water systems in the source protection area (Cardiff and Havelock) that are considered to be groundwater under the direct influence (GUDI) of surface water. The Cardiff well is considered GUDI because it is constructed in an overburden aquifer that is located within 90 m of a surface waterbody (Mink Creek) (Morrison Environmental Ltd., 2004). There are three wells in the Havelock system under the influence of surface water. In situ filtration removes particulate matter at two of these wells (Genivar Consultants, 2010).

> ***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.*

2.4.4.2 OTHER DRINKING WATER SYSTEMS

There are about 32 drinking water systems in the source protection area that are classified as non-municipal or non-residential systems under the *Drinking-Water Systems Regulation (O. Reg. 170/03)* (e.g., 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 2.4-4. Details for many of these systems are given in Appendix B, and their locations are shown on Map 2-10(CV). (Note that these systems were identified from the Drinking Water Information System database, which 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 2.4-4: Other Drinking Water Systems in the Crowe Valley Source Protection Area

Safe Drinking Water Act Classification	Estimated No. Systems
Large municipal non-residential	0
Small municipal non-residential	11
Non-municipal year-round residential	3
Non-municipal seasonal residential	6
Large non-municipal non-residential	0
Small non-municipal non-residential	12

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

2.4.5 TERRESTRIAL AND AQUATIC CHARACTERISTICS

2.4.5.1 NATURAL VEGETATIVE COVER

Natural vegetative cover in the Crowe Valley Source Protection Area includes wetlands, woodlands, and vegetated riparian areas. Natural vegetative cover plays a critical role in protecting drinking water sources by trapping sediments and soils, and 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 2.4-5.

Table 2.4-5: Natural Vegetative Cover in the Crowe Valley Source Protection Area

Natural Vegetative Cover Type		Area (km^2)	Land Coverage (%)
Wetlands	Provincially Significant	33	2
	Other Wetlands	192	13
Woodlands		1548	78
Vegetated Riparian Areas[1]		1115	56

[1]Vegetated riparian areas include vegetated lands located within 120 m of lakes, wetlands, and watercourses
Data Source: Ontario Geospatial Data Exchange, 2009

Wetlands

Wetlands found in the Crowe Valley Source Protection Area include swamps, fens, bogs, and marshes. Wetlands perform a significant role in improving water quality by contributing to groundwater recharge and 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 13% of the source protection area (192 km^2), which includes 15 Provincially Significant Wetlands that cover 33 km^2. Wetlands in the watershed are shown on Map 2-11(CV).

Woodlands

Woodland cover in the Crowe Valley Source Protection Area includes successional and climax forests, hedgerows, 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 watershed is shown on Map 2-11(CV).

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 in the watershed were delineated as vegetated lands located within 120 m of lakes, wetlands, and watercourses. Vegetated riparian areas in the Crowe Valley Source Protection Area are shown on Map 2-12(CV).

2.4.5.2 AQUATIC HABITATS

Aquatic habitats are the areas 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 Crowe Valley Source Protection Area, including fisheries and aquatic macroinvertebrates, and discusses the impacts of development on these aquatic communities. There are insufficient data to compare aquatic communities in the watershed to unimpacted reference sites or to fully characterize aquatic habitats in the watershed.

2.4.5.2.1 Fisheries

Location of Habitats

The Crowe Valley Source Protection Area includes many lakes, rivers, and streams that provide habitat for a variety of cold, cool, and warm water fish species. The lakes located north of Chandos Lake (and including Chandos) are generally deeper and colder than those found south of Chandos. Cold lakes support populations of Lake Trout and cool water sport fish. Many warm water streams are also found throughout the watershed and support a variety of fish species. The southern lakes such as Round, Belmont, and Crowe Lakes are warmer and support warm water fish species.

There are no data available that indicate the confirmed location of aquatic habitats in the watershed, however stream temperature can be used as an indicator to identify the potential locations of aquatic habitats. 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, 2009). Stream temperatures in the Crowe Valley Source Protection Area are shown on Map 2-13(CV).

Impacts of Development

Impacts of development on fish habitats in the Crowe Valley Source Protection Area include a reduction in the number of cold water streams and lakes and a loss of riparian vegetation. Some lakes, such as Steenburg and Paudash, have traditionally been known as cold water lakes, but in recent years they have developed characteristics of warmer water lakes. These impacts are particularly evident in Paudash Lake where a warm water fishery was established in Lower Paudash Lake through stocking. Lake Paudash now has a species composition typical of most warm water lakes in Southern Ontario (French Planning Services Inc., 2004). Development along lake shorelines, particularly for seasonal use, has resulted in the loss of lake-associated wetlands, important spawning areas, and riparian habitat. Increased boat traffic and fluctuating water levels and flows also have a negative impact on aquatic habitat. Additional data are required to fully characterize the fisheries in the Crowe Valley Source Protection Area; the condition of many lakes and streams remains unknown.

2.4.5.2.2 Aquatic Macroinvertebrates

Location of Habitats

Aquatic macroinvertebrates, commonly referred to as benthic macroinvertebrates, are the 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 Index for each location are shown on Map 2-14(CV). The Simpson's Diversity Index indicates the diversity of the benthic macroinvertebrate community. The location of benthic macroinvertebrate sampling sites and the Simpson's Diversity Index at each site are shown on Map 2-15(CV).

Impacts of Development

Analysis of benthic macroinvertebrate communities across the Crowe Valley 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 species diversity and abundance. Sites with moderate water quality are dominated by the presence of pollution-tolerant benthic macroinvertebrates. Sites with poor water quality are dominated by pollution-tolerant species of the taxa Chironomidae, Simuliidae, and Isopoda and show limited diversity and abundance. Map 2-14(CV) shows a scattering of sites across the watershed with a range of excellent to fairly poor sites, and no sites ranked as poor. Benthic monitoring began at Crowe Valley in 2006 and has continued annually. Out of 24 sampled sites in 2006 and 2007, two sites ranked as excellent quality, eight as very good/good, seven as fair with fairly substantial organic pollution likely, and seven as fairly poor with substantial organic pollution likely. These results are over a 3-year period and are considered preliminary. Continued collection and analysis of benthic macroinvertebrates over time will produce a more accurate picture of stream conditions in the Crowe Valley Source Protection Area.

2.4.6 SURFACE WATER QUALITY

This section is a summary of the available data that are suitable for a watershed-scale analysis of surface water quality in the Crowe Valley Source Protection Area. Surface water quality data specific to individual drinking water systems were analysed during the evaluation of drinking water issues (see Section 4.3). Surface water quality data for the watershed are available from the Provincial Water Quality Monitoring Network and from sampling at municipal water treatment plants. Surface water quality monitoring stations in the watershed are shown on Map 2-16(CV).

2.4.6.1.1 Indicator Parameters

There are many water quality parameters that can be used to characterize the quality of a water source. 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 Crowe Valley Source Protection Area. Indicator parameters and their associated standards or guidelines are identified in Table 2.4-7.

2.4.6.1.2 Summary of Provincial Water Quality Monitoring Network Data

The following subsections summarize the surface water quality data available from the Provincial Water Quality Monitoring Network (PWQMN) stations in the Crowe Valley Source Protection Area. Each subsection includes a brief discussion of the sampling results for the indicator parameters identified in Table 2.4-7. To characterize the surface water quality in the Crowe Valley Source Protection Area, two types of analysis were performed and two tables are provided for each parameter. The first table, “Statistical Summary of Data at Selected PWQMN Stations,” highlights the minimum, medium, and maximum values for each active monitoring station in the Crowe Valley watershed for the period of 2004 to 2009, where available.

The second table for each parameter, “Trends and Guideline Exceedances at Selected PWQMN Stations,” calculates water quality trends over time with both historical and active monitoring stations.

Trend analysis was performed on 16 sites across the watershed. The sites were chosen based on how many years of data existed and how many sites were sampled consistently through the entire data record without having large gaps in time.

While there are more than 16 historical monitoring stations in the Crowe Valley watershed, a number of sites were omitted based on an inadequate number of samples, or a lack of metals data from the Ministry of the Environment and Climate Change. It was assumed that the omitted sites would not be statistically viable as they lacked a sufficient number of data points for trend analysis.

General trends and statistical summaries have been performed below, however, continued sampling in the years to come will strengthen the significance of the observed trends and statistics. Even with the omission of certain historical sites, take note that some sites have very few samples and therefore must be interpreted with caution. Trends were identified, even if the statistical significance was weak – to find the statistical significance of the trend, take note of the P value to assure the significance of the trend.

Table 2.4-6: Provincial Water Quality Monitoring Network Stations and Available Data

Subwatershed	Station Name	Station ID	Data Record	Active/Historic
Crowe River	Crowe River	17002100302	1964-1998, 2006-present	Active
Beaver Creek	Beaver Creek	17002109502	2006-present	Active
North River	North River	17002109202	1976-1983, 2006-present	Active
Crowe River	Deer River	17002114602	2006-2008	Active
Crowe River	Crowe River	17002114502	2006-present	Active
Crowe River	Crowe River	17002104802	1971-1998	Historic
Crowe River	Paudash Lake	17002105901	1966-1992	Historic
Crowe River	Deer Creek	17002106002	1966-1992	Historic
Crowe River	Centre Lake Outlet	17002106102	1971-1992	Historic
Crowe River	Bow Lake Outlet	17002106202	1966-1996	Historic
Crowe River	Bentley Creek	17002106302	1966-1996	Historic
Crowe River	Bentley Creek	17002106402	1967-1996	Historic
Crowe River	Plato Creek	17002107202	1972-1998	Historic
Crowe River	Plato Creek	17002107802	1977-1990	Historic
Crowe River	Plato Creek	17002108102	1976-1981	Historic
Crowe River	Crowe River	17002108202	1976-1983	Historic
Crowe River	Crowe River	17002108302	1976-1983	Historic
Crowe River	Crowe River	17002108402	1976-1998	Historic
Crowe River	Crowe River	17002108502	1976-1979	Historic
Crowe River	Crowe River	17002108602	1976-1979	Historic
Crowe River	Deer Creek	17002108702	1976-1979	Historic
Crowe River	Crowe River	17002108902	1966-1996	Historic
Crowe River	Paudash Lake Narrows	17002109001	1966-1992	Historic
North River	North River	17002109102	1976-1985	Historic
North River	North River	17002109202	1976-1983	Historic
North River	North River	17002109402	1976-1977	Historic
Beaver Creek	Beaver Creek	17002109502	1976-1998	Historic
Beaver Creek	Beaver Creek	17002109602	1976-1998	Historic
Beaver Creek	Steenburg Creek	17002109702	1976-1997	Historic
Crowe River	Crowe River	17002109802	1966-1969	Historic
Crowe River	Crowe River	17002109902	1966-1969	Historic
Crowe River	Crowe River	17002110002	1966-1981	Historic
Crowe River	Paudash Lake	17002110101	1966-1984	Historic
Crowe River	Paudash Lake	17002110201	1966-1984	Historic
Crowe River	Paudash Lake	17002110301	1966-1984	Historic
Crowe River	Bow Lake	17002110401	1966-1969	Historic
Crowe River	Bow Lake	17002110501	1966-1969	Historic
Crowe River	Centre Lake	17002111101	1977-1980	Historic
Crowe River	Auger Lake	17002111201	1977-1980	Historic
Crowe River	Rib. Creek to Deer Creek	17002111302	1977-1992	Historic
Crowe River	Centre Lake Water Supply	17002111420	1977-1979	Historic
Beaver Creek	Twin Sister Lake	17002111701	1979	Historic

Data Source: Provincial Water Quality Monitoring Network, 2008

Table 2.4-7: Surface Water Indicator Parameters

Parameter	Standards		Source	Effects
	PWQO[1]	CEQG[2]		
Chloride (Cl^-)		250 mg/L	Naturally occurring salts, 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)
Copper (Cu)	5 µg/L		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		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		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		Incidental input or physical methods (e.g., erosion) (Sharpley et al., 1996). 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).
Total Suspended Solids			Includes particles of silt, clay, organic and inorganic matter, plankton, and other microscopic organisms. Sources of sediment loading to the aquatic environment include human activities such as construction (urbanization), agriculture, industrial wastewater discharge, and mining activities. Can occur naturally or through human activity.	Elevated levels negatively impact benthic invertebrate and periphyton communities and thus impact the food chain (Ministry of the Environment and Climate Change, 2003a).
Nitrate (NO_3^-)		2.9 mg/L	Wastewater, septic systems, agricultural land use, and atmospheric deposition.	The most stable and usable form of nitrogen, but can be toxic in high concentrations and cause rapid growth of aquatic vegetation.

[1]Provincial Water Quality Objective
[2]Canadian Environmental Quality Guideline

2.4.6.1.3 Chloride

Considering active monitored stations, the Crowe River site at Highway 620 (17002114502) had the greatest median chloride concentrations at 8.90 mg/L. The North River site at County Road 46, west of Round Lake (17002109202) had the lowest at 1.50 mg/L. Chloride concentrations were well below the Guidelines for Canadian Drinking Water Quality, with no exceedances at all representative monitoring stations for all years on record; the statistical summary and trends for these stations are illustrated trends in Tables 2.4-8 and 2.4-9.

Table 2.4-8: Statistical Summary of Chloride Data at Selected PWQMN Stations*

Station Name	Station ID	Years on Record	Descriptive Statistics (GCDWQ = 250 mg/L)						
			Years Analysed	n	min	median	max	Percentiles	
								25th	75th
Crowe River	17002100302	65-79, 81, 88-98, 07-09	07-09	9	4.70	5.90	7.10	5.40	6.40
Beaver Creek	17002109502	76-79, 88-98, 07-09	07-09	8	1.30	1.75	2.70	1.50	2.025
North River	17002109202	76-83, 07-09	07-09	7	1.00	1.50	1.80	1.20	1.63
Crowe River	17002114602	07-08	07-08	5	5.00	6.20	8.20	6.00	6.90
Crowe River	17002114502	07-09	07-09	7	6.90	8.90	12.10	7.50	9.00
Crowe River	17002108602	76-79, 09	09	1	8.00[1]				

*Includes stations with data available for the period of 2005-2009

[1]Insufficient data for statistical analysis (value is the result of one sample)

Table 2.4-9: Chloride Trends and Guideline Exceedances at Selected PWQMN Stations*

Station Name	Station ID	Years on Record	No. Samples on Record	GCDWQ Exceedances[1]		Trend	
				%	#	Direction	p[2]
Paudash Lake	17002105901	68-71; 78; 80-84; 87-89; 92	26	0	0	↓	0.95
Deer Creek	17002106002	68-71; 78; 81; 83-84; 87-89; 92	27	0	0	↓	0.20
Bow Lake Outlet	17002106202	68-71; 78; 88-96	97	0	0	↓	<0.01
Crowe River	17002100302	65-79; 88-98; 07-09	239	0	0	↓	0.07
Crowe River	17002104802	71-73; 76-79; 90-98	100	0	0	↑	0.03
Bentley Creek	17002106302	68-71; 77-78; 88-96	93	0	0	↓	0.20
Bentley Creek	17002106402	68-71; 77-78; 88-96	89	0	0	↑	0.75
Plato Creek	17002107202	72-98	246	0	0	↑	<0.01
Plato Creek	17002107802	77-90	142	0	0	↓	<0.01
Crowe River	17002108402	76-83; 90-98	117	0	0	↓	0.60
Crowe River	17002108602	76-79; 09	25	0	0	↑	0.67
Crowe River	17002108902	68-69; 71; 77-79; 87-96	114	0	0	↑	0.43
North River	17002109202	76-83; 07-09	69	0	0	↑	<0.01
Beaver Creek	17002109502	76-79; 88-98; 07-09	116	0	0	↓	<0.01
Crowe River	17002114502	07-09	7	0	0	↓	0.13
Deer River	17002114602	07-08	5	0	0	↓	0.58

*Includes stations with enough data available for trend analysis through the period of 1968-2009

[1]Indicates the quantity of samples on record that exceeded the Guidelines for Canadian Drinking Water Quality (aesthetic guideline of 250mg/L)

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

2.4.6.1.4 Total Suspended Solids

Considering active monitored stations, the Crowe River site at Highway 620 (17002114502) had the greatest total suspended solids median concentrations at 1.80 mg/L. The Crowe River site at Highway 7, Marmora (17002100302) had the lowest median concentration at 1.00 mg/L. Total suspended solids concentrations were low for all representative monitoring stations in all years on record; the total suspended solids statistical summary and trends for these stations are illustrated in Tables 2.4-10 and 2.4-11. There is no provincial water quality standard for total suspended solids, therefore exceedances have not been recorded.

Table 2.4-10: Statistical Summary of Total Suspended Solids Data at Selected PWQMN Stations*

Station Name	Station ID	Years on Record	Descriptive Statistics (mg/L)						
			Years Analysed	n	min	median	max	Percentiles	
								25th	75th
Crowe River	17002100302	65-79, 81, 88-98, 07-09	07-09	9	0.50	1.00	1.50	0.70	1.30
Beaver Creek	17002109502	76-79, 88-98, 07-09	07-09	8	1.00	1.50	1.80	1.20	1.63
North River	17002109202	76-83, 07-09	07-09	7	1.00	1.10	1.90	1.00	1.50
Crowe River	17002114602	07-08	07-08	5	1.10	1.90	2.80	1.30	2.10
Crowe River	17002114502	07-09	07-09	7	1.10	1.80	3.30	1.45	2.35
Crowe River	17002108602	76-79, 09	09	1	2.20[1]				

*Includes stations with data available for the period of 1965-2009

[1]Insufficient data for statistical analysis (value is the result of one sample)

Table 2.4-11: Total Suspended Solids Trends at Selected PWQMN Stations*

Station Name	Station ID	Years on Record	No. Samples on Record	Trend	
				Direction	p[1]
Paudash Lake	17002105901	68-72; 74-75; 77-78; 80	39	↑	<0.01
Deer Creek	17002106002	68-72; 74-75; 77	37	↓	0.44
Bow Lake Outlet	17002106202	68-71; 74-75; 88-96	114	↓	<0.01
Crowe River	17002100302	64-76; 78-81; 95-98; 07-09	163	↓	<0.01
Crowe River	17002104802	78-79; 90-98	57	↓	0.01
Bentley Creek	17002106302	68-71; 77-78; 88-96	109	↓	<0.01
Bentley Creek	17002106402	68-72; 74-75; 77; 88-96	103	↓	0.01
Plato Creek	17002107202	74-75; 78-81; 95-98	67	↓	0.01
Plato Creek	17002107802	77-80	39	↑	0.95
Crowe River	17002108402	78-83; 90-93; 95-98	72	↓	0.54
Crowe River	17002108602	78-79; 2009	12	↓	0.53
Crowe River	17002108902	68-71; 77-79; 88-96	111	↓	<0.01
North River	17002109202	78-83; 2007-2009	88	↓	0.23
Beaver Creek	17002109502	78-79; 95-98; 07-09	40	↓	0.08
Crowe River	17002114502	2007-2009	7	↑	0.03
Deer River	17002114602	2007-2008	5	↓	0.81

*Includes stations with enough data available for trend analysis through the period of 1968-2009

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

2.4.6.1.5 Metals

Copper

Considering active monitored stations, the Crowe River site at Highway 7 (17002100302) had the greatest copper median concentrations at 1.2 ug/L. The Beaver Creek site at Beaver Creek Road, North of Marmora (17002109502) had the lowest median concentration at 0.415 ug/L. Total copper concentrations were low for all representative monitoring stations for all years on record; the statistical summary and trends for these stations are illustrated in Tables 2.4-12 and 2.4-13. There are 106 Provincial Water Quality Objectives exceedances, which represent 11% of all samples on record across the Crowe Valley watershed. There have been no exceedances in the recent monitoring period of 2005 to 2009.

Table 2.4-12: Statistical Summary of Copper Data at Selected PWQMN Stations*

Station Name	Station ID	Years on Record	Descriptive Statistics (PWQO = 5 ug/L)						
			Years Analysed	n	min	median	max	Percentiles	
								25th	75th
Crowe River	17002100302	65-79, 81, 88-98, 07-09	07-09	9	0.597	1.200	1.600	0.726	1.525
Beaver Creek	17002109502	76-79, 88-98, 07-09	07-09	8	0.015	0.415	0.718	0.196	0.585
North River	17002109202	76-83, 07-09	07-09	7	0.056	0.700	1.020	0.469	0.800
Crowe River	17002114602	07-08	07-08	5	0.209	0.436	0.754	0.242	0.671
Crowe River	17002114502	07-09	07-09	7	0.000	0.950	1.800	0.780	1.188
Crowe River	17002108602	76-79, 09	09	1	0.791[1]				

*Includes stations with data available for the period of 2005-2009

Table 2.4-13: Copper Trends and Guideline Exceedances at Selected PWQMN Stations*

Station Name	Station ID	Years on Record	No. Samples on Record	PWQO Exceedances[1]		Trend	
				%	#	Direction	p[2]
Paudash Lake	17002105901	80-81; 83-84; 87-89; 92	9	22	2	↓	0.54
Deer Creek	17002106002	80-84; 87-89; 92	9	22	2	↑	0.73
Bow Lake Outlet	17002106202	1979; 1988-1996	77	0	0	↓	<0.01
Crowe River	17002100302	70-76; 80-81; 84-85; 88-98; 07-09	156	31	49	↓	<0.01
Crowe River	17002104802	81; 90-98	66	3	2	↓	<0.01
Bentley Creek	17002106302	79; 88-96	73	0	0	↓	0.03
Bentley Creek	17002106402	79; 88-96	73	1	1	↓	0.57
Plato Creek	17002107202	81-98	158	15	23	↓	<0.01
Plato Creek	17002107802	81-90	99	17	17	↓	0.28
Crowe River	17002108402	84-85; 90-98	67	0	0	↓	<0.01
Crowe River	17002108602	None	ND	ND	ND	ND	ND
Crowe River	17002108902	79; 87-96	81	2	2	↓	0.34
North River	17002109202	81-83; 07-09	26	19	5	↓	0.33
Beaver Creek	17002109502	81-84; 85; 88-98; 07-09	103	3	3	↑	0.44
Crowe River	17002114502	07-09	7	0	0	↑	0.56
Deer River	17002114602	07-08	5	0	0	↑	0.86

*Includes stations with enough data available for trend analysis through the period of 1970-2009
[1]Indicates the quantity of samples on record that exceeded the Provincial Water Quality Objective of 5 ug/L
[2]Indicates the statistical significance of the proposed hypothesis that the trend is occurring as reported (trends considered significant where p<0.05)

Zinc

Considering active monitored stations, the Crowe River site at Highway 620 (17002114502) had the greatest median zinc concentrations at 1.660 ug/L. The North River site at County Road 46, west of Round Lake (17002109202) had the lowest median concentration at 0.074 ug/L. Total zinc concentrations were low for all representative monitoring stations for all years on record; the statistical summary and trends for these stations are illustrated in Tables 2.4-14 and 2.4-15. There are 991 Provincial Water Quality Objectives exceedances, which represent 15% of all samples on record across the Crowe Valley watershed. There have been no exceedances in the recent monitoring period from 2005 to 2009.

Table 2.4-14: Statistical Summary of Zinc Data at Selected PWQMN Stations*

Station Name	Station ID	Years on Record	Descriptive Statistics (PWQO = 30 ug/L)						
			Years Analysed	n	min	median	max	Percentiles	
								25th	75th
Crowe River	17002100302	65-79, 81, 88-98, 07-09	07-09	9	0.031	0.846	2.060	0.638	1.300
Beaver Creek	17002109502	76-79, 88-98, 07-09	07-09	8	0.028	0.455	1.830	0.350	0.790
North River	17002109202	76-83, 07-09	07-09	7	0.000	0.074	1.550	0.455	1.163
Crowe River	17002114602	07-08	07-08	5	0.000	1.410	1.970	0.870	1.470
Crowe River	17002114502	07-09	07-09	7	0.000	1.660	4.660	1.360	2.285
Crowe River	17002108602	76-79, 09	09	1	0.017[1]				

*Includes stations with data available for the period of 2005-2009

[1]Insufficient data for statistical analysis (value is the result of one sample)

Table 2.4-15: Zinc Trends and Guideline Exceedances at Selected PWQMN Stations*

Station Name	Station ID	Years on Record	No. Samples on Record	PWQO Exceedances[1]		Trend	
				%	#	Direction	p[2]
Paudash Lake	17002105901	80-81; 83-84	4	50	2	↓	0.86
Deer Creek	17002106002	80-84	4	0	0	↑	0.16
Bow Lake Outlet	17002106202	88-96	75	1	1	↓	0.17
Crowe River	17002100302	70-76; 80-81; 84-85; 88-98; 07-09	158	18	29	↓	<0.01
Crowe River	17002104802	81; 90-98	66	3	2	↓	0.14
Bentley Creek	17002106302	88-96	72	0	0	↓	0.71
Bentley Creek	17002106402	88-96	72	1	1	↑	0.83
Plato Creek	17002107202	81-98	158	1	1	↓	0.83
Plato Creek	17002107802	81-90	99	0	0	↓	0.50
Crowe River	17002108402	84-85; 90-98	67	0	0	↓	<0.01
Crowe River	17002108602	None	ND	ND	ND	ND	ND
Crowe River	17002108902	88-96	77	22	17	↓	0.14
North River	17002109202	82-83; 07-09	25	2	8	↓	0.37
Beaver Creek	17002109502	81; 84-85; 88-98; 07-09	102	3	3	↑	0.92
Crowe River	17002114502	07-09	7	14	1	↑	0.13
Deer River	17002114602	07-08	5	0	0	↓	0.50

*Includes stations with enough data available for trend analysis through the period of 1970-2009

[1]Indicates the quantity of samples on record that exceeded the Provincial Water Quality Objective of 30ug/L

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

Lead

Considering active monitored stations, the Beaver Creek site at Beaver Creek Road, North of Marmora (17002109502) had the greatest median lead concentrations at 4.6 ug/L. The Deer River site at Country Road 602, Coe Hill had the lowest overall concentrations at 1.0 ug/L. Total lead concentrations exhibit the most exceedances out of all indicator parameters discussed in this report. There have been 615 Provincial Water Quality Objectives exceedances, which represent 65% of all samples on record across the Crowe Valley watershed; the statistical summary and trends for these stations are illustrated in Tables 2.4-16 and 2.4-17.

Table 2.4-16: Statistical Summary of Lead Data at Selected PWQMN Stations*

Station Name	Station ID	Years on Record	Descriptive Statistics (PWQO = 5 ug/L)						
			Years Analysed	n	min	median	max	Percentiles	
								25th	75th
Crowe River	17002100302	65-79, 81, 88-98, 07-09	07-09	9	0.00	1.77	7.36	0.00	3.36
Beaver Creek	17002109502	76-79, 88-98, 07-09	07-09	8	1.00	4.60	9.00	2.78	6.41
North River	17002109202	76-83, 07-09	07-09	7	1.00	1.00	5.49	1.00	2.00
Crowe River	17002114602	07-08	07-08	5	1.00	1.00	1.49	1.00	1.00
Crowe River	17002114502	07-09	07-09	7	0.00	1.30	1.50	0.65	1.30
Crowe River	17002108602	76-79, 09	09	1	3.74[1]				

*Includes stations with data available for the period of 2005-2009
[1]Insufficient data for statistical analysis (value is the result of one sample)

Table 2.4-17: Lead Trends and Guideline Exceedances at Selected PWQMN Stations*

Station Name	Station ID	Years on Record	No. Samples on Record	PWQO Exceedances[1]		Trend	
				%	#	Direction	p[2]
Paudash Lake	17002105901	80-81; 83-84; 92	6	4	2	↑	<0.01
Deer Creek	17002106002	80-84; 92	6	33	2	↑	<0.01
Bow Lake Outlet	17002106202	88-96	74	99	73	↑	0.07
Crowe River	17002100302	80-81; 84-85; 88-98;07-09	115	80	93	↓	<0.01
Crowe River	17002104802	81; 90-98	66	77	51	↓	0.01
Bentley Creek	17002106302	88-96	71	99	70	↑	0.03
Bentley Creek	17002106402	88-96	71	99	70	↑	0.04
Plato Creek	17002107202	81-98	158	51	80	↑	0.08
Plato Creek	17002107802	81-90	99	0	0	↑	0.01
Crowe River	17002108402	84-85; 90-98	67	55	82	↓	<0.01
Crowe River	17002108602	None	ND	ND	ND	ND	ND
Crowe River	17002108902	88-96	78	2	2	↓	0.06
North River	17002109202	81-83; 07-09	26	11	3	↓	0.04
Beaver Creek	17002109502	81-85; 88-98; 07-09	102	89	87	↓	<0.01
Crowe River	17002114502	07-09	7	0	0	↓	0.02
Deer River	17002114602	07-08	5	0	0	↓	0.33

*Includes stations with enough data available for trend analysis through the period of 1981-2009
[1]Indicates the quantity of samples on record that exceeded the Provincial Water Quality Objective of 5 ug/L
[2]Indicates the statistical significance of the proposed hypothesis that the trend is occurring as reported (trends considered significant where p<0.05)

2.4.6.1.6 Nutrients

Total phosphorus and nitrate were evaluated due to their role as nutrients that enter the landscape. Over time, nitrates have been measured with different methodologies by the Ministry of the Environment and Climate Change, therefore nitrates have been separated into four categories according to the sampling analysis method performed by the Ministry of the Environment and Climate Change at that time. Nitrate trends are shown in Tables 2.4-19, 2.4-20, and 2.4-21.

Nitrate Nitrogen

The North River site at County Road 46, west of Round Lake (17002109202) had the greatest median nitrate concentrations at 0.014 mg/L. The Crowe River site at Highway 620 (17002114502) had the lowest median concentrations at 0.009 mg/L. Total nitrate concentrations were low for all representative monitoring stations, with no exceedances for all years on record; the statistical summary and trends for these stations are illustrated in Tables 2.4-18, 2.4-19, 2.4-20, and 2.4-21.

Table 2.4-18: Statistical Summary of Nitrate Nitrogen Data at Selected PWQMN Stations*

Station Name	Station ID	Years on Record	Descriptive Statistics (CWQG = 2.9 mg/L)						
			Years Analysed	n	min	median	max	Percentiles	
								25th	75th
Crowe River	17002100302	07-09	07-09	9	0.005	0.011	0.021	0.010	0.011
Beaver Creek	17002109502	07-09	07-09	9	0.005	0.010	0.031	0.010	0.013
North River	17002109202	07-08	07-08	8	0.005	0.014	0.045	0.005	0.031
Crowe River	17002114602	07-08	07-08	5	0.007	0.010	0.015	0.010	0.014
Crowe River	17002114502	07-09	07-09	8	0.005	0.009	0.017	0.007	0.017
Crowe River	17002108602	09	09	1	0.027[1]				

*Includes stations with data available for the period of 2005-2009 (statistics represent total unfiltered reactive nitrate data)
[1]Insufficient data for statistical analysis (value is the result of one sample)

Table 2.4-19: Nitrate (Total Unfiltered Reactive) Trends and Guideline Exceedances at Selected PWQMN Stations*

Station Name	Station ID	Years on Record	No. Samples on Record	PWQO Exceedances[1]		Trend	
				%	#	Direction	p[2]
Paudash Lake	17002105901	None	ND	ND	ND	ND	ND
Deer Creek	17002106002	None	ND	ND	ND	ND	ND
Bow Lake Outlet	17002106202	94-96	16	0	0	↑	0.55
Crowe River	17002100302	95-98, 07-09	31	0	0	↓	0.03
Crowe River	17002104802	95-98	22	0	0	↑	0.72
Bentley Creek	17002106302	94-96	17	0	0	↓	0.90
Bentley Creek	17002106402	94-96	15	0	0	↑	0.58
Plato Creek	17002107202	95-98	22	0	0	↑	0.83
Plato Creek	17002107802	None	ND	ND	ND	ND	ND
Crowe River	17002108402	95-98	21	0	0	↑	0.64
Crowe River	17002108602	None	ND	ND	ND	ND	ND
Crowe River	17002108902	94-96	16	0	0	↓	0.76
North River	17002109202	07-08	23	0	0	↑	0.43
Beaver Creek	17002109502	95-98, 07-09	30	0	0	↓	0.04
Crowe River	17002114502	07-09	8	0	0	↑	0.04
Deer River	17002114602	07-08	5	0	0	↓	0.77

*Includes stations with enough data available for trend analysis through the period of 1994-2009 (trends represent total unfiltered reactive data)

[1]Indicates the quantity of samples on record that exceeded the Canadian Water Quality Guidelines for the Protection of Aquatic Life (2.9mg/L)
[2]Indicates the statistical significance of the proposed hypothesis that the trend is occurring as reported (trends considered significant where p<0.05)

*Table 2.4-20: Nitrate (Total Filtered Reactive) Trends and Guideline Exceedances at Selected PWQMN Stations**

Station Name	Station ID	Years on Record	No. Samples on Record	PWQO Exceedances[1]		Trend	
				%	#	Direction	p[2]
Paudash Lake	17002105901	81, 83-84, 87-89, 92	10	0	0	↑	0.14
Deer Creek	17002106002	81, 83-84, 87-89, 92	10	0	0	↑	0.06
Bow Lake Outlet	17002106202	88-94	64	0	0	↓	0.42
Crowe River	17002100302	88-94	66	0	0	↓	<0.01
Crowe River	17002104802	90-94	41	0	0	↓	0.14
Bentley Creek	17002106302	88-94	58	0	0	↑	0.59
Bentley Creek	17002106402	88-89, 90-94	59	0	0	↑	0.76
Plato Creek	17002107202	81-94	142	0	0	↓	0.97
Plato Creek	17002107802	81	6	0	0	↑	0.83
Crowe River	17002108402	81-83, 90-94	57	0	0	↓	0.37
Crowe River	17002108602	None	ND	ND	ND	ND	ND
Crowe River	17002108902	87-94	66	0	0	↑	0.71
North River	17002109202	81-83	25	0	0	↑	0.18
Beaver Creek	17002109502	88-94	60	0	0	↑	0.15
Crowe River	17002114502	None	ND	ND	ND	ND	ND
Deer River	17002114602	None	ND	ND	ND	ND	ND

*Includes stations with data available for the period of 1981-1994 (trends represent total filtered reactive data)
[1]Indicates the quantity of samples on record that exceeded the Canadian Water Quality Guidelines for the Protection of Aquatic Life (2.9 mg/L)
[2]Indicates statistical significance of the proposed hypothesis that the trend is occurring as reported (trends considered significant where p<0.05)

*Table 2.4-21: Nitrate (Filtered Reactive) Trends and Guideline Exceedances at Selected PWQMN Stations**

Station Name	Station ID	Years on Record	n	PWQO Exceedances (250mg/L)[2]		Trend	
				%	#	Direction	p[1]
Paudash Lake	17002105901	68-71, 78, 80-81, 83	38	0	0	↓	0.38
Deer Creek	17002106002	68-71, 81, 83	36	0	0	↓	0.09
Bow Lake Outlet	17002106202	68-71, 77, 80-81	46	0	0	↑	0.00
Crowe River	17002100302	65-79, 81	133	0	0	↓	0.00
Crowe River	17002104802	71-73, 76-83	65	0	0	↓	0.25
Bentley Creek	17002106302	68-71, 77, 80-81	46	0	0	↑	0.18
Bentley Creek	17002106402	68-71, 77, 80-81	37	0	0	↑	0.00
Plato Creek	17002107202	72-84	122	0	0	↓	0.00
Plato Creek	17002107802	77-81	48	0	0	↑	0.03
Crowe River	17002108402	76-83	57	0	0	↑	0.23
Crowe River	17002108602	76-79	22	0	0	↑	0.48
Crowe River	17002108902	68-71, 76-80	56	0	0	↓	0.06
North River	17002109202	76-83	62	0	0	↑	0.08
Beaver Creek	17002109502	76-81	33	0	0	↑	0.61
Crowe River	17002114502	ND	ND	ND	ND	ND	ND
Deer River	17002114602	ND	ND	ND	ND	ND	ND

*Includes stations with enough data available for trend analysis through the period of 1968-1983 (trends represent filtered reactive data)
[1] Indicates the statistical significance of the proposed hypothesis that the trend is occurring as reported (trends considered significant where p<0.05)
[2]Indicates the quantity of samples on record that exceeded the Canadian Water Quality Guidelines for the Protection of Aquatic Life (2.9 mg/L)

Total Phosphorous

Concentrations of the next two parameters, both total phosphorous and E. coli, are two parameters often related to land uses near watercourses. The highest median concentrations of total phosphorus in the Crowe River watershed were observed at the Deer River station, Country Road 620, Coe Hill, at 0.013 mg/L. The lowest median concentrations are at the Crowe River site on Highway 7, Marmora, at 0.010 mg/L. There have been 349 Provincial Water Quality Objectives exceedances, which represent 20% of all samples on record across the Crowe Valley watershed; the statistical summary and trends for these stations are illustrated in Tables 2.4-22 and 2.4-23. Please note there have not been any exceedances for the period of 2005 to 2009.

Table 2.4-22: Statistical Summary of Total Phosphorus Data at Selected PWQMN Stations*

Station Name	Station ID	Years on Record	Descriptive Statistics (PWQO = 0.03 mg/L)						
			Years Analysed	n	min	median	max	Percentiles	
								25th	75th
Crowe River	17002100302	65-79, 81, 88-98, 07-09	07-09	9	0.006	0.010	0.014	0.007	0.011
Beaver Creek	17002109502	76-79, 88-98, 07-09	07-09	8	0.006	0.011	0.018	0.010	0.012
North River	17002109202	76-83, 07-09	07-09	7	0.007	0.013	0.014	0.010	0.013
Crowe River	17002114602	07-08	07-08	5	0.011	0.013	0.016	0.012	0.015
Crowe River	17002114502	07-09	07-09	7	0.008	0.011	0.021	0.011	0.015
Crowe River	17002108602	76-79, 09	09	1	0.012[1]				

*Includes stations with data available for the period of 2005-2009

[1]Insufficient data for statistical analysis (value is the result of one sample)

Table 2.4-23: Total Phosphorus Trends and Guideline Exceedances at Selected PWQMN Stations*

Station Name	Station ID	Years on Record	No. Samples on Record	CWQG Exceedances[1]		Trend	
				%	#	Direction	p[1]
Paudash Lake	17002105901	66; 68-71; 78; 80-81; 83-84; 87-89; 92	47	38	18	↓	0.23
Deer Creek	17002106002	66; 68-71; 81; 83; 84; 87-89; 92	45	40	18	↓	0.01
Bow Lake Outlet	17002106202	68-71; 77; 80-81; 88-96	123	13	16	↓	0.15
Crowe River	17002100302	65-81; 84-85; 88-98; 07-08	261	13	33	↓	<0.01
Crowe River	17002104802	71-73; 76-81; 90-98	131	5	7	↓	0.15
Bentley Creek	17002106302	66; 68-71; 80-81; 88-96	118	19	22	↓	<0.01
Bentley Creek	17002106402	68-71; 77; 80-81; 88-96	109	15	16	↓	<0.01
Plato Creek	17002107202	72-98	250	54	134	↓	0.68
Plato Creek	17002107802	77-90	148	38	56	↑	0.40
Crowe River	17002108402	76-85; 90-98	130	0	0	↓	0.07
Crowe River	17002108602	76-79; 09	26	0	0	↓	1.00
Crowe River	17002108902	66; 68-71; 76-81; 87-96	139	12	16	↓	0.21
North River	17002109202	76-83; 07-09	71	11	8	↓	0.31
Beaver Creek	17002109502	76-77; 78; 79; 80; 81; 84-85; 88-98; 07-09	137	4	5	↑	0.01
Crowe River	17002114502	07-09	8	0	0	↑	0.02
Deer River	17002114602	07-08	5	0	0	↓	0.66

*Includes stations with enough data available for trend analysis through the period of 1976-2009

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

[2]Indicates the quantity of samples on record that exceeded the Canadian Water Quality Guidelines for the Protection of Aquatic Life (2.9 mg/L)

2.4.7 GROUNDWATER QUALITY

This section is a summary of the available data that is suitable for a watershed-scale analysis of groundwater quality in the Lower Trent Source Protection Area. Groundwater quality data specific to individual drinking water systems were analysed during the evaluation of drinking water issues (see Section 5.3). Sources of water quality data in the watershed include the Provincial Groundwater Monitoring Network, Ministry of the Environment and Climate Change Water Well Records Database, and various regional groundwater studies. The number of sampling sites, parameters reported, years of record, and quality of data vary among each data source. The following sections summarize the available groundwater quality data in the Crowe Valley Source Protection Area.

2.4.7.1 INDICATOR PARAMETERS

There are many water quality 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. The data sources and groundwater quality studies identified in this characterization of groundwater quality used indicator parameters that reflect the natural features and land uses in the watershed. Common groundwater indicator parameters are described in Table 2.4-25.

2.4.7.2 PROVINCIAL GROUNDWATER MONITORING NETWORK

The Provincial Groundwater Monitoring Network was established to provide data to characterize groundwater quantity and quality across the province. Nine monitoring wells were established in the Crowe Valley Source Protection Area in 2006 as part of the overall network; these wells generally represent the regional aquifers across the watershed. Provincial Groundwater Monitoring Network wells in the Crowe Valley Source Protection Area are described in Table 2.4-24 and their locations are shown on Map 2-17(CV).

Provincial Groundwater Quality Monitoring Network wells in the Crowe Valley Source Protection Area watersheds were sampled from 2003 and tested for most parameters in the *Ontario Drinking Water Quality Standards (O. Reg. 169/03)*. The results from this round of sampling are summarized in Table 2.4-26.

Table 2.4-24: Provincial Groundwater Quality Monitoring Network Wells in the Crowe Valley SPA

Well Identification Numbers		Subwatershed	Casing Inside Diameter (in)	Well Depth (m)	Static Water Level (m)	Number of Sampling Events
MECP[1] ID	Casing ID					
2910425/2915418	W227-1	Crowe River	6.25	>100	3.38	1
2909682/2907360	W228-1	Crowe River	6.25	31.89	3.97	1
4513396	W317-1	Crowe River	6.25	16.52	5.53	0
5100296/5110799	W258-1	Crowe River	6.25	61.87	8.8	1
2919840	W333-1	Beaver Creek	6.25	69.2	2.76	1
2919831	W316-1	Crowe River	4	51.52	1.8	1
4503120	W243-1	N/A	6.25	15.61	5.29	1
NA	W229-1	N/A	6.25	31.23	7.97	0
2705998/2706174	W310-1	Crowe River	6.25	16.37	5	0

Data source: Provincial Groundwater Quality Monitoring Network; Crowe Valley Conservation Authority
[1]Ministry of the Environment, Conservation and Parks

Table 2.4-25: 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. Sources include rocks, 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 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.	80-100 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-})	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. Natural sources include decomposing vegetation and rock or soil containing gypsum, barite, or other minerals.	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 numbers 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 a 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, 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 (2003b)

(1) Maximum Acceptable Concentration (MAC) and Aesthetic Objective (AO) / Operational Guideline (OG) values as per Ontario Regulation 169/03 made under *Safe Drinking Water Act* (amended to O. Reg. 327/08).
(2) The aesthetic objective for sodium in drinking water is 200 mg/L. As per the Ontario Drinking Water Standards, Objectives and Guidelines (June 2006), the local Medical Officer of Health should be notified when the sodium concentration exceeds 20 mg/L so that this information may be communicated to local physicians for their use with patients on sodium restricted diets.

Table 2.4-26: Provincial Groundwater Quality Monitoring Network data in the Crowe Valley Source Protection Area

Well ID	Years on Record	No. Samples	Range of Water Quality Sampling Results								
			Hardness (mg/L)	Sodium (mg/L)	Iron (µg/L)	Sulphate (mg/L)	Chloride (mg/L)	Nitrogen [Nitrate+Nitrite] (mg/L)	Organic Nitrogen (mg/L)	DOC[1] (mg/L)	TDS[2] (mg/L)
W0000227-1	2003	1	113	6.0	350 (+/- 58)	15.1	11.6	0.05	0.07	0.6	172
W0000316-1	2003, 2009	2	159 - 169	2.5 - 3.0	232 (+/- 39) - 600 (+/- 110)	14.9 - 16.7	0.7 - 1.2	*0.05	0.12 - 0.31	3.6 - 4.3	209 - 215
W0000333-1	2003	1	327	10.8	5 (+/- 6)	60.0	18.1	2.41	0.23	3.6	431
W0000228-1	2003	1	208	1.0	37 (+/- 8)	11.7	0.9	0.05	0.10	2.4	270
W0000258-1	2003	1	3140	2200.0	1430 (+/- 230)	2730.0	4030.0	0.05	3.37	4.6	11300
W0000243-1	2003	1	264	1.6	12 (+/- 6)	12.7	1.0	0.05	0.05	1.4	254

[1] Carbon; dissolved organic

[2] Total dissolved solids

* Samples from 2003 and 2009 returned a Nitrogen [Nitrate + Nitrite] concentration of 0.05 mg/L at Well W0000316-1

2.4.7.3 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.

2.4.7.4 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 map the groundwater resources and delineate wellhead protection areas in municipalities across the province. 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 Durham Region).

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 Trent Conservation Coalition Source Protection Region is naturally low in chloride, nitrate, and most metals, and occasionally exceeds 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.)

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2.5 LOWER TRENT SOURCE PROTECTION AREA

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. This is a watershed characterization of the Lower Trent Source Protection Area prepared in accordance with the *Clean Water Act*, *2006*, *O. Reg. 287/07*, and Part II of the *Technical Rules*. This watershed characterization draws from an earlier document prepared before the publication of the *Technical Rules* and has expanded on it where required to satisfy the legislation. The report was prepared in 2008 by Lower Trent Conservation and is entitled: *Watershed Characterization Report*: *Lower Trent Source Protection Area*.

2.5.1 OVERVIEW OF SOURCE PROTECTION AREA

The Lower Trent Source Protection Area includes the area under the jurisdiction of the Lower Trent Region Conservation Authority (2,121 km^2) and the area outside of Conservation Authority jurisdiction between the Lower Trent, Otonabee, and Crowe Valley watersheds (45 km^2). The Lower Trent Source Protection Area is bordered on the south by Lake Ontario and the Bay of Quinte. Rice Lake forms the northwestern boundary of the region. Several tributary streams including Cold, Rawdon, Salt, Squires (Hoards), Percy, Burnley (Mill), Trout, and Mayhew Creeks empty into the Trent River. Shelter Valley, Barnum House, Lakeport/Colborne and Butler Creeks empty into Lake Ontario while DND and Meyers Creeks empty into the Bay of Quinte. The Lower Trent Source Protection Area boundary and its subwatersheds are shown on Maps 2-1(LT) and 2-2(LT), respectively.

The predominant physical features of the Lower Trent Source Protection Area are the Oak Ridges Moraine, Peterborough Drumlin Field, and the Iroquois Plain. The Trent-Severn Waterway attracts many recreational boaters and is an important tourist draw, and the Bay of Quinte is a popular sport fishing destination.

The landscape of the watershed is a mosaic of agricultural land use, forest, wetlands, and transitional areas, separated by river systems or transportation and utility corridors. A large proportion of the population lives in rural areas. Urban areas are mostly confined to the shore of Lake Ontario and the Bay of Quinte with the exception of historic settlement areas that exist along main historic rail or road corridors and the Trent-Severn Waterway. Trenton is the largest urban centre with a population of 17,000.

Ten municipal drinking water systems serve approximately half of the watershed population, and the remaining population relies on private groundwater or surface water supplies.

2.5.2 GEOGRAPHY AND LAND USE

2.5.2.1 PHYSICAL GEOGRAPHY

The physiographic features in the Lower Trent Source Protection Area are the Oak Ridges and Dummer Moraines, Peterborough Drumlin Field, South Slope, and Iroquois Lake Plain. Physiographic regions in the watershed are shown on Map 2-3(LT) and the percent coverage of each physiographic feature is identified in Table 2.5-1. Physical characteristics of subwatersheds are summarized in Table 2.5-2.

The Oak Ridges Moraine occupies the west central portion of the watershed and is characterized by high relief, hummocky terrain, beds of stratified fine sands and clays, and a virtual absence of streams. The Dummer

Moraine lies along the watershed's northeastern boundary and is characterized by angular fragments and blocks of limestone, a variety of Precambrian rocks, and an extremely rough, stony surface.

The Peterborough Drumlin Field occupies the northwest corner of the watershed and an area south of the Dummer Moraine. It is the largest physiographic feature in the watershed and covers nearly half of its surface. There are thousands of drumlins in the watershed associated with the Peterborough Drumlin Field; these typically occur at a density of 2 to 3 per km^2.

The South Slope is a steep, heavily drumlinized till plain that occupies the area between the Iroquois Plain and the Oak Ridges Moraine. Rapid streamflow arising from the steepness of the plain has cut sharp valleys in the till and intermittent drainage and erosion have formed numerous gullies. Bare, eroding slopes are also common in the South Slope.

The Iroquois Plain occupies the central portion of the watershed and the area along the Lake Ontario shoreline. Most of the plain is gently rolling to flat and contains deposits of sand, fine sand, and silt. The plain has cliffs that extend an average of eight kilometres inland from the Lake Ontario shoreline; these are most prominent between Brighton and Colborne where they reach heights of up to twenty metres.

Table 2.5-1: Physiographic Regions in the Lower Trent Source Protection Area

Physiographic Region	Area (km^2)	Land Coverage (%)
Oak Ridges Moraine	87	4.2
Dummer Moraine	236	11.3
Peterborough Drumlin Field	412	19.7
South Slope	208	10.0
Iroquois Plain	1056	50.6
Napanee Plain	79	3.8
Prince Edward Peninsula	9	0.4

Data Source: Calculated using data supplied under license by members of the Ontario Geospatial Data Exchange

2.5.3 HUMAN GEOGRAPHY: POPULATION AND LAND USE

2.5.3.1 AREAS OF SETTLEMENT

The *Places to Grow Act, 2005* provides a legislative framework for the development of growth plans in designated growth areas. The *Places to Grow Act* provides the following definition for 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."* Within the Lower Trent Source Protection Area, the *Places to Grow Act* applies only to Northumberland County, however this definition has been used to define areas of settlement throughout the entire watershed. Areas of settlement in the watershed are generally found along the shore of Lake Ontario and the Bay of Quinte with the exception of historic settlement areas that exist along historic rail or road corridors and the Trent-Severn Waterway. A large proportion of residents live in rural areas, small towns, and hamlets. Areas of settlement in the Lower Trent Source Protection Area are shown on Map 2-4(LT).

Table 2.5-2: Physical Characteristics of Lower Trent Source Protection Area Subwatersheds

Subwatershed Name	Drainage Area (km^2)	Channel Length (km)	Total Fall (m)	Channel Average Slope (%)	Percent Land Cover			Physiographic Region
					Wetlands	Lakes	Woodlands	
Squires Creek	183	26.401	101.138	2.85	3.43	N/A	34	Dummer Moraine, Peterborough Drumlin Field, Iroquois Plain
Rawdon Creek	199	35.261	119.62	2.42	5.7	N/A	47	Peterborough Drumlin Field, Dummer Moraine, Iroquois Plain
Trout Creek	45	12.102	122.664	5.9	3.5	N/A	21	Peterborough Drumlin Field
Trent River Tributaries*	457	N/A	N/A	N/A	9.9	N/A	25	Peterborough Drumlin Field
Rice Lake Tributaries*	83	N/A	N/A	N/A	4.9	43	33	Oak Ridges Moraine, Peterborough Drumlin Field
Percy/Burnley Creek	241	41.149	236.137	3.4	4.9	N/A	38	Peterborough Drumlin Field, Oak Ridges Moraine, Iroquois Plain
Salt Creek	91	26.315	195.29	5.6	6.2	N/A	37	South Slope, Peterborough Drumlin Field, Iroquois Plain, Oak Ridges Moraine
Cold Creek	261	48.033	215.509	3.1	4.3	N/A	36	South Slope, Peterborough Drumlin Field, Iroquois Plain, Oak Ridges Moraine
Barnum House/Shelter Valley Creek	119	15.85	234.902	12.8	2.3	N/A	36	South Slope, Oak Ridges Moraine, Iroquois Plain
Mayhew Creek	40	10.081	182.209	7.7	0	N/A	42	
Lake Iroquois Plain Tributaries*	243	N/A	N/A	N/A	5.3	N/A	31	Iroquois Plain, South Slope
Colborne/Lakeport Creek	44	10.018	156.08	8.8	3.3	N/A	44	
Proctor(Butler) Creek	29	15.017	175.533	9.8	1.3	N/A	57	
Bay of Quinte Tributaries*	71	N/A	N/A	N/A	2.8	N/A	24	Iroquois Plain, Peterborough Drumlin Field
DND Creek	6.5	4.921	44.083	5.7	0	N/A	16	
Meyers Creek	27	27	79.225	4.4	3.8	N/A	40	

*These subwatersheds include a large number of very small watercourses

Data Source: Calculated using data supplied under license by members of the Ontario Geospatial Data Exchange

Most of the major industrial facilities in the source protection area are located in Trenton and include paper packaging production and food processing operations. Smaller industrial facilities are located in urban areas such as Brighton, Colborne, Campbellford, Hastings, and Warkworth.

2.5.3.2 MUNICIPALITIES

There are nine municipalities located within or partially within the Lower Trent Source Protection Area. The total population of these municipalities is 109,972 (Statistics Canada, 2006) and about 78,457 of them are located within the source protection area boundary. Population density is typically low: about 90% of the watershed by area has less than 50 people/km^2 and about 25% has less than 10 people/km^2. Population density is highest in the City of Quinte West where two parts of Trenton Ward exceed 4,000 people/km^2. There is a seasonal increase of population in some parts of the source protection area during the summer months. Municipal boundaries, populations, and population densities in the source protection area are shown on Maps 2-5(LT), 2-6(LT), and 2-7(LT), respectively. Municipalities located in the source protection area, their total population and area, and the portion of their population and area located in the source protection area are listed in Table 2.5-3.

Table 2.5-3: Municipal Populations in the Lower Trent Source Protection Area

Municipality	Portion within SPA		Entire Municipality	
	Area (km^2)	Population	Area (km^2)	Population
Municipality of Trent Hills	506	11,392	538	12,247
City of Quinte West	394	38,882	506	42,697
Township of Alnwick/Haldimand	393	5721	436	6435
Township of Stirling-Rawdon	234	4513	285	4906
Municipality of Brighton	226	10,253	226	10,253
Township of Cramahe	203	5950	203	5950
Township of Centre Hastings	115	1406	233	4386
Township of Havelock-Belmont-Methuen	29	620	594	4637
Township of Hamilton*	1	6	294	10,972

*Located only marginally within the Source Protection Area
Data Source: Calculated from Statistics Canada, GeoSuite, 92-150-XCB, 2006 Census

2.5.3.3 FIRST NATIONS

The Alderville First Nation, located south of Rice Lake, is the only First Nation in the Lower Trent Source Protection Area. The reserve has a population of approximately 575 and a population density of 50 people/km^2. The Alderville First Nation is shown on Map 2-8(LT).

2.5.3.4 INTERACTIONS BETWEEN HUMAN AND PHYSICAL GEOGRAPHY

The Iroquois Plain, located along Lake Ontario, is the most densely populated portion of the Lower Trent Source Protection Area and is where the largest urban centres and the most productive farmlands are found. The Trent River provides a natural geographic focus attracting visitors, cottagers, and permanent residents to the area.

The utilization of intensely drumlinized areas in the Peterborough Drumlin Field is affected by stoniness, steep slopes, and wet, swampy hollows. The original township surveys had a profound impact on land use patterns throughout most of the area. In common with the rest of Ontario, the land was surveyed into townships, concessions, and lots with baselines parallel to the shores of the Great Lakes. This means that in the Peterborough Drumlin Field the roads and farm lines make angles of about 45^{o} with the general trend of the drumlin axes. Consequently, there are a great number of triangular and diamond-shaped fields and many lots too small or awkward to be useful for agriculture.

The Dummer Moraine is an area of rough, stony land bordering the Canadian Shield that is best suited to forest cover. About half the land was ploughed, about a quarter left as woodland, and the rest was used as rough pasture. Over time, a large area of the cropped land was allowed to revert to permanent grass.

The Oak Ridges Moraine provides important groundwater recharge functions and is a source of water for human use. With the arrival of European settlers much of the forest cover on the Oak Ridges Moraine was cleared first for pine masts for the British navy and later for farmland. By the late 19th century, farmers on the Oak Ridges Moraine were faced with serious soil erosion and fertility problems. In the early 20th century, the Northumberland County Forest was created by large scale reforestation brought about by an agreement between the United Counties of Northumberland and Durham and the provincial government.

The South Slope is a heavily drumlinized till plain lying between the Oak Ridges Moraine and the Iroquois Plain. The South Slope contains some soils which have proved to be excellent through more than a century of agricultural use. The eastern end of the South Slope has retained much of its rural character.

2.5.3.5 FEDERAL LANDS

Lands in the Lower Trent Source Protection Area that are under the jurisdiction of the Government of Canada include Canadian Forces Base Trenton and lands along the Trent-Severn Waterway (including lands located at the bottom of lakes on the waterway) that are managed by Parks Canada. Federal lands in the watershed are shown on Map 2-9(LT).

2.5.4 OVERVIEW OF DRINKING WATER SYSTEMS

Drinking water systems in the Lower Trent 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 *Safe Drinking Water Act, 2002* 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. Over half of the population of the source protection area relies on private wells and lake sources, which are not regulated under the *Safe Drinking Water Act*. There are also five public drinking water systems operated by the Alderville First Nation in the source protection area.

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.

2.5.4.1 MUNICIPAL RESIDENTIAL DRINKING WATER SYSTEMS

About 47% of the source protection area population (37,072 people) in the Lower Trent Source Protection Area obtains their drinking water from 10 municipal residential drinking water systems. These systems are discussed in more detail below, and their locations and approximate service areas are shown on Map 2-10(LT).

2.5.4.1.1 Surface Water Systems

There are six existing municipal residential surface water supply systems in the source protection area that serve about 27,500 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 detail in Chapter 4.

2.5.4.1.2 Groundwater Systems

There are four existing municipal residential groundwater supply systems in the source protection area that obtain their water from groundwater sources. These systems serve about 9,600 people. Under the *Drinking-Water Systems Regulation (O. Reg. 170/03)*, half of these systems are classified as large municipal residential systems and the other half are classified as small municipal residential systems. These systems are discussed in detail in Chapter 5.

> ***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 (GUDI) 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.*

The Stirling residential drinking water system draws water from a total of five wells. A 2010 study by Earthfx determined that of the four production wells (wells 1, 3, 4, 5) in the earlier DWS, only two of the wells (well 4 & 5) are considered to be groundwater under the direct influence (GUDI) of surface water. A well (well 6) has been added to the earlier four production wells at this drinking water system. According to a 2019 study by BluMetric, the new well (well 6), installed in the same aquifer and at a similar depth and distance from Rawdon Creek as existing wells (4 & 5), can reasonably assumed to be GUDI. A 2002 study by Middle Earth Hydrogeology determined that the municipal wells appear to be under the influence of surface water from Rawdon Creek and the water table around the pumped wells. This conclusion was based on the following observations:

- Analysis of the flow system during pumping of Well 4, with best estimates for the hydraulic parameters of the aquifer and the overlying aquitard, indicates that the flow to Well 4 from Rawdon Creek would take about 54 days. These results are considered to be similar for Well 3.
- Within a 50-metre radius around Well 4, the estimated groundwater discharge through the aquitard is about 4 to 8 cubic metres per hour (m^3/h) under typical pumping conditions, which represents 7 to 14% of the total pumping rate from Well 4 (58 m^3/h).
- There have been sporadic occurrences of coliforms in the raw water from the municipal wells since monitoring was begun in 1995.

The Colborne residential drinking water system consists of wells 1 and 2. Well 2 is the duty well and well 1 is the backup well – used only when demand exceeds the capacity of well 2. Well 1 has experienced sanding problems and is replaced by well 1A, installed in 2016.

The average combined flow rate of the system was 926.7 m^3/d during 2014-18. The maximum permitted capacity is 3283.2 m^3/d for each well and up to 6566.4 m^3/d with two wells operating.

Recent installation and testing of the new municipal well 1A has required updated groundwater modelling to determine time-of-travel based capture zones or wellhead protection areas (WHPAs), when the wells are pumping at their maximum permitted rates.

2.5.4.2 OTHER DRINKING WATER SYSTEMS

There are about 67 drinking water systems in the Lower Trent Source Protection Area that are classified as non-municipal or non-residential systems under the *Drinking-Water Systems Regulation (O. Reg. 170/03)* (e.g., 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 2.5-4. Details for many of these systems are given in Appendix C, and their locations are shown on Map 2-11(LT). (Note that these systems were identified from the Drinking Water Information System database, which 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 2.5-4: Other Drinking Water Systems in the Lower Trent Source Protection Area

Safe Drinking Water Act Classification	Estimated No. Systems
Large municipal non-residential	0
Small municipal non-residential	10
Non-municipal year-round residential	1
Non-municipal seasonal residential	19
Large non-municipal non-residential	0
Small non-municipal non-residential	37

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

2.5.4.3 FIRST NATIONS SYSTEMS

Most residents of Alderville First Nation are served by private wells. Systems that are owned and operated by the First Nation are listed in Table 2.5-5. These systems are not classified under the *Drinking-Water Systems Regulation (O. Reg. 170/03)*.

Table 2.5-5: First Nations Drinking Water Systems in the Lower Trent Source Protection Area

Drinking Water System	Users Served (Approx.)
Alderville Church/Administration Building/Learning Centre/Community Centre/Day Care Well System	150
Alderville Health Services Well System	40
Alderville Community Owned Apartment Building Well System	15
Alderville Student Services	40
Alderville Women's Shelter	20

Data Source: Alderville First Nation

2.5.5 TERRESTRIAL AND AQUATIC CHARACTERISTICS

2.5.5.1 NATURAL VEGETATIVE COVER

Natural vegetative cover in the Lower Trent Source Protection Area includes wetlands, woodlands, and vegetated riparian areas. Natural vegetative cover plays a critical role in protecting drinking water sources by trapping sediments and soils, and 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 2.5-6.

Table 2.5-6: Natural Vegetative Cover in the Lower Trent Source Protection Area

Natural Vegetative Cover Type		Area (km^2)	Land Coverage (%)
Wetlands	Provincially Significant	102	5
	Other Wetlands	12	0.5
Woodlands		715	33
Vegetated Riparian Areas[1]		625	29

[1]Vegetated riparian areas include vegetated lands located within 120 m of lakes, wetlands, and watercourses
Data Source: Ministry of Natural Resources and Forestry

Wetlands

Wetlands found in the Lower Trent Source Protection Area include swamps and marshes. Fens and bogs are very uncommon. Wetlands perform a significant role in improving water quality by contributing to groundwater recharge and 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 10% of the source protection area (217 km^2), which includes 48 Provincially Significant Wetlands that cover 102 km^2. Wetlands in the watershed are shown on Map 2-12(LT).

Woodlands

Woodland cover in the Lower Trent Source Protection Area includes successional and climax forests, hedgerows, 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 watershed is shown on Map 2-12(LT).

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 in the watershed were delineated as vegetated lands located within 120 m of lakes, wetlands, and watercourses. Vegetated riparian areas in the Lower Trent Source Protection Area are shown on Map 2-13(LT).

2.5.5.2 AQUATIC HABITATS

Aquatic habitats are the areas 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 Lower Trent Source Protection Area, including fisheries and aquatic macroinvertebrates, and discusses the impacts of development on these aquatic communities. There are insufficient data to compare aquatic communities in the watershed to unimpacted reference sites.

2.5.5.2.1 Fisheries

Location and Types of Habitats

The Lower Trent Source Protection Area includes many rivers and streams that provide habitat for a variety of cold, cool, and warm water fish species. Most watercourses originating in the Oak Ridges Moraine provide cold water habitat, at least in their headwaters. Watercourses originating east of the Trent River generally provide warm water habitat. The Trent River is an important warm water fishery.

There are no data available that indicate the confirmed location of aquatic habitats in the watershed, however stream temperature can be used as an indicator to identify the potential locations of aquatic habitats. 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, 2009). Stream temperatures in the Lower Trent Source Protection Area are shown on Map 2-14(LT).

Impacts of Development

Impacts of development on fish habitats in the Lower Trent Source Protection Area include a reduction in the number of cold water streams and a loss of riparian vegetation. Stormwater outfalls also have a significant impact on water quality in the urban areas. Intensive development along lake shorelines, particularly for seasonal use, has resulted in the loss of wetlands associated with lakes and the Trent River, important spawning areas, and riparian habitat. Increased boat traffic and fluctuating water levels and flows also have a negative impact on aquatic habitat.

2.5.5.2.2 Aquatic Macroinvertebrates

Location and Types of Habitats

Aquatic macroinvertebrates, commonly referred to as benthic macroinvertebrates, are the 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 Index value for each location are shown on Map 2-15(LT). The Simpson's Diversity Index indicates the diversity of the benthic macroinvertebrate community. The location of benthic macroinvertebrate sampling sites and the Simpson's Diversity Index value at each site are shown on Map 2-16(LT).

Impacts of Development

Analysis of benthic macroinvertebrate communities across the Lower Trent Source Protection Area indicated a range of water quality conditions and species diversity. Most sites demonstrate good water quality and are dominated by pollution-intolerant species of the taxa Ephemeroptera, Trichoptera, and Plecoptera, and demonstrate species diversity and abundance. Sites with moderate water quality are dominated by the presence of pollution-tolerant benthic macroinvertebrates. A few sites in the source protection area exhibit moderate water quality particularly in urbanized and agricultural areas. Sites with poor water quality are dominated by pollution-tolerant species of the taxa Chironomidae, Simuliidae, and Isopoda, and show limited diversity and abundance. There are no poor or very poor sites in the watershed.

2.5.6 SURFACE WATER QUALITY

This section is a summary of the available data that are suitable for a watershed-scale analysis of surface water quality in the Lower Trent Source Protection Area. Surface water quality data specific to individual drinking water systems were analysed during the evaluation of drinking water issues (see Section 4.3). Surface water quality data for the watershed are available from the Provincial Water Quality Monitoring Network. Microbiological data are available from water treatment plants and from sampling at beaches. Surface water quality monitoring stations are shown on Map 2-17(LT).

2.5.6.1 INDICATOR PARAMETERS

There are many water quality parameters that can be used to characterize the quality of a water source. 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 watershed. Indicator parameters and their associated standards or guidelines are identified in Table 2.5-8.

2.5.6.2 SUMMARY OF PROVINCIAL WATER QUALITY MONITORING NETWORK DATA

The following subsections summarize the surface water quality data available from the Provincial Water Quality Monitoring Network stations in the Lower Trent Source Protection Area. Each subsection includes a brief discussion of the sampling results for the indicator parameters identified above. Two tables are provided for each parameter: one summarizes the historical exceedances and trends for all data on record, and the second is 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.

Lower Trent currently maintains nine stations in the network. Water quality information has been collected from four of these locations for over twenty years whereas the other five locations were newly introduced in 2002. There are fourteen additional sites that have been discontinued. All of the newly established stations are used in this evaluation as well as four long-term stations that have been discontinued. Provincial Water Quality Monitoring Network monitoring stations in the watershed are described in Table 2.5-7.

Table 2.5-7: Provincial Water Quality Monitoring Network Stations and Available Data

Subwatershed	Station Name	Station ID	Data Record
Barnum House/Shelter Valley	Grafton Creek	06014100102	1964-1971
Barnum House/Shelter Valley	Shelter Valley (N.of 401)	06014200102	1971-1998
Barnum House/Shelter Valley	Shelter Valley (Orchard Grove Rd.)	06014200202	1975-1977
Lake Iroquois Plain Tributaries	Colborne Creek	06014600102	1964-1998
Lake Iroquois Plain Tributaries	Salem Creek	06014800102	1964-1983
Lake Iroquois Plain Tributaries	Proctor Creek	06015100102	1964-1998
Lake Iroquois Plain Tributaries	Smithfield Creek	06015200102	1964-1990
Cold Creek	Cold Creek (Frankford)	17002104602	1971-present
Rawdon Creek	Rawdon Creek (Cnty. Rd. 33)	17002104702	1971-1998
Trent River Tributaries	Healey Falls dam	17002105702	1971-present
Salt Creek	Salt Creek	17002107102	1972-1998
Trent River Tributaries	Glen Ross	17002111802	1971-present
Rawdon Creek	Rosebush Rd., River Valley	17002112702	1988-1998
Burnley/Mill Creek	Cnty. Rd 29, downstream Warkworth	17002113102	2002-present
Burnley/Mill Creek	Banta Rd.	17002113202	2002-present
Cold Creek	Orland	17002113302	2002-present
Trent River Tributaries	Trent River Dundas St., Trenton	17002100102	1964-1992
Trent River Tributaries	Trent River Hwy. 401@ Cnty. Rd. 33	17002104502	1971-1998
Trent River Tributaries	Trent River Dixon Dr., Trenton	17002106802	1996-present
Trent River Tributaries	Trent River Dixon Dr., Trenton	17002106883	1972-1998
Mayhew Creek	Trent River Front St., Trenton	17002112802	2002-present
Mayhew Creek	Trent River Fraser Rd., Murray	17002112902	2002-present
Trent River Tributaries	Trent River Dundas St., Hwy 2	17002100102	1964-1992

Data Source: Provincial Water Quality Monitoring Network

Table 2.5-8: Surface Water Indicator Parameters

Parameter	Standards		Source	Effects
	PWQO[1]	CEQG[2]		
Chloride (Cl^-)		250 mg/L	Naturally occurring salts, 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)
Copper (Cu)	5 µg/L		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)	1-5 µg/L (hardness dependent)		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		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		Incidental input or physical methods (e.g., erosion) (Sharpley et al., 1996). 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^-)		2.9 mg/L	Wastewater, septic systems, agricultural land use, and atmospheric deposition.	The most stable and usable form of nitrogen, but can be toxic in high concentrations and cause rapid growth of aquatic vegetation.

[1]Provincial Water Quality Objective
[2]Canadian Environmental Quality Guideline

2.5.6.2.1 Chloride

Chloride data are available from the Provincial Water Quality Monitoring Network. Concentrations at all locations are well below the Canadian Water Quality Guideline of 250 mg/L. These data indicate a trend of increasing chloride concentrations in all but three of the locations. The highest concentrations are currently found in the Mayhew Creek area. This area is the most urban of the locations and chloride could potentially be entering the system from road salts used for winter de-icing. Storm water runoff from the urban areas may assist in concentrating the chemical. The lowest concentrations are found in the Mill Creek area, which is the most rural of all locations and may be under less direct influence of road salt application. Chloride sampling data at Provincial Water Quality Monitoring Network stations are summarized in Tables 2.5-9 and 2.5-10.

Table 2.5-9: Statistical Summary of Chloride Data at Selected PWQMN Stations*

Station Name	Station ID	Years on Record	Descriptive Statistics (GCDWQ = 250 mg/L)						
			Years Analysed	n	min	median	max	Percentiles	
								25th	75th
Trent River (Dixon Drive)	17002106802	96-08	04-08	22	11.50	13.00	15.20	12.75	14.28
Cold Creek (Frankford)	17002104602	71-08	04-08	22	11.40	13.30	16.50	15.58	14.30
Trent River (Healey Falls)	17002105702	71-08	04-08	22	12.00	12.25	16.80	13.18	15.23
Trent River (Glen Ross)	17002112802	71-08	04-08	22	10.60	12.70	14.90	12.33	13.78
Mill Creek (Banta Rd.)	17002113202	02-08	04-08	22	4.60	6.50	9.80	5.83	7.55
Mill Creek (County Rd. 29)	17002113102	02-08	04-08	22	6.70	9.50	22.30	7.63	11.98
Cold Creek (County Rd. 30)	17002113302	71-08	04-08	22	9.20	10.50	16.30	10.13	11.53
Mayhew Creek (Fraser Rd.)	17002112902	02-08	04-08	22	28.90	42.55	48.30	39.95	46.45
Mayhew Creek (Front St.)	170021012802	02-08	04-08	22	42.40	49.70	180.00	45.25	131.25

*Includes stations with data available for the period of 2004-2008

Table 2.5-10: Chloride Trends and Guideline Exceedances at Selected PWQMN Stations*

Station Name	Station ID	Years on Record	No. Samples on Record	PWQO Exceedances[1]		Trend[2]
				%	#	
Colborne Creek	6014600102	64-98	351	0	0	↓
Proctor Creek	6015100102	64-98	321	0	0	↓
Shelter Valley (Orchard Grove)	6014200202	75-77	273	0	0	↑
Salt Creek	17002107102	72-98	254	0	0	↑
Trent River (Campbellford dam)	17002100202	64-98	330	0	0	↑
Trent River (Dixon Dr)	17002106883	72-98	282	0	0	↑
Cold Creek	17002104602	71-08	181	0	0	↑
Trent River (Healey Falls)	17002105702	71-08	122	0	0	↑
Trent River (Glen Ross)	17002111802	71-08	135	0	0	↑
Rawdon Creek	17002104702	71-98	174	0	0	↓

*Includes a selection of stations that represent all major subwatersheds in the Source Protection Area

[1]Indicates the quantity of samples on record that exceeded the Guidelines for Canadian Drinking Water Quality (250 mg/L)

[2]Trend observed but not statistically validated

2.5.6.2.2 Metals

Copper

Copper concentrations at all Provincial Water Quality Monitoring Network stations in the watershed show a declining trend. Several observations prior to 1990 were above the Provincial Water Quality Objective; since 1991 there has only been one exceedance at the Trent River (Glen Ross) station. Copper sampling data at Provincial Water Quality Monitoring Network stations are summarized in Tables 2.5-11 and 2.5-12.

Table 2.5-11: Statistical Summary of Copper Sampling Data at Selected PWQMN Stations*

Station Name	Station ID	Years on Record	Descriptive Statistics (PWQO = 5 ug/L)						
			Years Analysed	n	min	median	max	Percentiles	
								25th	75th
Trent River (Dixon Drive)	17002106802	96-08	04-08	22	0.094	0.850	2.000	0.590	1.020
Cold Creek (Frankford)	17002104602	71-08	04-08	21	-0.326	0.505	1.450	0.140	0.744
Trent River (Healey Falls)	17002105702	71-08	04-08	21	-0.161	0.303	1.090	0.108	0.636
Trent River (Glen Ross)	17002112802	71-08	04-08	21	-0.781	0.611	5.410	0.420	0.872
Mill Creek (Banta Rd.)	17002113202	02-08	04-08	21	-0.425	0.214	1.490	0.030	0.583
Mill Creek (County Rd. 29)	17002113102	02-08	04-08	21	-0.092	0.302	1.180	0.059	0.594
Cold Creek (County Rd. 30)	17002113302	71-08	04-08	21	-0.246	0.341	1.880	0.117	0.450
Mayhew Creek (Fraser Rd.)	17002112902	02-08	04-08	21	-0.741	0.378	1.410	0.164	0.578
Mayhew Creek (Front St.)	170021012802	02-08	04-08	22	-0.096	0.605	3.17	0.212	1.595

*Includes stations with data available for the period of 2004-2008

Table 2.5-12: Copper Trends and Guideline Exceedances at Selected PWQMN Stations*

Station Name	Station ID	Years on Record	No. Samples on Record	PWQO Exceedances[1]		Trend[2]
				%	#	
Colborne Creek	6014600102	64-98	166	13.25	22	↓
Proctor Creek	6015100102	64-98	141	21.28	30	↓
Shelter Valley (Orchard Grove)	6014200202	75-77	160	13.13	21	↓
Salt Creek	17002107102	72-98	162	13.58	22	↓
Trent River (Campbellford dam)	17002100202	64-98	200	25	50	↓
Trent River (Dixon Dr)	17002106883	72-98	1080	19.26	34	↓
Cold Creek	17002104602	71-08	144	0	0	↓
Trent River (Healey Falls)	17002105702	71-08	143	0	0	↓
Trent River (Glen Ross)	17002111802	71-08	108	0	0	↓
Rawdon Creek	17002104702	71-98	134	10.45	14	↓

*Includes a selection of stations that represent all major subwatersheds in the Source Protection Area
[1]Indicates the quantity of samples on record that exceeded the Provincial Water Quality Objective of 5 ug/L
[2]Trend observed but not statistically validated

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. In the last five years the median concentrations are below the Provincial Water Quality Objective, however only the Dixon Drive station has not had an exceedance. Lead sampling data at Provincial Water Quality Monitoring Network stations are summarized in Tables 2.5-13 and 2.5-14.

*Table 2.5-13: Statistical Summary of Lead Sampling Data at Selected PWQMN Stations**

Station Name	Station ID	Years on Record	Descriptive Statistics (PWQO = 5 ug/L)					Percentiles	
			Years Analysed	n	min	median	max	25th	75th
Trent River (Dixon Drive)	17002106802	96-08	04-08	22		-2.110	4.800	-3.798	1.292
Cold Creek (Frankford)	17002104602	71-08	04-08	21	-11.500	-1.640	7.960	-3.260	0.474
Trent River (Healey Falls)	17002105702	71-08	04-08	21	-6.410	-1.050	6.470	-4.320	0.063
Trent River (Glen Ross)	17002112802	71-08	04-08	21	-9.740	-1.280	6.470	-2.690	1.450
Mill Creek (Banta Rd.)	17002113202	02-08	04-08	21	-11.400	-0.781	16.800	-4.340	0.951
Mill Creek (County Rd. 29)	17002113102	02-08	04-08	22	-6.210	-0.946	8.680	-4.533	1.221
Cold Creek (County Rd. 30)	17002113302	71-08	04-08	21	-8.890	-1.300	6.490	-3.140	1.400
Mayhew Creek (Fraser Rd.)	17002112902	02-08	04-08	21	-21.100	0.542	12.400	-3.550	2.200
Mayhew Creek (Front St.)	170021012802	02-08	04-08	22	-9.280	-0.577	5.410	-2.938	1.678

*Includes stations with data available for the period of 2004-2008

*Table 2.5-14: Lead Trends and Guideline Exceedances at Selected PWQMN Stations**

Station Name	Station ID	Years on Record	No. Samples on Record	PWQO Exceedances[1]		Trend[2]
				%	#	
Colborne Creek	6014600102	64-98	166	51	84	↓
Proctor Creek	6015100102	64-98	141	46.8	66	↓
Shelter Valley (Orchard Grove)	6014200202	75-77	160	51.9	83	↓
Salt Creek	17002107102	72-98	162	52.5	85	↓
Trent River (Campbellford dam)	17002100202	64-98	164	51.3	84	↓
Trent River (Dixon Dr.)	17002106883	72-98	1099	52.7	579	↓
Cold Creek	17002104602	71-08	144	3.5	5	↓
Trent River (Healey Falls)	17002105702	71-08	108	2.8	3	↓
Trent River (Glen Ross)	17002111802	71-08	142	0.14	1	↓
Rawdon Creek	17002104702	71-98	134	55.2	74	↓

*Includes a selection of stations that represent all major subwatersheds in the Source Protection Area

[1]Indicates the quantity of samples on record that exceeded the Provincial Water Quality Objective of 5 ug/L

[2]Trend observed but not statistically validated

Zinc

Zinc concentrations have fluctuated over time with a declining trend at all stations. Currently zinc concentrations are below the Provincial Water Quality Objective. Zinc concentrations are highest at the Mayhew Creek (Front Street) location, which is more heavily impacted by storm water runoff. Zinc sampling data at Provincial Water Quality Monitoring Network stations are summarized in Tables 2.5-15 and 2.5-16.

*Table 2.5-15: Statistical Summary of Zinc Sampling Data at Selected PWQMN Stations**

Station Name	Station ID	Years on Record	Descriptive Statistics (PWQO = 30 ug/L)						
			Years Analysed	n	min	median	max	Percentiles	
								25th	75th
Trent River (Dixon Drive)	17002106802	96-08	04-08	22	0.433	3.055	17.100	1.313	4.833
Cold Creek (Frankford)	17002104602	71-08	04-08	21	0.007	1.350	14.300	0.621	2.810
Trent River (Healey Falls)	17002105702	71-08	04-08	21	-0.407	0.800	4.270	0.263	1.750
Trent River (Glen Ross)	17002112802	71-08	04-08	21	0.816	2.100	5.520	1.530	2.510
Mill Creek (Banta Rd.)	17002113202	02-08	04-08	21	-0.674	0.838	4.110	0.242	1.410
Mill Creek (County Rd. 29)	17002113102	02-08	04-08	21	-0.227	0.879	7.420	0.439	1.840
Cold Creek (County Rd. 30)	17002113302	71-08	04-08	21	-0.738	0.531	10.800	0.053	1.134
Mayhew Creek (Fraser Rd.)	17002112902	02-08	04-08	21	-1.080	0.710	4.470	0.366	1.780
Mayhew Creek (Front St.)	170021012802	02-08	04-08	22	-0.978	0.705	29.800	0.163	5.790

*Includes stations with data available for the period of 2004-2008

*Table 2.5-16: Zinc Trends and Guideline Exceedances at Selected PWQMN Stations**

Station Name	Station ID	Years on Record	No. Samples on Record	PWQO Exceedances[1]		Trend[2]
				%	#	
Colborne Creek	6014600102	64-98	166	0.6	1	↓
Proctor Creek	6015100102	64-98	141	1.4	1	↓
Shelter Valley (Orchard Grove)	6014200202	75-77	160	0	0	↓
Salt Creek	17002107102	72-98	162	0.6	1	↓
Trent River (Campbellford dam)	17002100202	64-98	202	14.9	30	↓
Trent River (Dixon Dr.)	17002106883	72-98	1301	1.3	16	↓
Cold Creek	17002104602	71-08	144	4.8	7	↓
Trent River (Healey Falls)	17002105702	71-08	142	4.2	6	↓
Trent River (Glen Ross)	17002111802	71-08	108	3.7	4	↓
Rawdon Creek	17002104702	71-98	134	0.7	1	↓

*Includes a selection of stations that represent all major subwatersheds in the Source Protection Area
[1]Indicates the quantity of samples on record that exceeded the Provincial Water Quality Objective of 30ug/L
[2]Trend observed but not statistically validated

2.5.6.2.3 Nutrients

Total Phosphorus

Total phosphorus is a measure of all forms of phosphorus present in water. Historically, total phosphorus concentrations in the watershed have frequently exceeded the Provincial Water Quality Objective at all Provincial Water Quality Monitoring Network stations. Concentrations were highest in the early 1970s, being well above the Provincial Water Quality Objective. Since the 1970s concentrations have remained at, or just below, the objective. Elevated concentrations are observed at Mayhew Creek, which is under the influence of storm water runoff. Cold Creek had higher concentrations at the upstream site than the downstream location. Exceedances of the objective are also observed at both locations in Mill Creek. Median concentrations in the Trent River sites are below the objective, but concentrations may be diluted as they move down the larger river. Total phosphorus sampling data at Provincial Water Quality Monitoring Network stations are summarized in Tables 2.5-17 and 2.5-18.

Table 2.5-17: Statistical Summary of Total Phosphorus Sampling Data at Selected PWQMN Stations*

Station Name	Station ID	Years on Record	Descriptive Statistics (PWQO = 0.03 mg/L)						
			Years Analysed	n	min	median	max	Percentiles	
								25th	75th
Trent River (Dixon Drive)	17002106802	96-08	04-08	21	0.016	0.024	0.038	0.021	0.027
Cold Creek (Frankford)	17002104602	71-08	04-08	21	0.013	0.027	0.064	0.023	0.032
Trent River (Healey Falls)	17002105702	71-08	04-08	21	0.014	0.023	0.060	0.018	0.027
Trent River (Glen Ross)	17002112802	71-08	04-08	21	0.015	0.022	0.043	0.018	0.028
Mill Creek (Banta Rd.)	17002113202	02-08	04-08	21	0.003	0.029	0.062	0.024	0.034
Mill Creek (County Rd. 29)	17002113102	02-08	04-08	21	0.010	0.022	3.400	0.018	0.031
Cold Creek (County Rd. 30)	17002113302	71-08	04-08	21	0.013	0.022	0.053	0.019	0.031
Mayhew Creek (Fraser Rd.)	17002112902	02-08	04-08	21	0.015	0.022	0.080	0.018	0.028
Mayhew Creek (Front St.)	170021012802	02-08	04-08	21	0.015	0.029	0.406	0.024	0.113

*Includes stations with data available for the period of 2004-2008

Table 2.5-18: Total Phosphorus Trends and Guideline Exceedances at Selected PWQMN Stations*

Station Name	Station ID	Years on Record	No. Samples on Record	PWQO Exceedances[1]		Trend[2]
				%	#	
Colborne Creek	6014600102	64-98	358	79.9	286	↓
Proctor Creek	6015100102	64-98	329	49.6	163	↓
Shelter Valley (Orchard Grove)	6014200202	75-77	280	25.4	71	↓
Salt Creek	17002107102	72-98	258	68.2	176	↓
Trent River (Campbellford dam)	17002100202	64-98	338	45	152	↓
Trent River (Dixon Dr.)	17002106883	72-98	1179	48.2	568	↓
Cold Creek	17002104602	71-08	243	50.6	123	↓
Trent River (Healey Falls)	17002105702	71-08	154	39.6	61	↓
Trent River (Glen Ross)	17002111802	71-08	202	44.5	90	↓
Rawdon Creek	17002104702	71-98	233	42.5	99	↓

*Includes a selection of stations that represent all major subwatersheds in the Source Protection Area
[1]Indicates the quantity of samples on record that exceeded the Provincial Water Quality Objective of 0.03 mg/L
[2]Trend observed but not statistically validated

Nitrate Nitrogen

Nitrate nitrogen is the concentration of nitrogen present in water in the form of the nitrate ion (NO_3^-). Provincial Water Quality Monitoring Network data indicate that past nitrate nitrogen levels infrequently exceeded the Canadian Environmental Quality Guideline; only the Salt Creek and the Dixon Drive locations have shown exceedances. There have been no exceedances in the last five years. The highest concentrations are found in the Cold Creek area, where agriculture is a significant land use. The Mayhew Creek and Mill Creek areas also show detectable nitrate nitrogen concentrations, perhaps resulting from storm water outflows. Concentrations in the Trent River are much lower. Nitrate nitrogen sampling data at Provincial Water Quality Monitoring Network stations are summarized in Tables 2.5-19 and 2.5-20.

*Table 2.5-19: Statistical Summary of Nitrate Nitrogen Sampling Data at Selected PWQMN Stations**

Station Name	Station ID	Years on Record	Descriptive Statistics (CWQG = 2.9 mg/L)						
			Years Analysed	n	min	median	max	Percentiles	
								25th	75th
Trent River (Dixon Drive)	17002106802	96-08	04-08	22	0.005	0.065	0.285	0.021	0.115
Cold Creek (Frankford)	17002104602	71-08	04-08	22	0.005	0.551	1.110	0.446	0.630
Trent River (Healey Falls)	17002105702	71-08	04-08	22	0.005	0.011	0.243	0.005	0.054
Trent River (Glen Ross)	17002112802	71-08	04-08	22	0.005	0.055	0.768	0.015	0.108
Mill Creek (Banta Rd.)	17002113202	02-08	04-08	22	0.061	0.206	0.390	0.133	0.268
Mill Creek (County Rd. 29)	17002113102	02-08	04-08	22	0.035	0.135	0.440	0.117	0.167
Cold Creek (County Rd. 30)	17002113302	71-08	04-08	22	0.356	0.510	1.070	0.454	0.600
Mayhew Creek (Fraser Rd.)	17002112902	02-08	04-08	22	0.005	0.025	0.467	0.015	0.055
Mayhew Creek (Front St.)	170021012802	02-08	04-08	22	0.053	0.383	2.410	0.142	0.832

*Includes stations with data available for the period of 2004-2008

*Table 2.5-20: Nitrate Nitrogen Trends and Guideline Exceedances at Selected PWQMN Stations**

Station Name	Station ID	Years on Record	No. Samples on Record	PWQO Exceedances[1]		Trend[2]
				%	#	
Colborne Creek	6014600102	64-98	362	0	0	↓
Proctor Creek	6015100102	64-98	326	0	0	↑
Shelter Valley (Orchard Grove)	6014200202	75-77	281	0	0	↓
Salt Creek	17002107102	72-98	255	0.39	1	↓
Trent River (Campbellford dam)	17002100202	64-98	193	0	0	↓
Trent River (Dixon Dr.)	17002106883	72-98	1127	0.09	1	↓
Cold Creek	17002104602	71-08	203	0	0	↓
Trent River (Healey Falls)	17002105702	71-08	117	0	0	↓
Trent River (Glen Ross)	17002111802	71-08	90	0	0	↓
Rawdon Creek	17002104702	71-98	198	0	0	↓

*Includes a selection of stations that represent all major subwatersheds in the Source Protection Area
[1]Indicates the quantity of samples on record that exceeded the Canadian Water Quality Guideline for the Protection of Aquatic Life (2.9 mg/L)
[2]Trend observed but not statistically validated

2.5.7 GROUNDWATER QUALITY

This section is a summary of the available data that are suitable for a watershed-scale analysis of groundwater quality in the Lower Trent Source Protection Area. Groundwater quality data specific to individual drinking water systems were analysed during the evaluation of drinking water issues (see Section 5.3). The available data include limited groundwater quality data from the Provincial Groundwater Monitoring Network and a variety of groundwater quality studies performed at local and regional scales.

2.5.7.1 INDICATOR PARAMETERS

There are many water quality 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. The data sources and groundwater quality studies identified in this characterization of groundwater quality use indicator parameters that reflect the natural features and land uses in the watershed. Common groundwater indicator parameters are described in Table 2.5-21.

2.5.7.2 PROVINCIAL GROUNDWATER QUALITY MONITORING NETWORK

The Provincial Groundwater Monitoring Network was established in 2002 to provide data to characterize groundwater quantity and quality across the province. Thirteen monitoring wells were established in the Lower Trent Source Protection Area as part of the overall network; these wells generally represent the regional aquifers across the watershed. Eleven of these wells are sampled for water quality regularly. They are described in Table 2.5-22 and their locations are shown on Map 2-18(LT).

The number of samples and the range of sampling results up to 2008 for the indicator parameters indicated above are listed in Table 2.5-23. Since sampling through this network started recently (2002), there are insufficient data to make observations regarding trends in groundwater quality.

Table 2.5-21: 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. Sources include rocks, 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 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.	80-100 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-})	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. Natural sources include decomposing vegetation and rock or soil containing gypsum, barite, or other minerals.	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 500mg/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 numbers 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 a 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 the 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: Ontario Ministry of the Environment and Climate Change (2003)

1) Maximum Acceptable Concentration (MAC) and Aesthetic Objective (AO) / Operational Guideline (OG) values as per Ontario Regulation 169/03 made under *Safe Drinking Water Act* (amended to O. Reg. 327/08).

2) The aesthetic objective for sodium in drinking water is 200 mg/L. As per the Ontario Drinking Water Standards, Objectives and Guidelines (June 2006), the local Medical Officer of Health should be notified when the sodium concentration exceeds 20 mg/L so that this information may be communicated to local physicians for their use with patients on sodium restricted diets.

Table 2.5-22: Provincial Groundwater Quality Monitoring Network Wells in the Lower Trent Source Protection Area

Well Identification Numbers		Subwatershed	Casing Inside Diameter (in)	Well Depth (m)	Static Water Level (m)	Number of Water Quality Sampling Events
MOECC[1] ID	Casing ID					
none	GA121	Squires Creek	8.250	13.03	5.50	6
74978	GA122	Cold Creek	6.250	28.33	6.93	6
174233	GA123	Rice Lake Tributaries	6.250	82.37	62.11	6
none	GA172	Trent River Tributaries	6.250	13.26	4.88	3
90698	GA173	Trent River Tributaries	6.250	15.92	3.31	7
none	GA174	Lake Iroquois Tributaries	6.250	13.59	9.23	7
242608	GA212	Rawdon Creek	6.000	15.20	1.23	5
242602	GA213	Rawdon Creek	6.250	51.11	37.57	6
242606	GA214	Cold Creek	6.250	11.08	7.42	6
none	GA411	Barnum House/Shelter Valley	6.250	48.46	42.47	6
none	GA411	Barnum House/Shelter Valley	2.000	180.06	46.55	3

Data source: Provincial Groundwater Quality Monitoring Network; Lower Trent Conservation

[1]Ministry of the Environment and Climate Change

Table 2.5-23: Summary of Provincial Groundwater Monitoring Network data in the Lower Trent Source Protection Area

Well ID	Years on Record	No. Samples	Range of Water Quality Sampling Results								
			Hardness	Sodium	Iron	Sulfate	Chloride	Nitrate	Organic Nitrogen	DOC	TDS
GA121	2003, 2005-2008	6	314-547	306-262	<0.005-6	30-170	39-1650	<0.1-4	0.3-0.6	1.1	859-1120
GA122	2002, 2005-2008	6	210-242	2.4-3.7	0.521-1.07	12-32.2	1.9-3	<0.1-1.7	<0.1	0.3-3.8	269-333
GA123	2003, 2005-2008	6	172-233	5.9-7.9	0.274-119	4-19.8	10.3-19	<0.1-2.7	0.05-1.15	0.7-1.5	273-309
GA172	2005, 2008	3	315-398	9.7-44.8	0.21-278	16-220	14-460	15.8-24.6	0.23-0.9	1.1-7.1	367-450
GA173	2003, 2005-2008	7	278-541	12.2-207	0.069-1200	7-20	13.5-544	<0.1-0.2	0.06-0.5	1.4-8	353-680
GA174	2003, 2005-2008	7	122-281	2.2-4.2	0.003-9	7-15	1-7	0.1-1.5	0.08-0.2	<0.05-0.05	203-342
GA212	2005-2008	5	262-277	5.8-8.34	0.155-77	13-15	13-25.3	0.2-0.3	0.05-0.3	1-2.6	262-277
GA213	2003, 2005-2008	6	212-245	2.5-2.9	0.18-545	21-25.5	0.9-3	<0.1	0.05-0.2	0.1-2	257-274
GA214	2003, 2005-2008	6	218-268	3.3-29.1	0.274-194	16-28	3-50.2	<0.1-1.3	<0.1-1.9	0.9-2.3	259-413
GA411A	2005-2008	6	158-262	2.3-20.4	<0.005-6	15-17.1	1-35	0.1-0.3	<0.1-1	0.5-5.8	180-367
GA411B	2007-2008	3	75-79	28.9-35.7	0.126-5	8-10	3.3-4	<0.1-0.1	0.19-0.4	0.8-1.3	162-178

2.5.7.3 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.

2.5.7.4 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 map the groundwater resources and delineate wellhead protection areas in municipalities across the province. The Trent Conservation Coalition Municipal Groundwater Study was completed by Morrison Environmental Ltd. The Aquifer Characterization component of the study (Volume 1) evaluated groundwater quality in bedrock and overburden wells across most of the Trent Conservation Coalition Source Protection Region.

In the Paleozoic Area, the study observed that the vast majority of bedrock wells yield fresh water though they may require treatment to meet Ontario Drinking Water Standards (Morrison Environmental Ltd., 2004). There are some occurrences of sulphurous water where Paleozoic and Precambrian meet; this is attributed to the high organic content of the rock. The study also noted that salty and sulphurous water had been reported in bedrock wells north of the City of Peterborough and east of Chemong Lake.

In the Precambrian Area, the vast majority of bedrock wells yield fresh water although treatment to decrease the hardness and remove iron may be required to meet Ontario Drinking Water Standards (Morrison Environmental Ltd., 2003). Hardness and sulphates in the water were reported primarily along the Paleozoic-Precambrian contact. In addition, salty water was noted as having been reported and the study states that this may be due to anthropogenic activities such as road salting/stockpiling, dust control activities, and landfills.

Water quality observations from the Water Well Records Database compiled by the Municipal Groundwater Study in the Lower Trent Source Protection Area are illustrated in Figures 2.5-1 and 2.5-2.

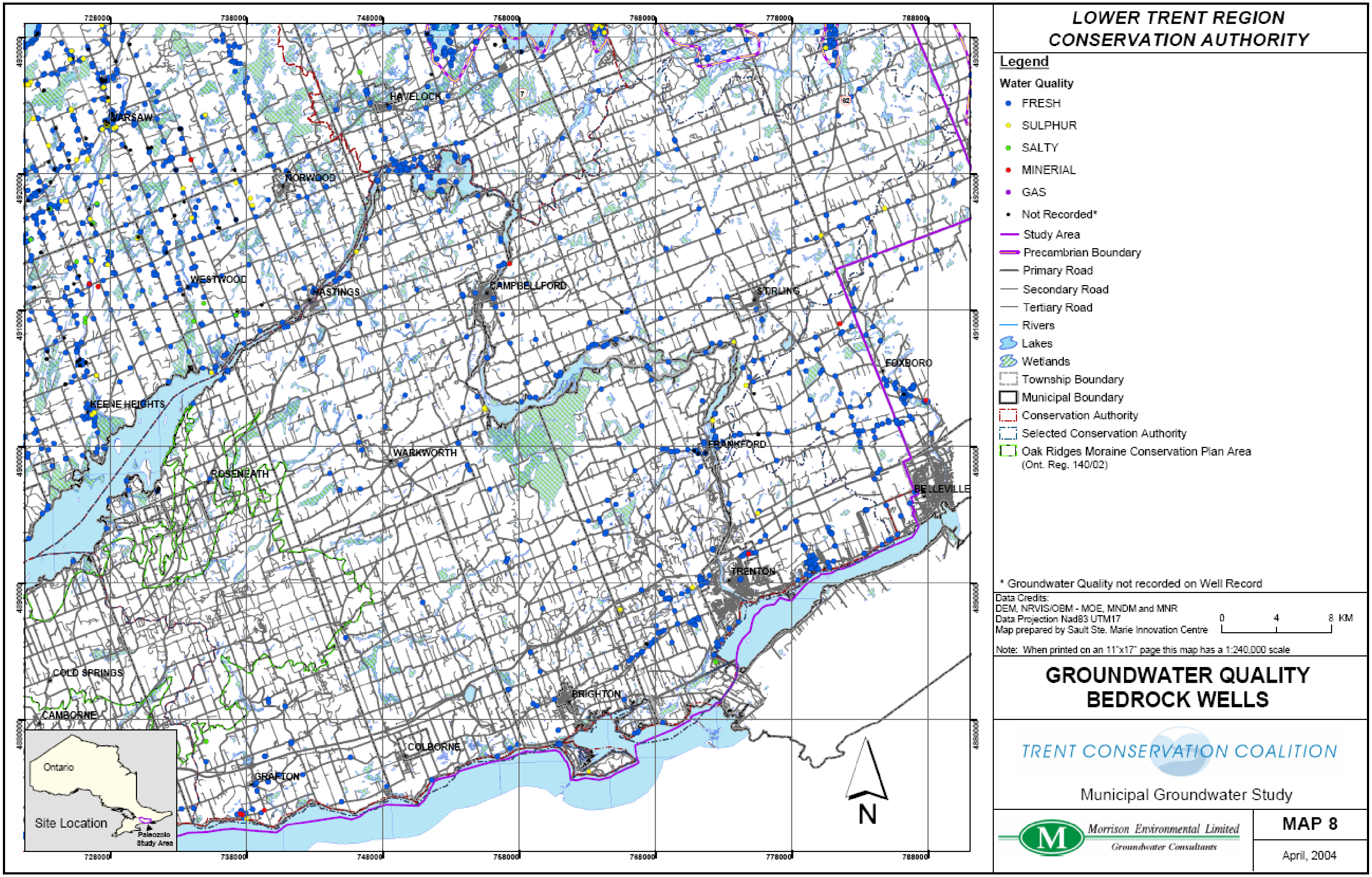

Figure 2.5-1: Groundwater Quality in Bedrock Wells in the Lower Trent Source Protection Area (Morrison, 2004)

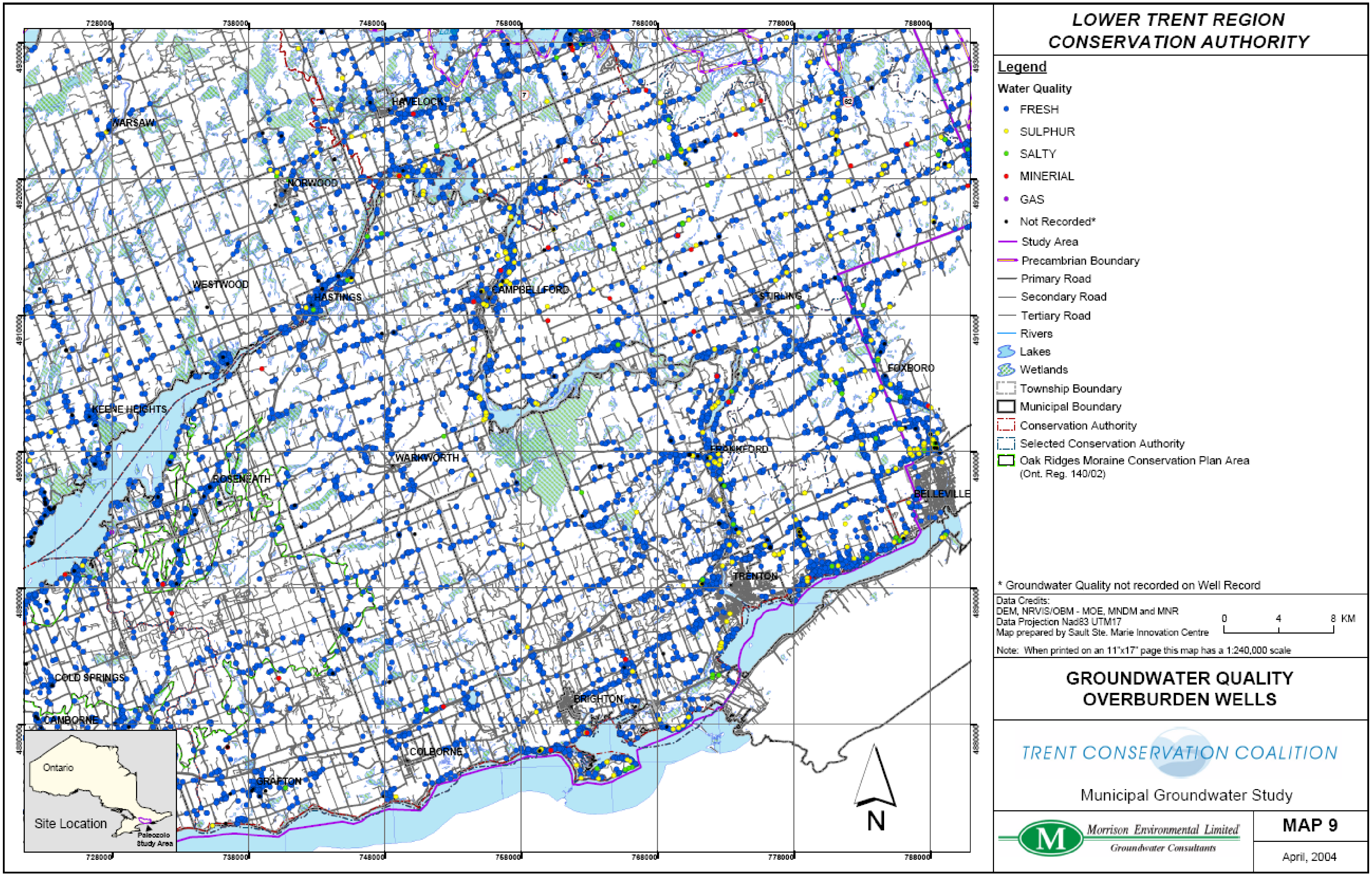

Figure 2.5-2: Groundwater Quality in Overburden Wells in the Lower Trent Source Protection Area (Morrison, 2004)

2.5.8 REFERENCES

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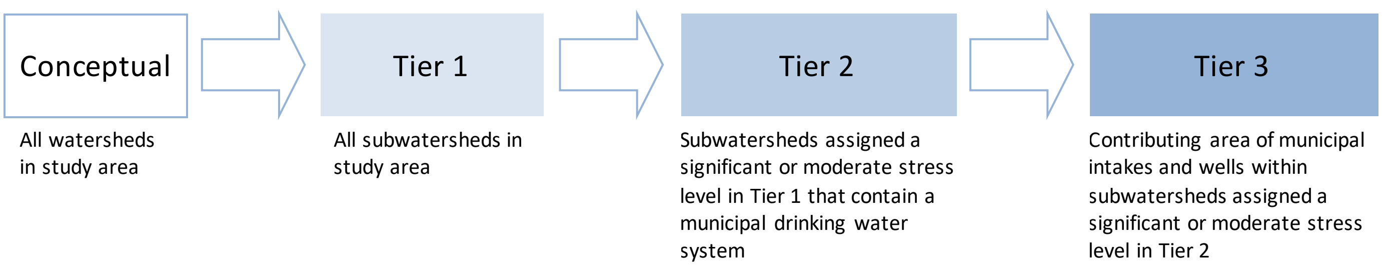
CHAPTER 3: WATER BUDGET AND WATER QUANTITY STRESS ASSESSMENT

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 using 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.

3.1.1 OVERVIEW OF REQUIREMENTS

The water budget process required by the *Technical Rules* 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 subwatershed in the 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 subject to 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. The conceptual, Tier 1, and Tier 2 water budgets for the Trent source protection areas are discussed in this chapter. No Tier 3 water budgets were required.



3.1.2 STUDY AREA

The water budgets described in this chapter were developed for the Trent source protection areas and a small portion of the Ganaraska Region Source Protection Area. The study area includes the Crowe Valley, Kawartha-Haliburton, and Otonabee-Peterborough Source Protection Areas, which all drain into the Trent River, and the Lower Trent Source Protection Area, which drains partially into the Trent River and partially into Lake Ontario and the Bay of Quinte. The study area also includes a small portion of the Rice Lake watershed that is located in the Ganaraska Region Source Protection Area.

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 are calculated using the water balance equation.

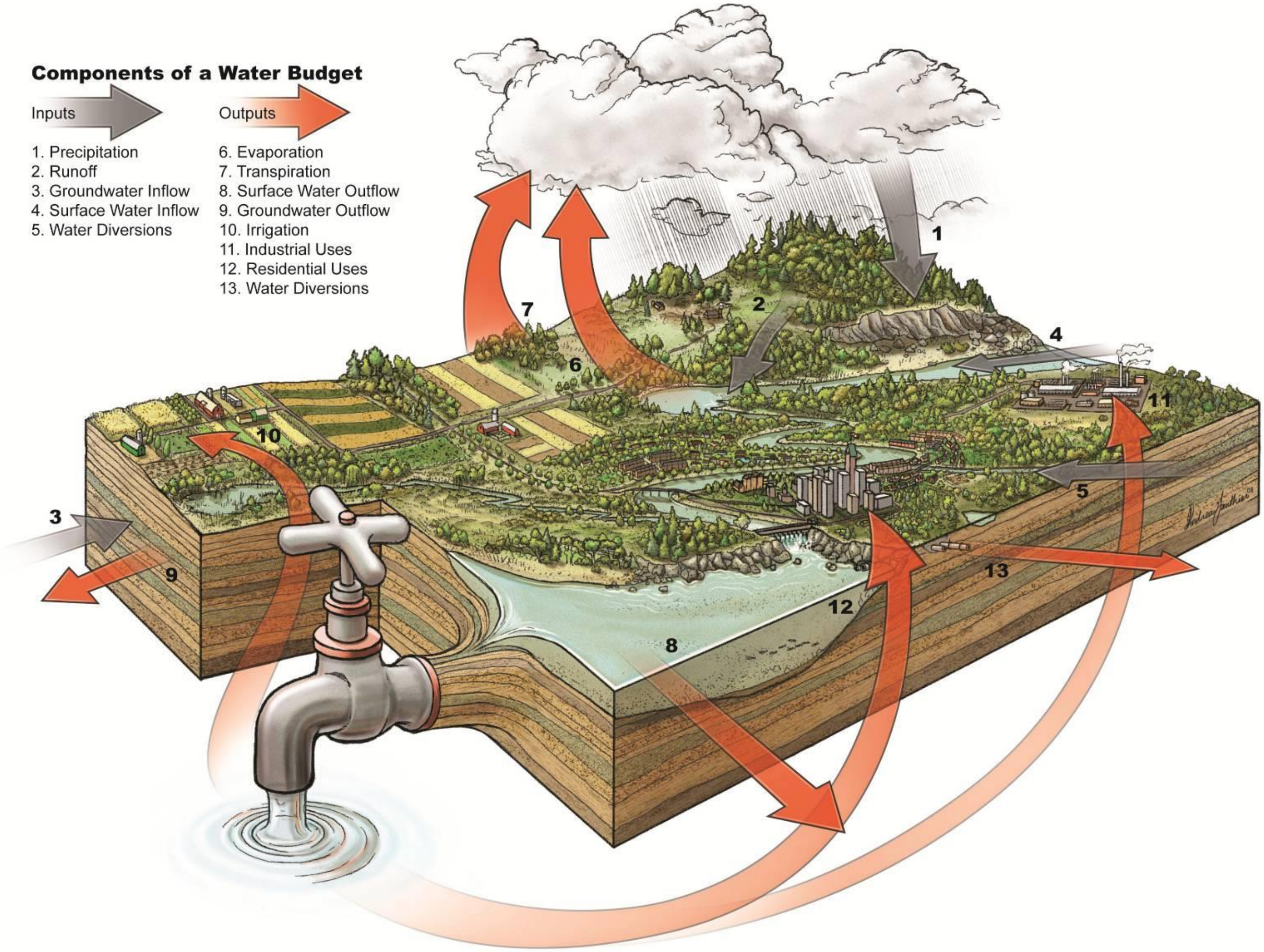


Figure 3.1-1: Components of a Water Budget

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:

(Input) – (Output) = (Change in Storage)

Or, in finite difference form:

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

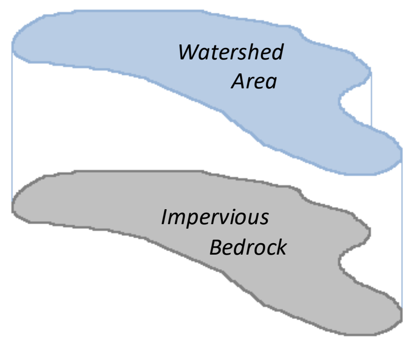
Where: ΔS = change in storage
Δt = time interval over which water budget is evaluated

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



The water budget equation is applied to a fixed volume in space defined by a watershed projected vertically downwards to impervious bedrock.

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).

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 conceptual water budget was developed separately for the Trent River watershed and the subwatersheds of Lake Ontario and Bay of Quinte tributaries that are located in the Lower Trent Source Protection Area. These conceptual water budgets are documented in the following reports:

- *Conceptual Water Budget: Trent River Watershed (March 2007)*
- *Conceptual Water Budget: Lake Ontario/Bay of Quinte Tributaries (Lower Trent Watershed) (March 2007).*

This section is a summary of these reports.

3.2.1 SUBWATERSHEDS

Since the study area is large and complex, it has been divided into 10 subwatersheds for purposes of the conceptual water budget (see Map 3-1). The delineation of these subwatersheds was based on local geology, physiography, and the location of hydrometric stations. Most subwatershed outlets were defined at the location of hydrometric stations with sufficiently long flow records that were located near the outlets of major tributaries of the Trent River or along the Trent-Severn Waterway. The Lower Trent South subwatershed was associated with the Trenton hydrometric station despite its limited data record (1999 to 2002) because it is located at the outlet of the Trent River. Further, because there are no hydrometric stations in the Bay of Quinte tributaries subwatershed, flow data at this station was estimated using the Ontario Flow Assessment Techniques software. Subwatersheds and the hydrometric stations selected as their outlets are described in Table 3.2-1.

3.2.2 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.

3.2.2.1 DATA SOURCES

Climate data in the study area are available from climate stations operated by the Meteorological Service of Canada (Environment Canada), Conservation Authorities, Ministry of Natural Resources and Forestry, Ministry of Transportation, Hydro One, Airport Authorities, municipalities, universities and colleges, and other research organizations. In the Trent River watershed, the coverage of climate stations in the Paleozoic area is reasonable, but data are sparse in portions of the Precambrian area. In the Lake Ontario and Bay of Quinte tributaries subwatersheds, stations are concentrated in the south and in larger communities along the shore of Lake Ontario. Climate stations in the study area are listed in Table 3.2-2 and shown on Map 3-2.

Table 3.2-1: Subwatersheds Delineated for the Conceptual Water Budget

Subwatershed	Drainage Area (km^2)	Source Protection Areas	Major Water Bodies	Representative Hydrometric Station				
				Station Name	Station ID	Current Status	Owner/ Operator[1]	Years on Record
Gull River	1,280	KHSPA	Gull River	Gull River at Norland	02HF002	Active	WSC	1962-2004
Burnt River	1,270	KHSPA	Burnt River	Burnt River at Burnt River	02HF003	Active	WSC; TSW	1962-2004
Kawartha Lakes West	3,500	KHSPA; OPSPA	Balsam, Cameron , Scugog, Pigeon, Chemong, Buckhorn, and Sturgeon Lakes; Nogies Creek	Lock #31 at Buckhorn Lake			TSW	1990-2004[2]
Kawartha Lakes East	1,250	OPSPA	Lower Buckhorn, Lovesick, Buckhorn, Stony, and Katchewanooka Lakes; Eel's Creek; Jack Creek; Mississauga River	Otonabee River at Lakefield	02HJ002	Active	TSW	1962-2004
Rice Lake	1,800	OPSPA; LTSPA; GRSPA	Rice Lake	Trent River at Healey Falls			WSC; TSW	
Crowe River	1,990	CVSPA	Crowe River; North River; Beaver Creek	Crowe River at Marmora	02HK003	Active	WSC	1959-2003
Lower Trent North	1,000	LTSPA; CVSPA	Burnley Creek	Trent River at Glen Ross	02HK004 02HK012	Discontinued	WSC; TSW	1963-1995
Lower Trent South	400	LTSPA	Cold Creek; Rawdon Creek; Mayhew Creek	Trent River at Trenton	02HK010	Discontinued[3]	WSC	1999-2002
Lake Ontario Tributaries	193	LTSPA	Shelter Valley Creek	Shelter Valley Creek near Grafton		Active	LTC; WSC	1995-2004
Bay of Quinte Tributaries	72	LTSPA	DND Creek	None	NA	NA	NA	NA[3]

[1]WSC = Water Survey of Canada; TSW = Trent-Severn Waterway; LTC = Lower Trent Conservation
[2]Only lake level data is available at this station. Daily flow was calculated using lake level and control gate setting data in conjunction with a rating curve developed by the Trent-Severn Waterway
[3]Flow data for the Bay of Quinte tributaries subwatershed was estimated using the Ontario Flow Assessment Techniques (Version 1.0) software
[3]WSC station discontinued; new TSW station added upstream of former station location (upstream of highway 401)

Table 3.2-2: Selected Climate Stations in the Study Area

Climate Station Name	AES[7] ID	WMO[8] ID	Latitude (DD)	Longitude (DD)	Elevation (MAMSL)	Years on Record		Date Interval[9]	Code[10]
						Start	End		
Trent River Watershed									
Bancroft Auto	616I001	71294	45.067	-77.867	330.700	1995	2005	H/D/M/A	A
Belleville	6150689	-	44.150	-77.383	76.200	1866	2005	D/M/A	A
Dorset MOECC	6112072	-	45.217	-78.917	323.100	1976	2002	D/M/A	C
Frankford MOECC	6152555	-	44.217	-77.600	114.300	1959	1994	D/M/A	C
Haliburton A	6163156	-	45.000	-78.567	320.000	1883	1992	H/D/M/A	C
Janetville	6153853	-	44.217	-78.617	296.900	1981	2005	D/M/A	D
Lindsay Frost[2]	6164433	-	44.317	-78.717	262.100	1974	2005	D/M/A	A
Minden[1]	6165195	-	44.917	-78.717	274.300	1883	2005	D/M/A	A
Peterborough A[3]	6166418	-	44.217	-78.367	191.400	1969	2005	H/D/M/A	A
Peterborough AWOS	6166420	71629	44.217	-78.367	191.400	2004	2005	H/D/M/A	A
Peterborough Dobbins TS	6166428	-	44.317	-78.400	243.800	1965	1994	D/M/A	C
Peterborough STP	6166450	-	44.267	-78.317	192.000	1964	1993	D/M/A	C
Peterborough Trent U	6166456	71672	44.350	-78.300	216.000	2005	2006	H/D/M/A	A
Peterborough Trent U	6166455	-	44.367	-78.300	198.100	1968	2005	D/M/A	A
Smithfield CDA	6157831	-	44.067	-77.667	119.000	1949	1990	D/M/A	D
Lake Ontario & Bay of Quinte Tributaries									
Centreton	6151307	-	44.067	-78.067	244.00	1990	1992	D/M/A	-
Colborne	6151745	-	44.000	-77.867	105.00	1991	1991	D/M/A	-
Cobourg STP[5]	6151689	-	43.854	-78.321	79.20	1970	2006	D/M/A	-
Trenton A[4]	6158875	71621	44.117	-77.517	86.30	1953	2005	H/D/M/A	A
Trenton Domtar	6158878	-	44.117	-77.500	80.00	1989	1990	D/M/A	-
Trenton MOECC	6158888	-	44.117	-77.567	76.20	1960	1978	D/M/A	-
Smithfield CDA	6157831	-	44.067	-77.667	119.00	1949	1990	D/M/A	-
Smithfield CDA Automatic Climate Station	6157832	-	44.067	-77.667	119.00	1987	1996	D/M/A	-

[1]Zone 1 station (northern TRW)
[2]Zone 2 station (central TRW)
[3]Zone 3 station (south TRW)
[4]Zone 4 station (Bay of Quinte)
[5]Zone 5 station (Lake Ontario)

[7]Atmospheric Environment Service
[8]World Meteorological Organization

[9]Indicates the frequency of climate data:
H: Hourly
D: Daily
M: Monthly
A: Annually

[10]Climate codes indicate the availability of data (Environment Canada, 2009):
A: No more than 3 consecutive or 5 total missing years between 1971-2000
B: At least 25 years of record between 1971-2000
C: At least 20 years of record between 1971-2000
D: At least 15 years of record between 1971-2000

3.2.2.2 CLIMATE ZONES

Trent River Watershed

For purposes of the conceptual water budget, the climate of the Trent River watershed was divided into three zones of uniform climate. The delineation of these climate zones was based on a spatial analysis of long-term precipitation and temperature averages at selected climate stations (see Maps 3-3 and 3-4) and by a review of eco-districts established by Agriculture and Agri-Food Canada (see Map 3-6). The climate station with the best data available in each zone was selected to represent the climate of that zone. All three representative climate stations selected for the Trent River watershed (Minden, Lindsay Frost, and Peterborough Airport) meet the World Meteorological Organization standards. Climate zones used for the Trent River watershed and their representative climate stations are described in Table 3.2-3 and illustrated on Maps 3-5 and 3-6.

Lake Ontario & Bay of Quinte Tributaries

To account for microclimates associated with coastal Lake Ontario, the Lake Ontario and Bay of Quinte tributaries subwatersheds were assigned climate data from local climate stations. The representative climate stations selected for these subwatersheds are described in Table 3.2-3. The station at the Cobourg sewage treatment plant does not meet the World Meteorological Organization standards, but was used because it was the station with the best available data.

Table 3.2-3: Climate Zones and Climate Normals per Zone

Zone	Location	Bedrock Geology	Subwatersheds In Climate Zone	Representative Climate Station	Climate Normals[1]		Actual Evapo-transpiration[2] (mm)
					Temperature (°C)	Precipitation (mm)	
Trent River Watershed							
1	Northern	Precambrian	Gull River; Burnt River 40% of Kawartha Lakes East 50% Crowe River	Minden	5.2	1045	502
2	Central	Transitional	70% Kawartha Lakes West 60% Kawartha Lakes East 50% Crowe River	Lindsay Frost	6.6	870	525
3	Southern	Paleozoic	Rice Lake Lower Trent North Lower Trent South 30% Kawartha Lakes West	Peterborough Airport	5.9	840	512
Lake Ontario & Bay of Quinte Tributaries							
4	Lake Ontario	Paleozoic	Lake Ontario tributaries	Cobourg STP	7.1	871	532
5	Bay of Quinte	Paleozoic	Bay of Quinte tributaries	Trenton Airport	7	894	536

[1]National Climate Data Archive of Canada; based on 1971-2000 data (Environment Canada, 2005)
[2]Calculated using a spreadsheet model based on the Thornthwaite-Mather (1955) model modified by Hamon (1963)

3.2.2.3 PRECIPITATION

Average annual and average monthly precipitation was estimated for each subwatershed by calculating the weighted average of the Environment Canada precipitation normals for the period of 1971 to 2000 based on the percent coverage of climate zones. The mean annual precipitation of climate zones in the study area is listed in Table 3.2-3, and the mean monthly precipitation is illustrated in Figure 3.2-1. The long-term distribution of precipitation across the study area is illustrated on Map 3-3.

Trent River Watershed

Mean annual precipitation ranges from 840 mm/year in Zone 3 to 1,045 mm/year in Zone 1. Zone 2 receives about 870 mm every year. Overall, precipitation trends are the same in Zones 2 and 3. On the local scale, mean annual precipitation in the Precambrian area ranges from about 895 mm/year at Fenelon Falls to about 1,092 mm/year at Haliburton, and in the Paleozoic area it ranges from about 797 mm/year at Codrington to about 990 mm/year at Woodville.

About 70 to 85% of annual precipitation in the watershed falls as rain, usually between May and November. November is the wettest month of the year. Between December and March, most precipitation falls as snow. In November and April precipitation is mixed with a trend toward greater rainfall. February and July are generally the driest months of the year.

The pattern of mean annual precipitation is complicated and varies across the watershed. The northern region (Zone 1) receives the most precipitation, probably due to the influence of westerly air masses moving off Lake Huron and Georgian Bay and/or the orographic effect. This contrasts with the southern region (Zone 3), which may experience a slight rain shadow effect from the presence of the Oak Ridges Moraine to the north of Lake Ontario. The northern region (Zone 1) tends to receive the most snowfall, and in this zone snow remains on the ground for a longer period of time (Trent University, 2005).

Temperature gradients have distinct effects on the ice and snow cover of lakes in the watershed. The Haliburton Lakes receive about 40 centimetres (cm) more annual snow than the surrounding areas, and they freeze earlier and stay frozen longer than either the Kawartha Lakes or the Lake Ontario shoreline. They also tend to have a thicker snow cover and a larger proportion of white ice. Lower temperatures, thicker ice, and greater snow and white ice covers delay and prolong break-up in the Haliburton Lakes as compared with the Kawartha Lakes. As a result, the period of snowmelt is longer for the watershed's northern lakes, and it extends the freshet further into the spring (Trent University, 2005).

Lake Ontario & Bay of Quinte Tributaries

Mean annual precipitation in the Lake Ontario tributaries is 871.1 mm/year. This value is slightly less than that of the Bay of Quinte tributaries. It is possible that the Lake Ontario tributaries receive less overall precipitation than the Bay of Quinte tributaries because of a slight rain shadow effect caused by the Oak Ridges Moraine. About 88% of the annual average precipitation falls as rain, usually between April and November, with September being the wettest month of the year. In this area, the majority of the precipitation that falls during the winter months is rain, although the area does still receive a fair amount of snowfall. From November through April, precipitation is mixed (usually more rain falling than snow). Generally, February and July are the driest months of the year. The mean monthly precipitation in the Lake Ontario tributaries climate zone is illustrated in Figure 3.2-3.

Mean annual precipitation for the Bay of Quinte tributaries is 893.8 mm. About 81% of the annual average precipitation falls as rain, usually between May and November, with November being the wettest month of the year. Between December and February, most precipitation falls as snow. In November and April, precipitation is mixed with a trend toward greater rainfall. Generally, February and July are the driest months of the year. The mean monthly precipitation in the Bay of Quinte tributaries climate zone is illustrated in Figure 3.2-4.

3.2.2.4 TEMPERATURE

The factors that affect the temperature of an area are latitude, altitude, and distance from the moderating influences of large waterbodies. The temperature gradient in the study area decreases from south to north due to increases in latitude, altitude, and distance from the moderating influences of Lake Ontario. Average annual and average monthly temperatures were estimated for each subwatershed by calculating the weighted average of the Environment Canada temperature normals for the period of 1971 to 2000 based on the percent coverage of climate zones. The mean annual temperature of all climate zones in the study area is listed in Table 3.2-3, and the long-term temperature distribution across the study area is illustrated on Map 3-4.

Trent River Watershed

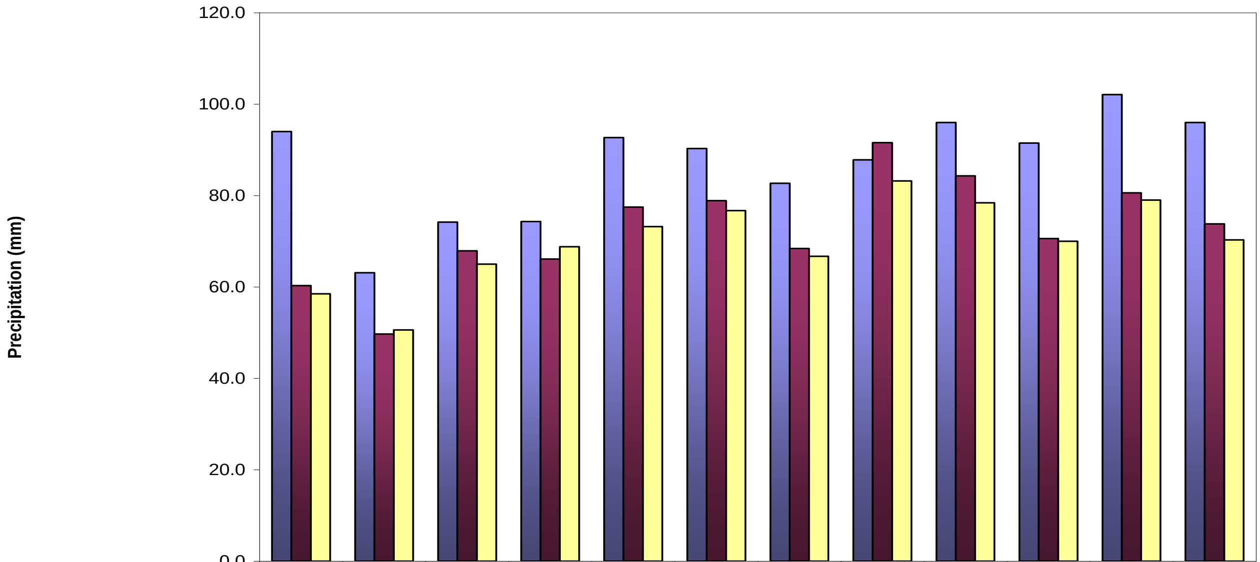
Mean monthly temperature in the Trent River watershed climate zones is illustrated in Figure 3.2-2. The mean annual daily temperature in the Paleozoic region ranges from 5.9 to 7.7 ^{o}C (Morrison Environmental Ltd., 2004). The mean annual temperature in the Precambrian area ranges from 4.0 to 5.9 ^{o}C (Morrison Environmental Ltd., 2003).

January is the coldest month over the entire watershed; mean daily temperature in January from south to north ranges from -7 to -10 ^{o}C (based on at least 15 years of data between 1971 and 2000). Average monthly temperatures rise above freezing in April and reach a peak near 20 ^{o}C in July. Temperatures fall below freezing in December. Temperature trends are similar among all zones, however Zone 1 has lower summer temperatures and colder winters, Zone 2 has high temperatures in summer, and Zone 3 has moderate temperatures in summer and winter.

Lake Ontario & Bay of Quinte Tributaries

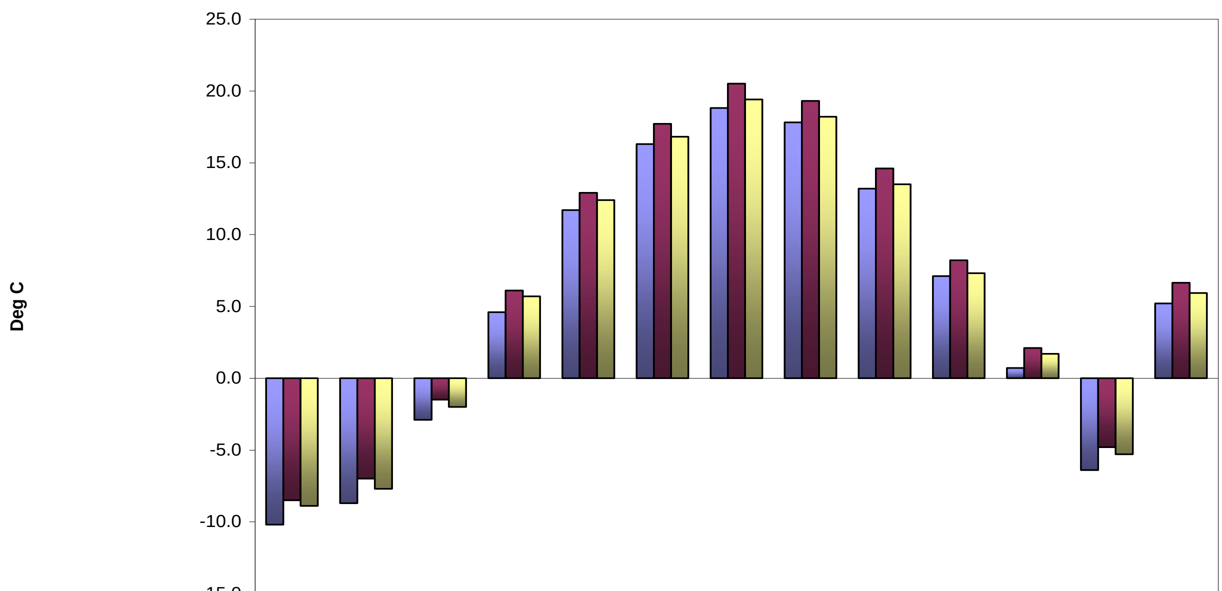
Mean monthly temperatures in the Lake Ontario and Bay of Quinte tributaries climate zones are illustrated in Figure 3.2-5 and Figure 3.2-6. (Figures also include maximum and minimum daily temperature.) The mean annual temperature in the Bay of Quinte tributaries subwatershed is 7 ^{o}C. Average monthly temperatures rise above the freezing mark in mid-March and reach an average high temperature of 20.5 ^{o}C in July. The temperature then falls below 0 ^{o}C again in late November and reaches a low temperature of -7.5 ^{o}C in January.

The mean annual temperature in the Lake Ontario tributaries subwatershed area is 7.1 ^{o}C. Average monthly temperatures rise above the freezing mark in mid-March and reach an average high temperature of 19.6 ^{o}C in July. The temperature then falls below 0 ^{o}C again in early December and reaches a low temperature of -6.0 ^{o}C in January.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Zone 1: Minden	94.0	63.1	74.2	74.3	92.7	90.3	82.7	87.8	96.0	91.5	102.1	96.0
Zone 2: Lindsay/Pet TU	60.3	49.7	67.9	66.1	77.5	78.9	68.4	91.6	84.3	70.6	80.6	73.8
Zone 3: Pet Airport	58.5	50.6	65.0	68.8	73.2	76.7	66.7	83.2	78.4	70.0	79.0	70.3

Figure 3.2-1: Mean monthly precipitation in Trent River watershed climate zones (based on 1971-2000 data)



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg
Zone 1: Minden	-10.2	-8.7	-2.9	4.6	11.7	16.3	18.8	17.8	13.2	7.1	0.7	-6.4	5.2
Zone 2: Lindsay/Pet TU	-8.5	-7.0	-1.5	6.1	12.9	17.7	20.5	19.3	14.6	8.2	2.1	-4.8	6.6
Zone 3: Pet Airport	-8.9	-7.7	-2.0	5.7	12.4	16.8	19.4	18.2	13.5	7.3	1.7	-5.3	5.9

Figure 3.2-2: Mean monthly temperature in Trent River watershed climate zones (based on 1971-2000 data)

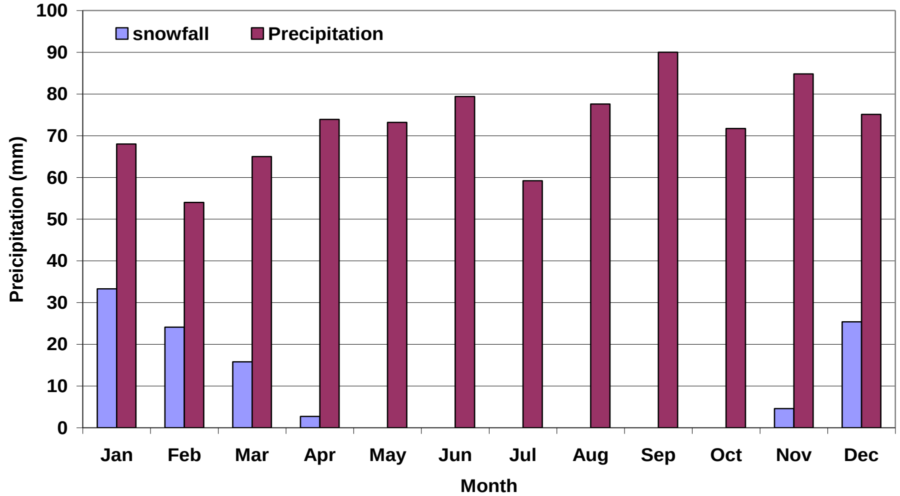


*Figure 3.2-3: Mean monthly precipitation in Lake Ontario tributaries climate zone (Cobourg STP climate station)**

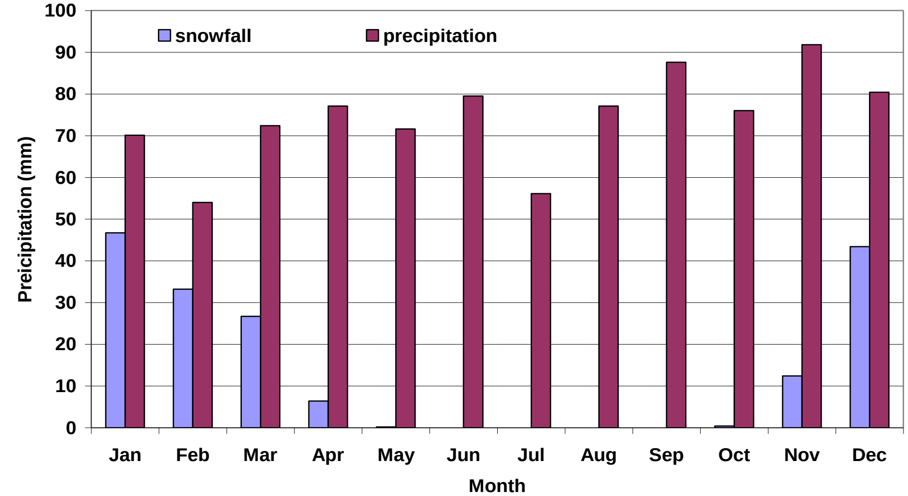


*Figure 3.2-4: Mean monthly precipitation in Bay of Quinte tributaries climate zone (Trenton airport climate station)**

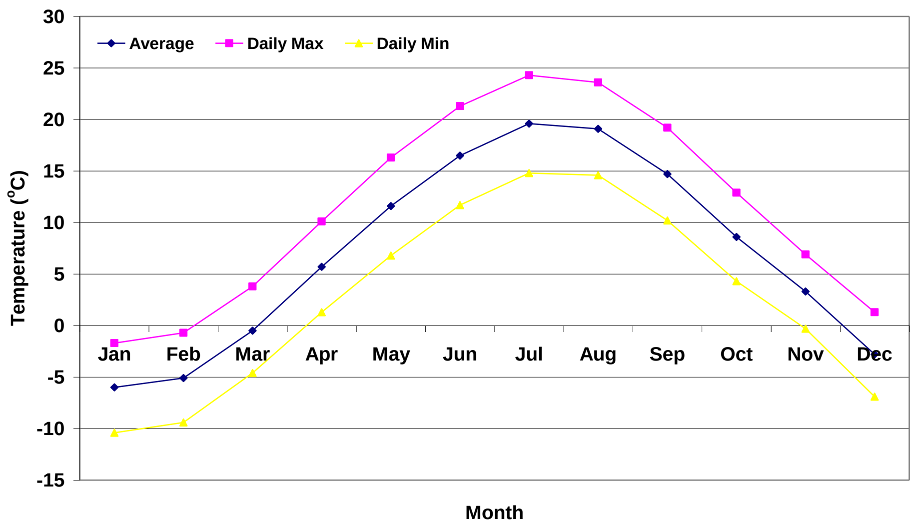


*Figure 3.2-5: Summary of temperature data in Lake Ontario tributaries climate zone (Cobourg STP climate station)**

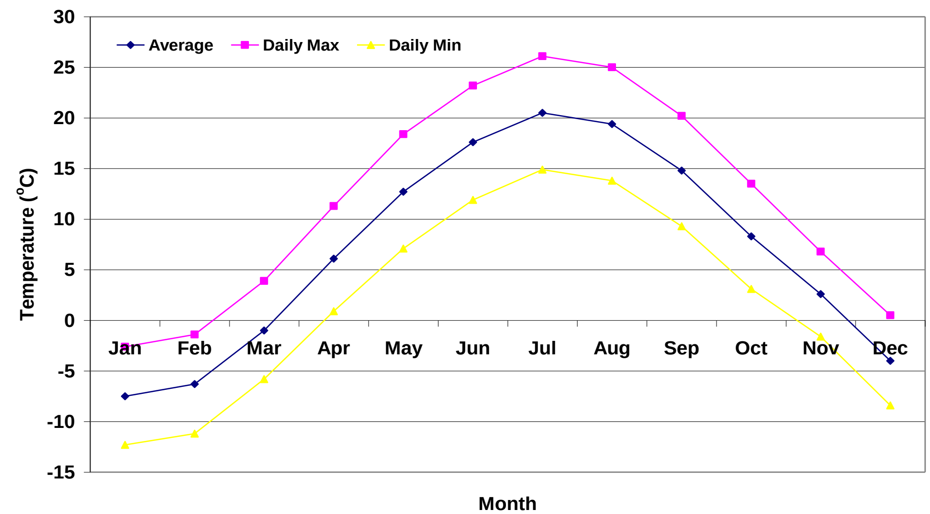


*Figure 3.2-6: Summary of temperature data in Bay of Quinte tributaries climate zone (Trenton Airport climate station)**

*Based on Environment Canada climate data for 1971-2000

3.2.2.5 EVAPOTRANSPIRATION

Evapotranspiration is the sum of water loss 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 streamflow.

The amount of evapotranspiration varies among the Paleozoic and Precambrian areas due to differences in physiography and climate. In the Paleozoic area and the transition zone, most rain water percolates into the soil; some recharges the groundwater (that 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 transpiration, whereby water passes through the plant to the atmosphere, largely in response to the drying properties of the overlying air. The condition is different in the Precambrian area where steep slopes, rocky terrain, and low infiltration and evapotranspiration rates cause water to run off as overland flow.

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 modified by Hamon (1963). 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 and the soil water holding capacity, which was assumed from the dominant hydrologic soil group and land cover in the study area to be in the range of 200 to 300 mm.

Mean potential evapotranspiration at selected climate stations, estimated using the modified Thornthwaite-Mather model, is illustrated on Map 3-7 and listed by climate zone in Table 3.2-3. 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).

3.2.3 GEOLOGY

3.2.3.1 BEDROCK GEOLOGY

The bedrock geology of the study area (Map 3-8) is very complex. It can be divided into three areas: the Precambrian area, the Paleozoic area, and a transition zone between them.

The Precambrian area includes the parts of the Kawartha-Haliburton, Otonabee-Peterborough, and Crowe Valley Source Protection Areas that are located north of the Kawartha Lakes. The bedrock in this area is composed of ancient, erosion-resistant igneous and metamorphic rocks of the Precambrian Era. This bedrock is associated with the Canadian Shield.

South of the Kawartha Lakes, the Precambrian bedrock is overlain by thick layers of younger sedimentary rocks of the Paleozoic Era. These rocks belong to the Ottawa Group (which are part of the Middle and Upper Ordovician strata) and consist of five formations: Lindsay, Verulam, Bobcaygeon, Gull River, and Shadow Lake. The Paleozoic bedrock dips gently to the southwest and is composed of limestone with calcareous shale, sandstone, and mudstone (Morrison Environmental Ltd., 2004). The bedrock geology of the Lower Trent Lake Ontario tributaries subwatersheds is also Paleozoic.

***Igneous rocks** (top) were formed by the cooling of molten lava; **metamorphic rocks** have been changed by temperature or pressure; **sedimentary rocks** (bottom) were formed by deposition and consolidation of fragments of pre-existing rocks and/or organic materials.*

There is a transition zone between the Precambrian and Paleozoic areas that is located in the south of the Crowe Valley Source Protection Area and north of the Kawartha Lakes (in the Kawartha-Haliburton and Otonabee-Peterborough Source Protection Areas). In this transition zone, only thin layers of flat-lying Paleozoic bedrock overlie the Precambrian rock and there are frequent outcrops of Precambrian rock. The surface of the transition zone is very rough and is littered with angular fragments, large blocks of limestone, and Precambrian rocks.

Bedrock geology and lithology in the Trent River watershed are summarized in Table 3.2-4. A cross-section of the Trent River watershed is shown in Figure 3.2-7, and two cross-sections of the Lower Trent Source Protection Area are shown in Figure 3.2-8 and Figure 3.2-9. The cross-sections are based on stratigraphic surfaces provided by the Geological Survey of Canada and are subject to ongoing refinement.

Table 3.2-4: Bedrock Lithology of the Trent River Watershed (adapted from Chapman and Putnam, 1984)

Formation	Member	OGS Formation Unit	Age	Thickness	Lithology
Simcoe Group					
Lindsay	Upper	6b	Upper Ordovician	0 to 90 m	limestone and shale
	Lower	6a	Upper Ordovician	Usually <30 m	nodular limestone with shale interbeds
Verulam		5	Middle Ordovician	0 to 70 m	interbedded limestone and shale
Bobcaygeon	Upper	1c, 4b	Middle Ordovician	0 to 60 m	limestone with shaly partings
	Lower	1c, 4a	Middle Ordovician		limestone and calcarenite
Gull River	Upper	1b, 3, 3c	Middle Ordovician	0 to 30 m	dolomitic limestone and weathered limestone
	Middle	1b, 3, 3b	Middle Ordovician		shaly laminated limestone and massive bedded
	Lower	1b, 3, 3a	Middle Ordovician		crystalline limestone
Basal Group					
Shadow Lake		1a,2	Middle Ordovician	0 to 20 m	dolostone with interbeds of sandstone and shaly partings
Precambrian		37 to 48	Precambrian	Basement rock	igneous and metamorphic rocks

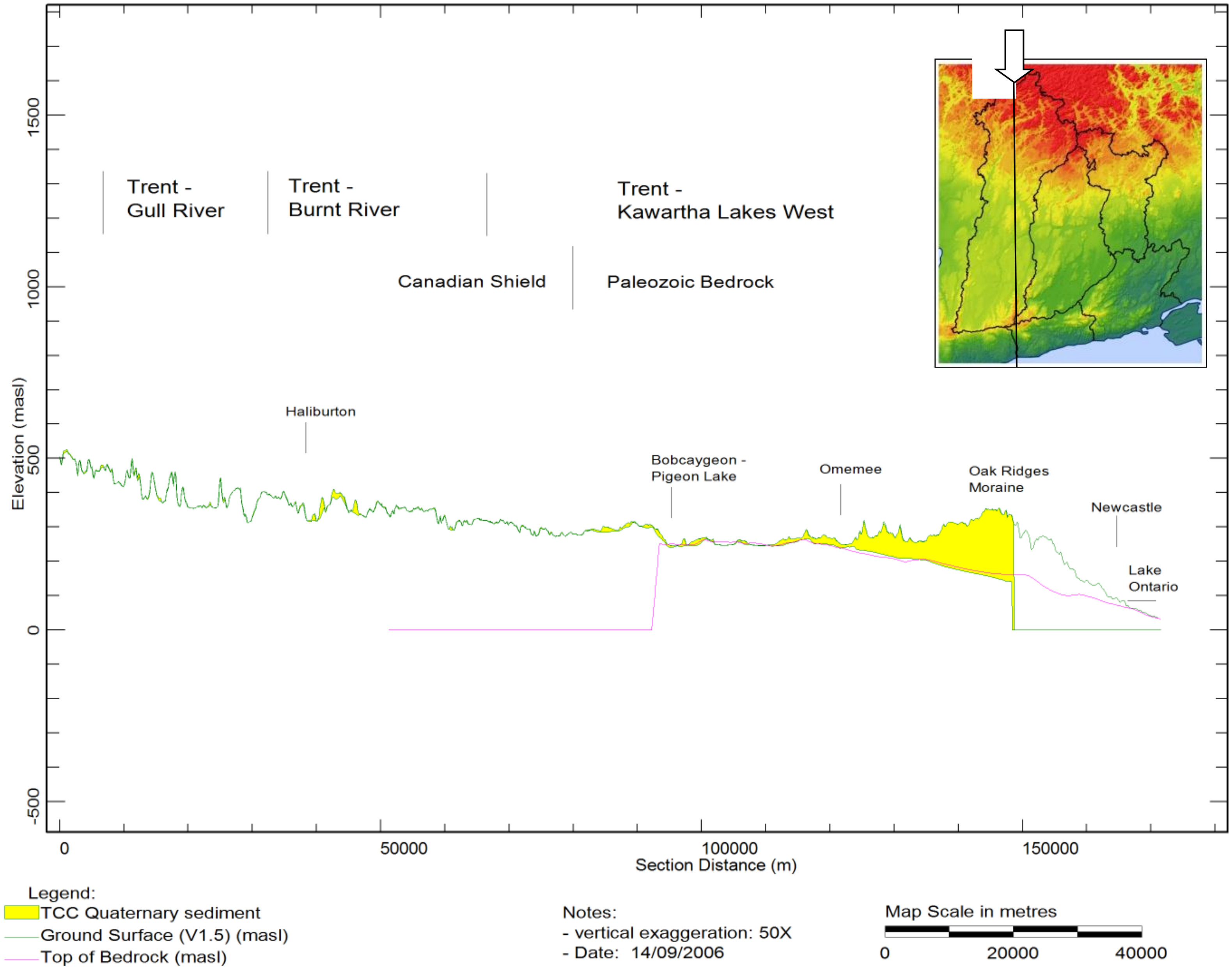


Figure 3.2-7: Cross-section of Trent River Watershed

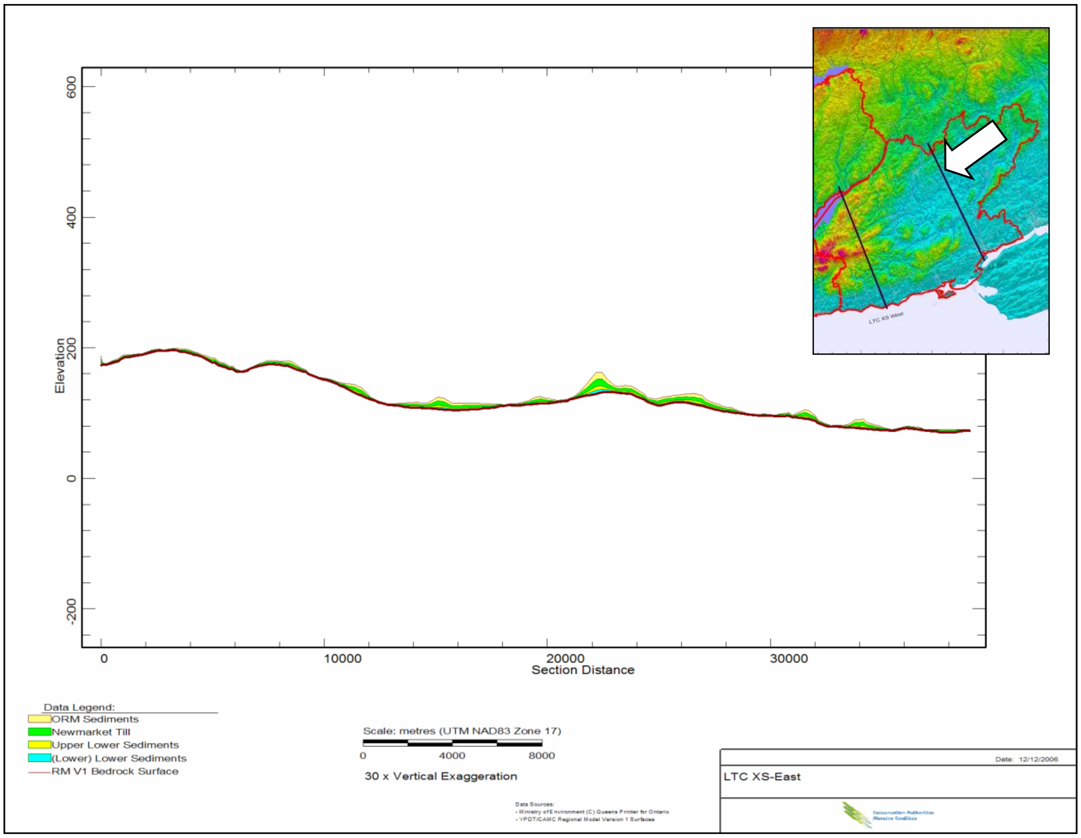


Figure 3.2-8: Cross-section (east) of Lower Trent Source Protection Area

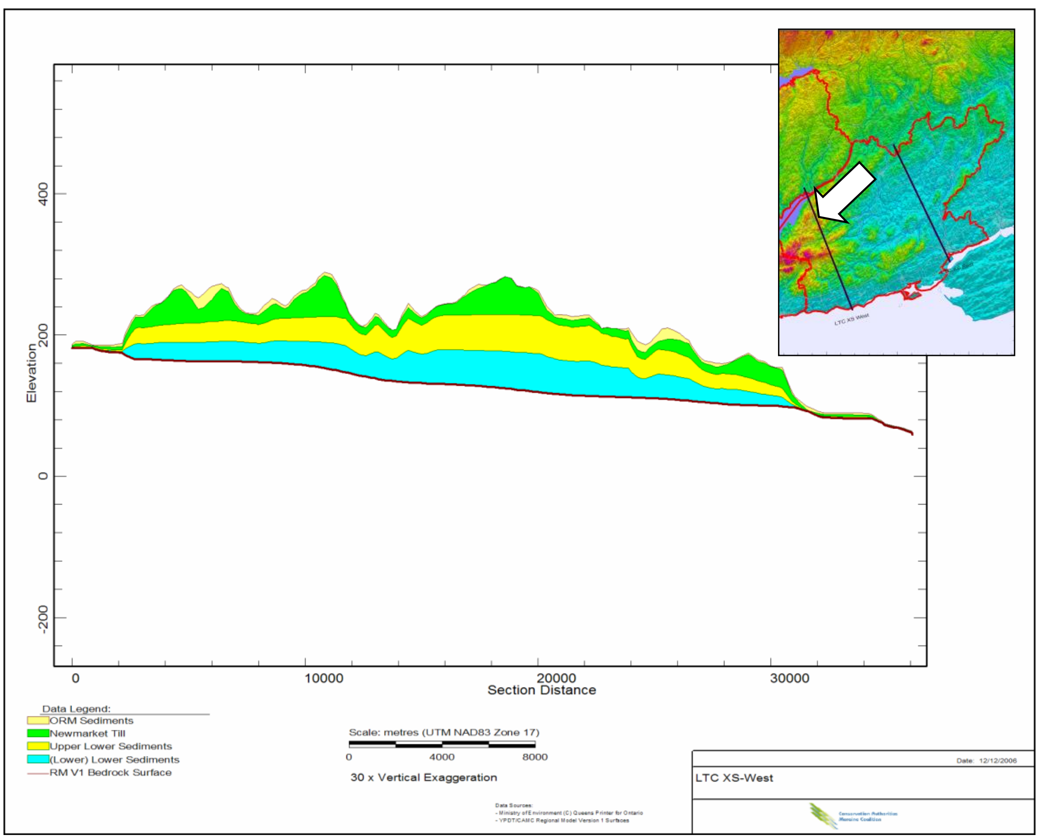


Figure 3.2-9: Cross-section (west) of Lower Trent Source Protection Area

3.2.3.2 SURFICIAL GEOLOGY

The surficial geology of the study area, classified by material type, is illustrated on Map 3-9. The map shows that common surficial materials in the study area include gravel, sand, silt, and clay. Clay is common across the south. In the north, bedrock is exposed in many areas. The surficial geology of the region can be attributed to glacial activity.

The Pleistocene Epoch (approximately 2.5 million to 12,000 years ago) consisted of several glacial periods during which great ice sheets covered, retreated, and re-covered southern Ontario. At its peak, the ice thickness exceeded two kilometres in some areas. The most recent ice advance (known as the Wisconsinan glaciation) more or less obliterated evidence of previous glacial periods, so the surficial geology of the study area is largely a result of the Wisconsinan glaciation. It was both the advance and withdrawal of the ice sheet that shaped the landform we see today. The tremendous forces of the ice scraped and pulverized the underlying material as it advanced, and huge volumes of meltwater deposited unconsolidated materials as the glacier retreated.

As the ice advanced, it picked up boulders, gravel, sand, and clay. It scraped the bedrock and reshaped valleys. In the northern portion of the watershed (the Precambrian area), surficial materials have been scraped away by glacial activity and the area is now characterized by barren rock knobs, ridges, and shallow soil cover. Valleys in this area are floored with outwash sand and gravel deposits, and swamps and bogs frequently occupy these depressions.

As the ice advanced in the south, sheets of heterogenous material were laid down directly by the ice. In some areas, it was moulded to form drumlins. As the glaciers withdrew, the huge volumes of meltwater shaped the landscape further. This formed glacial features such as eskers and moraines, and glacial meltwater created and modified valleys. Sorted deposits of clays, silts, and fine sands were laid down as beach deposits in the area of the former Lake Iroquois shoreline.

The thickness of the overburden (the material above the bedrock) varies greatly across the study area. It is illustrated on Map 3-10 and was determined by calculating the difference between surface topography (Map 3-11) and bedrock topography (Map 3-12). Much of the Precambrian area has exposed bedrock at the surface and thus very little or no overburden, but there are some exceptions in bedrock valleys and in isolated pockets. For example, there are thick overburden deposits (about 130 m deep) in the area north of Minden. The overburden in the Paleozoic area is generally much thicker than in the Precambrian area, reaching its maximum depth near the community of Pontypool (about 237 m). These thick overburden deposits are visible at many locations in the Paleozoic area (e.g., the landforms of the Oak Ridges Moraine and Peterborough Drumlin Field).

3.2.4 PHYSIOGRAPHY

Physiography is the study of the origin and distribution of the various landforms on the Earth’s surface. In the Precambrian area, the knob and basin topography of the Precambrian rocks of the Canadian Shield is evident at the surface, and overburden deposits are thin and discontinuous. In the Paleozoic area, landforms in the overburden were formed by glacial deposits, glacial meltwater, and glacial ice and include numerous drumlins, occasional kame mounds, esker ridges, and sand plains (Singer et al., 2003).

Chapman and Putnam (1984) described the physiography of southern Ontario and divided it into a number of physiographic regions. The following sections summarize the Chapman and Putnam (1984) descriptions of the nine major physiographic units present in the study area (listed as they appear from north to south). Physiographic regions in the study area are illustrated on Map 3-13.

Algonquin Highlands

The Algonquin Highlands area is found in the northern portion of the Trent River watershed. The region is underlain by granite and other Precambrian rocks. The physiographic region is broadly dome-shaped and slopes from 275 m in the west to 180 m in the east. Locally, these rough, rounded knobs and ridges are from 15 to 60 m in height. There are frequent outcrops of bare rock across this area.

Georgian Bay Fringe

The Georgian Bay Fringe is a broad belt that borders Georgian Bay and extends eastward across Haliburton and Peterborough Counties, north of the Kawartha Lakes, and into the Crowe Valley Source Protection Area. This physiographic unit is characterized by bare rock knobs, ridges, scanty drift covering, and shallow soil. This rocky, forested, and hilly region is the source of the Gull, Burnt, and Mississaugua Rivers and Nogies, Eels, and Jack Creeks. These run in a general southwest direction toward the Kawartha Lakes, which serve as reservoirs for the Trent River system.

Carden Plain

The Carden Plain is a limestone plain overlain by shallow overburden that occupies the area surrounding Balsam Lake. The overburden is mostly till material that is composed of sandy and silty materials in the south and coarse material with boulders and sandy materials in the north. There are also several limestone bedrock outcrops across the area. The plain, formed by proglacial Lake Algonquin, has lacustrine features such as beaches and sand deposits scattered throughout. The area is covered by grassland, shrub land, and alvar (a biological environment based on a limestone plain with thin or no soil). More than 70% of the occupied land is covered by rough pasture.

Dummer Moraine

The Dummer Moraine is an area of rough, stony land that borders the Canadian Shield from the Kawartha Lakes eastward to Kingston. The area is characterized by till moraines that are made up of angular fragments and blocks of limestone combined with many Precambrian rock fragments. The surface is extremely rough even though most of the morainic ridges are quite low. Among the moraines are areas of shallow drift that consist of sand and gravel or bare limestone.

Peterborough Drumlin Field

The Peterborough Drumlin Field occupies the area immediately north of the Oak Ridges Moraine and stretches from Lake Simcoe to Trenton. About three thousand drumlins occur in the area at an average density of two to three drumlins per square kilometre. The drumlins are typically elongated, low-lying hills less than 1.5 km in length, 400 m or less in width, and 25 m in height (Gillespie and Acton, 1981). The general orientation of the drumlins in the Peterborough Drumlin Field is from northeast to southwest (Singer et al., 2003). The drumlins are composed of highly calcareous glacial till that consists of sand and gravel. The area between the individual drumlins typically consists of clay flats with intervening swampy areas.

Schomberg Clay Plains

The Schomberg Clay Plains occupies the area surrounding Lake Scugog. This physiographic region consists of stratified clay and silt deposits and a few drumlins on top of a flat till plain.

Oak Ridges Moraine

The Oak Ridges Moraine is a kame moraine that extends from the Niagara Escarpment to the Trent River. It covers small southern portions of the Kawartha-Haliburton and Otonabee-Peterborough Source Protection Areas and extends into the Ganaraska Region and Lower Trent Source Protection Areas south of Rice Lake. It is one of the most distinctive physiographic regions of southern Ontario, and it is about 160 km long, ranges from 5 to 20 km wide, and reaches an elevation of up to about 400 m. The moraine is oriented in an approximately east-west direction. The surface of the moraine has hilly or hummocky relief. Much of the moraine is till, but its crest is covered with sand hills and coarse outwash. In some areas, mainly along its southern flank, the moraine is partly capped by thin Halton Till.

South Slope

The South Slope physiographic region is a gently sloping strip of land between the low-lying Iroquois Plain and the Oak Ridges Moraine. The surficial soil of the South Slope is composed predominantly of 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. Two regional till deposits have been identified in the South Slope: Halton Till, which is a sheet of silt till deposited by the last major glacial advance in the area, and Newmarket Till (also known as the Northern Till), which is a deposit of sandy silt till, interpreted to extend below the Oak Ridges Moraine, that is stratigraphically older than the Halton Till. The Newmarket Till is believed to be correlative with till deposits north of the Oak Ridges Moraine.

The northwestern portion of the South Slope region is drumlinized, but the drumlins are scattered, long and thin, and point directly toward the slope of the Oak Ridges Moraine. Streams flow directly and rapidly down the South Slope and erode sharp valleys into the tills. Numerous gullies have also been cut by intermittent drainage so that east-west side roads cross a succession of valleys.

Iroquois Plain

The Iroquois Plain physiographic region is a plain of glaciolacustrine deposits situated south of the former Glacial Lake Iroquois shoreline. It exists between modern-day Lake Ontario and the South Slope region. In the shoreline area of the former Glacial Lake Iroquois, sand and gravel were deposited in beaches, bars, and spits due to wave action. The deposits grade into massive and laminated silts and clays to the south that define the lower lake plain area. In some areas of the southern Trent River watershed, the abandoned Lake Iroquois shoreline is well defined by cliffs and beach material, and in certain areas its position can be inferred from the presence of lacustrine materials and altitude.

3.2.5 SOILS

Soils can be classified into hydrologic soil groups based on their runoff or infiltration potential under similar storm and cover conditions. Soils are commonly classified into four hydrologic soil groups: A, B, C, and D (Soil Conservation Service, 1986), described in Table 3.2-5. Hydrologic soil groups in the study area are illustrated on Map 3-14.

Soils with a high infiltration rate (soil group A) are most common in the southern portion of the Trent River watershed, especially on the Oak Ridges Moraine. The deep soils of the moraine have high rates of infiltration and water transmission. Soils with a moderate infiltration rate (soil group B) occur throughout most of the central and southern parts of the watershed. Small pockets of soil group C and D occur throughout the area, the largest areas being around Lindsay and east of Trenton. These soils contain clay and have low infiltration capacity. The Burnt and Gull subwatersheds and the east half of the Crowe Valley subwatershed have not been classified by soil group. These areas have very little overburden, and soil cover is often shallow with only a few pockets of deeper soils.

Table 3.2-5: 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

3.2.6 LAND COVER

Land cover is the composition and characteristics of land surface elements and results from a complex mixture of natural and anthropogenic influences (Cihlar, 2000). The Ministry of Natural Resources and Forestry, through its Provincial Land Cover Program, has separated Ontario land cover data into different types (including various types of forest and wetlands, cropland, pasture and abandoned lands, bedrock quarries, water, and settlement areas). Land cover types in the study area are illustrated on Map 3-15. The distribution of land cover types in the study area and the effects of each type of land cover on groundwater and surface water are identified in Table 3.2-6.

Table 3.2-6: Land Cover in the Trent River Watershed

Land Cover Type	Area		Level of Cover	Effects on Groundwater and Surface Water
	km²	% Total		
Woodland[1]	6695	48.54	High	Shielding snow from early melting Significant storage of snow High infiltration Low runoff High evapotranspiration
Row Crops[1]	2581	18.71	Minimal	Erosion/Re-deposition of snow Sublimation of snow Moderate infiltration/runoff Evapotranspiration
Hay / Pasture[1]	1633	11.84	Moderate	Erosion/Re-deposition of snow Sublimation of snow Moderate infiltration/runoff Evapotranspiration
Water	1196	8.67	Impervious	Storage Evaporation
Wetland	1154	8.37	Moderate	Significant storage Infiltration Moderate evapotranspiration Can act as either recharge or discharge area
Roads[2]	213	1.54	Minimal	Minimal infiltration High runoff Minimal evapotranspiration
High Intensity Developed	179	1.3	Minimal	Minimal infiltration High runoff Minimal evapotranspiration
Quarries	76	0.55	Minimal	High infiltration
Low Intensity Developed	59	0.43	Minimal	Moderate infiltration High runoff Moderate evapotranspiration
Transitional	6	0.05	Moderate	Erosion/Re-deposition of snow Sublimation of snow Moderate infiltration/runoff Evapotranspiration

[1]Fence lines and tree lines in these areas store significant amounts of snow
[2]Road ditches store significant amounts of snow

3.2.7 SURFACE WATER

Surface water refers to water on the ground surface and includes lakes, rivers, and wetlands. The following sections describe the surface waterbodies, control structures, hydrology, and aquatic habitat in the study area.

3.2.7.1 WATERBODIES AND WATERCOURSES

Trent River Watershed

The headwaters of the Trent River consist of many lakes, rivers, and creeks that rise on the Canadian Shield and flow southwest toward the Kawartha Lakes. This includes 218 lakes in the Haliburton Highland area. The largest tributaries that drain into the Kawartha Lakes from the Canadian Shield are the Gull, Burnt, and Mississauga Rivers. The Gull and Burnt Rivers originate in Haliburton County and the northern portions of the City of Kawartha Lakes and Peterborough County, and they drain into Balsam and Cameron Lakes, respectively, from the north. Eels, Jack, and Nogies Creeks are also significant headwaters of the Trent River. The flows between surface waterbodies and the configuration of water control structures and flow gauging stations in the Gull and Burnt River subwatersheds are illustrated schematically in Figure 3.2-10 and Figure 3.2-11. These figures also summarize the drainage area and surface area of lakes in these subwatersheds.

There are also several rivers that drain the generally lower-lying area of limestone and glacial drift to the south of the Kawartha Lakes. Two of these, the Scugog and Pigeon Rivers, flow northward into the Kawartha Lakes. A number of smaller rivers such as Jackson Creek (that flows through the City of Peterborough) flow into the Otonabee River between Lakefield and Rice Lake, while most of the remaining lowland area east of Peterborough is drained by the Indian and Ouse Rivers that flow directly into Rice Lake.

The Kawartha Lakes include Balsam, Cameron, Sturgeon, Pigeon, Buckhorn, Lower Buckhorn, Lovesick, Chemong, Katchewanooka, and Stony Lakes. These lakes lie along the juncture of the Paleozoic rocks and the Precambrian rocks of the Canadian Shield. The Kawartha Lakes drain to Rice Lake mainly through the Otonabee River and minimally through the Indian River. The Trent River issues from Rice Lake and flows northeast and then east before it is joined by the Crowe River at the Crowe Bridge Conservation Area. The Trent River then flows south, east, and south again until it joins the Bay of Quinte at Trenton.

The flows between surface waterbodies and the configuration of water control structures and flow gauging stations in the Trent River watershed are illustrated schematically in Figure 3.2-12. The figure also summarizes the drainage area and surface area of lakes in the watershed. Waterbodies and watercourses in the watershed and the flows between them are illustrated on Map 3-16.

Lake Ontario & Bay of Quinte Tributaries

The streams in the Lake Ontario and Bay of Quinte tributaries subwatersheds can be divided into the following three broad groups:

1. Lake Ontario tributaries with headwaters in the Oak Ridges Moraine
2. Lake Ontario tributaries with headwaters in the South Slope or Iroquois Plain
3. Clay plain tributaries (that drain into the Bay of Quinte).

The physical characteristics of the streams in the area are listed in Table 3.2-7.

Table 3.2-7: Physical characteristics of creeks in the Lake Ontario and Bay of Quinte tributaries subwatersheds

Subwatershed	Streams	Drainage Area (km^2)	Main Channel Length (km)	Total Fall (m)	Slope (%)
Bay of Quinte Tributaries	York Creek	7.8	7.2	34.6	0.48
	Dead Creek	11.5	6	6.6	0.11
	DND Creek	7	8	40.0	0.5
	Meyers Creek	26.1	14.4	96.5	0.67
	Massey Creek	19.2	9.94	53.7	0.54
Lake Ontario Tributaries (Headwaters in Oak Ridges Moraine)	Barnum House Creek	21.1	11	194.7	1.77
	Shelter Valley Creek	69	20	220.0	1.1
Lake Ontario Tributaries (Headwaters in South Slope or Iroquois Plain)	Lakeport/Colborne Creek	44	8	96.0	1.2
	Salem Creek	7.92	5.94	104.5	1.76
	Butler Creek	24	11	136.4	1.24
	Smithfield Creek	18	11	103.4	0.94

3.2.7.2 CONTROL STRUCTURES

Water levels in the Trent River watershed are heavily regulated. There are approximately 213 control structures in the watershed, and over 125 of them are associated with the Trent-Severn Waterway (a system of rivers, lakes, canals, locks, and control structures that forms a navigable route through the adjacent Trent and Severn watersheds). Many of the major watercourses in the Trent River watershed form the navigation channel of the waterway, and there are about 44 dammed reservoir lakes located on tributaries of the Gull, Burnt, and Mississauga Rivers and the Nogies, Eels, and Jack Creeks that are used to help regulate water levels. Water control structures and channel diversions in the Trent River watershed are illustrated on Map 3-17. The majority of streams in the Lake Ontario & Bay of Quinte tributaries subwatersheds are unregulated.

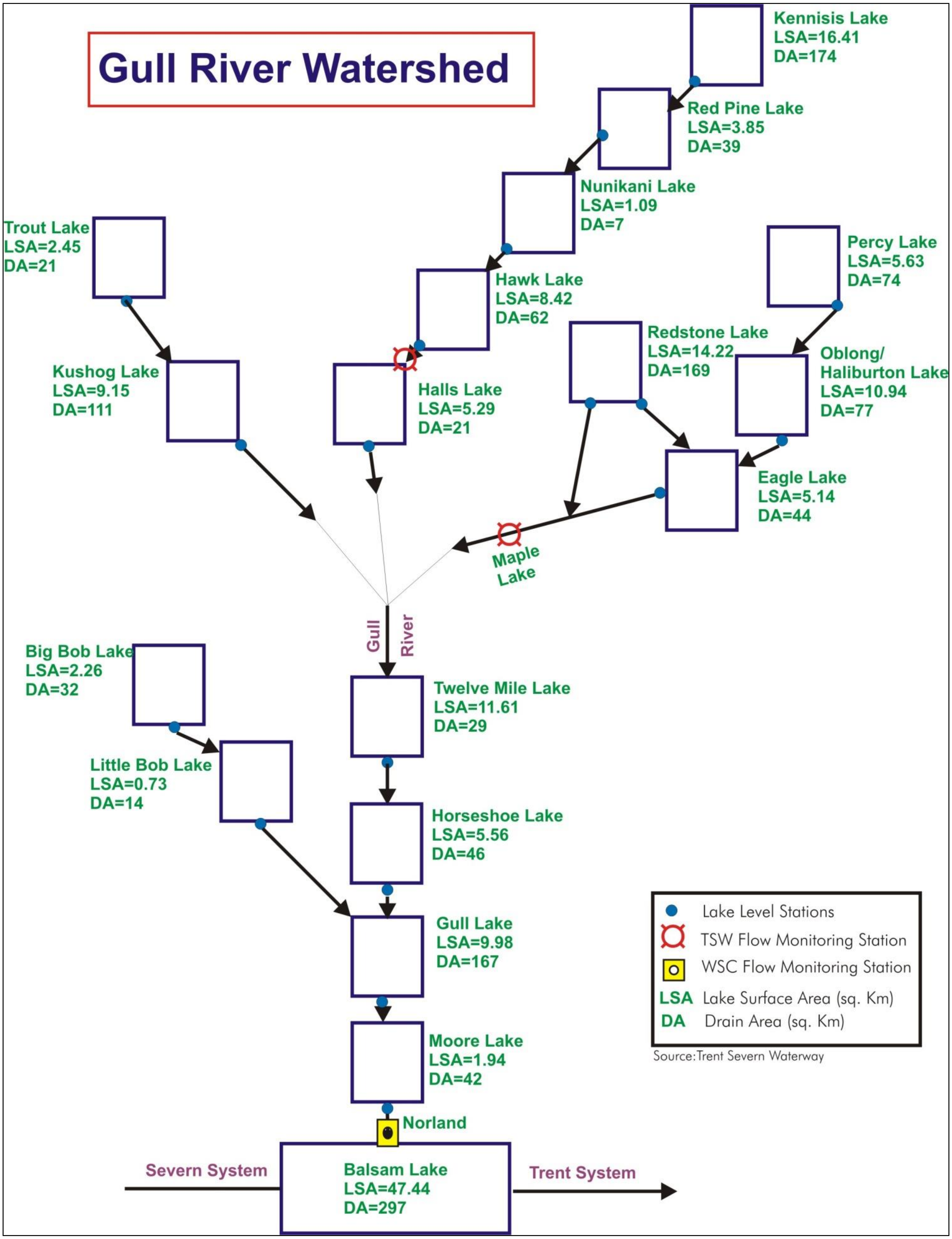


Figure 3.2-10: Flows between surface waterbodies and configuration of water control structures and flow gauging stations in the Gull River subwatershed (only controlled surface waterbodies are shown)

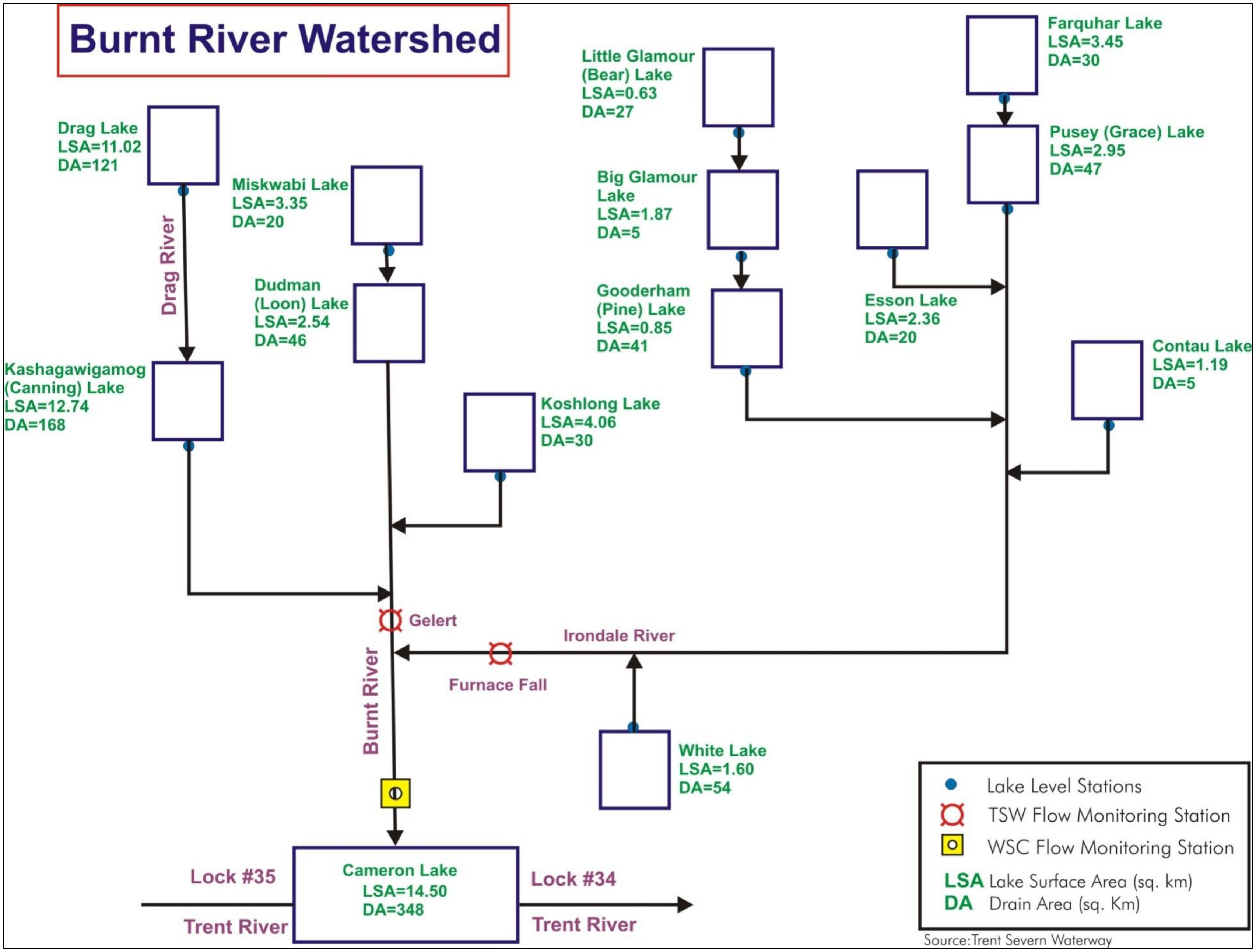


Figure 3.2-11: Flows between surface waterbodies and configuration of water control structures and flow gauging stations in the Burnt River subwatershed (only controlled surface waterbodies are shown)

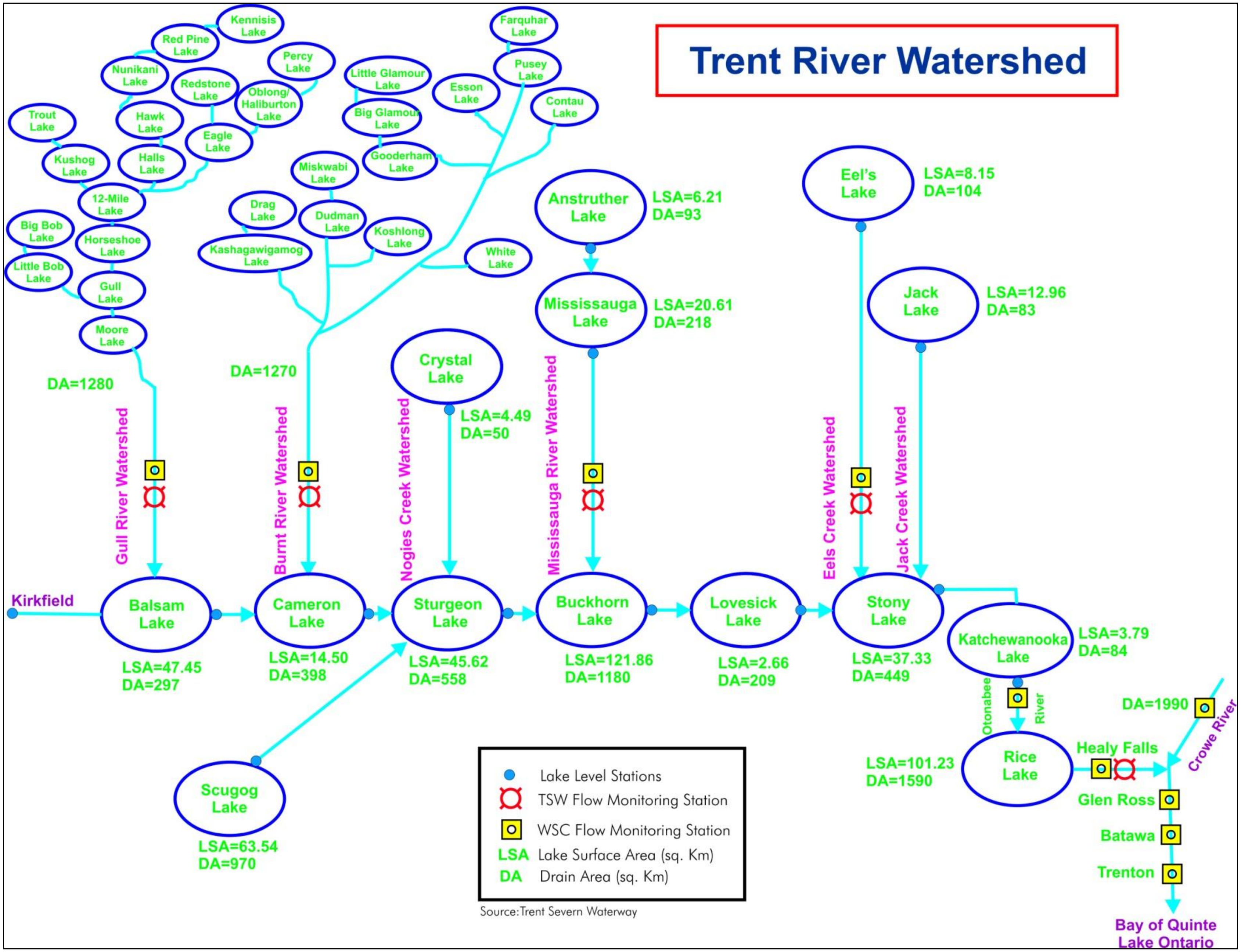


Figure 3.2-12: Flows between surface waterbodies and configuration of water control structures and flow gauging stations in the Trent River watershed (only controlled surface waterbodies are shown)

Table 3.2-8: Lake Level Gauges Operated by the Trent-Severn Waterway

Watershed	Lakes	Surface Area (km²)	Drainage Area* (km²)	Years on Record**
Gull River	Kennsis	16.41	174	1988-present
	Red Pine	3.85	40	1988-present
	Crab	1.09	7	1988-present
	Hawk	8.42	62	1988-present
	Halls	5.29	22	1988-present
	Sherborne	2.45	22	1988-present
	Kushog	9.15	111	1988-present
	Percy	5.63	74	1988-present (except 1996)
	Haliburton	10.94	77	1988-present
	Redstone	14.22	169	1988-present
	Eagle	5.15	44	1988-present
	Twelve Mile	11.61	29	1984-present
	Horseshoe	5.56	46	1984-present
	Big Bob	2.26	32	1988-present
	Little Bob	0.73	14	1988-present
	Gull	9.98	167	1988-present
	Moore	1.94	42	1988-present (except 1991 & 1997)
Burnt River	Drag	11.02	121	1988-present (except 1989)
	Canning	12.74	168	1988-present
	Miskwabi	3.35	20	1988-present
	Dudman	2.54	46	1988-present
	Koshlong	4.06	30	1988-present (except 1989)
	Farquhar	3.45	30	1988-present (except 1989)
	Grace	2.95	47	1988-present
	Esson	2.36	20	1988-present
	Little Glamour	0.63	27	1988-present
	Big Glamour	1.87	5	1988-present
	Gooderham	0.85	41	1988-present
	Contau	1.19	5	1988-present
	White	1.60	54	1988-present
Nogies Creek	Crystal	4.49	50	1988-present
Mississauga	Anstruther	6.21	93	
	Mississauga	20.61	218	1988-present
Eel's Creek	Eel's	8.15	104	1988-present (except 1996)
Jack Creek	Jack	12.96	83	1988-present
Kawartha Lakes	Balsam	47.45	297	1984-present
	Cameron	14.50	398	1984-present
	Scugog	63.54	970	1988-present
	Sturgeon	45.62	558	1973-present
	Buckhorn	121.86	1180	1984-present
	Lower Buckhorn	12.51	252	1989-present (except 1997)
	Lovesick	2.66	209	1989-present
	Stony	37.33	449	1973-present
	Katchewanooka	3.79	84	1988-present (except 1997)
	Rice Lake	101.23	1590	1986-present

Source: Trent-Severn Waterway
*Drainage area between the gauge stations
**Trent-Severn Waterway data (additional hardcopy data is available from the TSW)

Table 3.2-9: Water Survey of Canada Hydrometric Stations in the Trent River Watershed

River	Station ID	Geologic Area	Drainage Area (km^2)	Years on Record**
Trent River Watershed				
Gull River at Norland	02HF002	Precambrian	1,280	1962-04
Burnt River near Burnt River	02HF003	Precambrian	1,270	1962-04
Bob Creek near Minden	02HF004	Precambrian	22	1975-92
Mississauga River below Mississauga Lake	02HH002	Precambrian	326	1972-93
Nonquon River near Port Perry	02HG002	Paleozoic	33	1993-03
Mariposa Brook near Little Britain	02HG001	Paleozoic	189	1982-03
Eel's Creek below Apsley	02HH001	Precambrian	241	1967-93
Otonabee River at Lakefield	02HJ002	Precambrian /Paleozoic	7,360	1962-63; 1965-85; 1992-02*
Jackson Creek at Peterborough	02HJ001	Paleozoic	110	1962-03
Ouse River near Westwood	02HJ003	Paleozoic	282	1967-04
Crowe River near Glen Alda	02HK005	Precambrian	456	1968-98
Crowe River at Marmora	02HK003	Precambrian	1,990	1959-03
Beaver Creek near Marmora	02HK006	Precambrian	541	1973-04
Burnley Creek above Warkworth	02HK009	Paleozoic	82	1983-04
Rawdon Creek near West Huntingdon	02HK008	Paleozoic	87	1982-04
Cold Creek at Orland	02HK007	Paleozoic	159	1981-04
Mayhew Creek near Trenton	02HK011	Paleozoic	33	1993-04
Trent River at Healey Falls	02HK002	Paleozoic	9,090	1949-03
Trent River at Healey Falls (Power Plant)	02HK802	Paleozoic		1995-03
Trent River at Healey Falls (Spillway)	02HK902	Paleozoic		1993-03
Trent River at Glen Ross	02HK004	Paleozoic	12,000	1963-95
Trent River at Glen Ross	02HK012	Paleozoic	12,000	1995-95
Trent River near Batawa	02HK014	Paleozoic	12,333	1995-97
Trent River at Trenton	02HK010	Paleozoic	12,400	1999-02
Lake Ontario & Bay of Quinte Tributaries				
Shelter Valley Creek	02HD010	Paleozoic	65	1995-2004
Butler Creek	02HD018	Paleozoic		2002-2004

*Partial record

3.2.7.3 HYDROLOGY

The hydrological regime of the study area is highly variable from year to year. Although the basic seasonal pattern is repeated every year, the detailed pattern is determined by weather conditions. The magnitude of the spring runoff peak, for example, depends on both the amount of snow accumulation over the previous winter and the weather conditions during the snowmelt period itself. Also, in some years, the snow melts relatively slowly and steadily and causes no flooding problems in the system. In other years, the melt may be very rapid and may also be accompanied by heavy rain; under these circumstances severe flooding is much more likely.

Another factor that is important in influencing the spring runoff is the extent of frozen ground in the watersheds. Frozen soil, especially if it had high moisture content at the time of freezing, has a much lower infiltration capacity than unfrozen soil, and it sheds a greater proportion of meltwater as surface runoff. The extent of frozen ground in the spring is determined mainly by conditions early in the previous winter, particularly whether or not the ground was covered by an insulating snow cover before persistent sub-freezing temperatures occurred.

3.2.7.3.1 Sources of Hydrometric Data

Hydrometric stations in the study area are maintained by the Water Survey of Canada, the Trent-Severn Waterway, and local Conservation Authorities. Sources of hydrometric data in the study area are discussed in the following subsections. The locations of hydrometric stations are shown on Map 3-18.

Trent-Severn Waterway

The Trent-Severn Waterway operates and maintains about 46 level gauging stations in the study area from which daily, monthly, mean, and maximum and minimum stream and lake level data are available from 1988 to the present. They also operate and maintain flow gauging stations for the Gull, Burnt, Irondale, Otonabee, and Trent Rivers. Monitoring of the Mississauga River and Eels Creek was carried out until 1993 (records are available past this time, but they are not at Water Survey of Canada standards). Lakes equipped with level gauging stations, their surface area, drainage area, and their years on record are listed in Table 3.2-8 (the location of these stations is illustrated schematically in Figure 3.2-10, Figure 3.2-11, and Figure 3.2-12.

Water Survey of Canada

The Water Survey of Canada monitors the flow of several rivers and creeks in the study area. The data include daily, monthly, mean, maximum, and minimum flows and levels (sediment data is also available at some sites). The data also contain descriptive information and geographical coordinates of all hydrometric stations and indicate the period of operation and type of each station. The data are made available through the HYDAT database. Rivers and creeks in the study area equipped with hydrometric stations and their drainage area, bedrock geology, and period of hydrometric record are listed in Table 3.2-9.

Other Stream Measurements

A number of smaller streams in the watershed have been gauged at various times by the Ministry of the Environment and Climate Change. Further, the five Conservation Authorities in the source protection region also monitor dry weather flows on a number of local streams for low flow assessment purposes.

3.2.7.3.2 Average Streamflow

Flow per unit area is the ratio between the average streamflow in a watershed to its area. Flow per unit area depends on factors such as topography, physiography, geology, climate, soil, and land cover. These factors being equal, higher than average flow per unit area in a watershed suggests that it is gaining water from adjacent watersheds. Conversely, lower flow per unit area suggests that the watershed may be losing water to adjacent watersheds. Smaller watersheds tend to produce higher peak flows per unit area than large ones because they tend to have less natural and artificial storage capacity.

Average streamflow was calculated for most subwatersheds from real-time streamflow data collected at the hydrometric stations selected as subwatershed outlets. However, the Buckhorn Lake (Lock #31) station (the outlet for the Kawartha Lakes West subwatershed) only records real-time lake level data (not flow); average annual streamflow at this station was calculated using lake level and control gate setting data in conjunction with a rating curve developed by the Trent-Severn Waterway. Further, since there are no hydrometric stations in the Bay of Quinte tributaries subwatershed, average annual flow for this subwatershed was estimated using Ontario Flow Assessment Techniques software, which was developed to automatically estimate flow information for watersheds in Ontario (it is not as reliable as stream gauge data, but provides a reasonable estimate of streamflow based on historical flow data and related isolines). Average streamflow in the study area is shown on Map 3-19.

The U.S. Geological Survey in cooperation with Environment Canada (National Water Research Institute) calculated streamflow statistics for Ontario and the Great Lakes States in 2005. A summary of statistics generated for the gauged streams in the study area watershed is presented in Table 3.2-11.

Flows at ungauged creeks in the Lake Ontario and Bay of Quinte subwatersheds were estimated by transposing the data from the gauged creeks (on a flow per unit area basis) to the ungauged creeks located in areas with similar hydrological conditions. For example, the data from the Shelter Valley Creek gauge station was used to provide an estimate for Barnum House Creek (both streams have their headwaters in the Oak Ridges Moraine). The flow per unit area for creeks in the Lake Ontario and Bay of Quinte tributaries subwatersheds is listed in Table 3.2-10.

Table 3.2-10: Mean Annual Flow of Creeks in the Lake Ontario and Bay of Quinte Tributaries Subwatersheds

Creek	Watershed	Period	Drainage	Mean Annual Discharge	
			Area (km^2)	m^3/s	$l/s/km^2$
Shelter Valley Creek	Lake Ontario	1995-04	69.0	0.88	12.75
Barnum House Creek	Lake Ontario	-	21.10	0.27	12.75
Butler Creek	Lake Ontario	2002-04	24.00	0.25	10.52
Lakeport-Colborne Cr.	Lake Ontario	-	44.00	0.46	10.52
Grafton Creek	Lake Ontario	-	8.70	0.09	10.52
Salem Creek	Lake Ontario	-	7.92	0.08	10.52
Smithfield Creek	Lake Ontario	-	18.00	0.19	10.52
DND Creek	Bay of Quinte	OFAT	7.00	0.10	13.92
Dead Creek	Bay of Quinte	-	11.50	0.16	13.92
Meyers Creek	Bay of Quinte	-	26.10	0.36	13.92
Massey Creek	Bay of Quinte	-	19.20	0.27	13.92
York Creek	Bay of Quinte	-	7.80	0.11	13.92

Table 3.2-11: Selected Streamflow Statistics from U.S. Geological Survey and Environment Canada National Water Research Institute

Stream	Drainage Area (km^2)	No. Daily Flow Data Points	Flow (m^3/s)				Percentile Flow Exceedance				
			Extreme Max Daily	Mean	Extreme Min Daily	Standard Deviation	5%	25%	50%	75%	95%
Gull River At Norland	1280	14171	80.00	19.55	1.37	10.270	40.970	23.430	17.200	12.660	7.704
Burnt River near Burnt River	1270	14008	200.00	18.31	0.69	18.740	56.090	21.500	11.690	7.598	4.810
Bob Creek near Minden	22	6157	7.31	0.23	0.00	0.471	0.954	0.226	0.084	0.014	0.000
Mariposa Brook near Little Britain	189	6690	50.00	1.78	0.00	2.983	7.295	1.975	0.762	0.252	0.054
Nonquon River near Port Perry	33	2922	5.00	0.28	0.01	0.403	0.981	0.280	0.151	0.093	0.044
Eel's Creek below Apsley	241	9418	50.00	3.60	0.25	3.646	11.000	4.090	2.436	1.567	0.824
Mississauga River below Mississauga Lake	326	7838	30.00	4.38	0.18	3.747	10.810	5.382	3.465	2.125	0.896
Jackson Creek at Peterborough	110	14102	30.00	1.09	0.00	1.988	4.296	1.120	0.467	0.195	0.053
Otonabee River at Lakefield	7360	10923	400.00	84.58	9.20	65.690	227.900	112.700	65.530	35.030	19.710
Ouse River near Westwood	282	9883	60.00	2.94	0.01	4.443	11.880	3.349	1.381	0.570	0.160
Trent River at Healey Falls	9090	18720	600.00	94.54	3.11	78.170	266.700	128.200	73.110	35.760	17.230
Crowe River at Marmora	1990	15068	200.00	23.58	0.10	27.530	83.670	30.770	14.700	4.858	1.229
Trent River at Glen Ross	12000	11571	700.00	143.20	4.80	119.400	408.800	195.100	111.600	50.760	22.160
Crowe River near Glen Alda	456	10957	70.00	6.51	0.10	7.584	22.440	7.619	3.916	2.299	0.534
Beaver Creek near Marmora	541	8951	90.00	7.39	0.00	9.344	27.870	9.761	4.205	1.252	0.158
Cold Creek at Orland	159	7039	30.00	2.01	0.47	1.988	5.083	2.168	1.462	1.023	0.680
Rawdon Creek near West Huntingdon	87	4766	10.00	1.13	0.01	1.248	3.682	1.479	0.723	0.310	0.081
Burnley Creek above Warkworth	82	5410	20.00	0.85	0.11	1.050	2.432	0.911	0.563	0.367	0.212
Trent River at Trenton (AFFRA)	12400	677	500.00	120.20	19.60	83.900	273.000	165.500	99.830	53.780	29.610
Mayhew Creek near Trenton	33	2922	7.96	0.40	0.01	0.564	1.335	0.447	0.243	0.105	0.030
Trent River at Glen Ross (AFFRA)	12000	345	500.00	146.40	14.10	125.500	402.600	213.700	109.700	40.430	19.310
Trent River near Batawa (AFFRA)	12333	643	500.00	166.70	17.20	114.700	391.900	229.100	142.700	66.830	31.060
Trent River at Healey Falls (Power Plant)	9090	2192	90.00	52.75	3.00	21.480	75.590	69.860	63.640	33.530	13.530
Trent River at Healey Falls (Spillway)	9090	2922	300.00	44.67	0.00	63.830	204.100	68.540	11.530	1.418	0.524
Shelter Valley Creek near Grafton	65	12931	43.9	0.81	0.13	0.976	2.061	0.849	0.568	0.430	0.308

3.2.7.3.3 Hydrographs

To provide a general understanding of water availability, damming effects, watershed response, and flow distribution under various streamflow conditions, hydrographs were developed for the subwatersheds in the study area. Hydrographs were plotted using long-term monthly averages.

Trent River Watershed

Hydrographs for four of the Trent River subwatersheds are shown in Figure 3.2-13. The hydrographs depict the same general pattern in all four subwatersheds but with some important differences that could be caused by a number of factors. In general, moderate flow conditions occur during the winter months; this occurs because precipitation is primarily in the form of snow that is stored on the surface until spring. The maximum flows occur in the spring and are due to snowmelt and increased rainfall. The lowest flows are observed during the summer months; this is caused by high evaporation and transpiration rates. The increasing flows through the fall are caused by decreasing evapotranspiration rates and increasing precipitation. The hydrographs are discussed in more detail below.

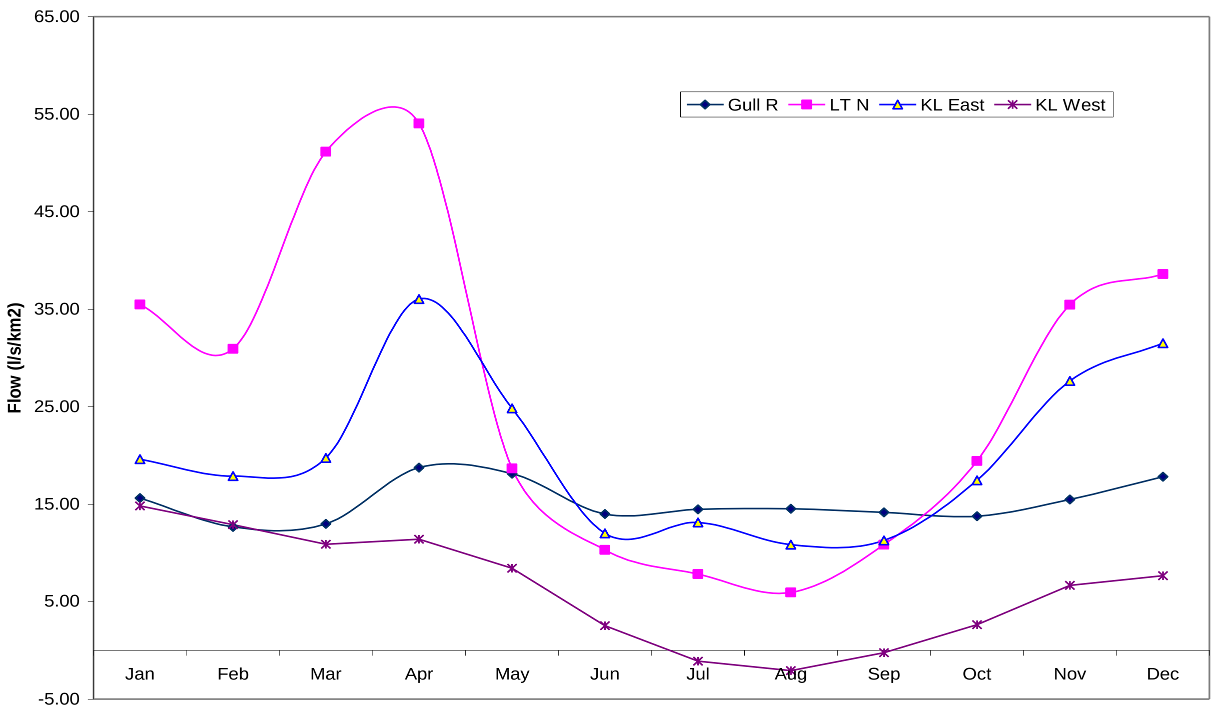


Figure 3.2-13: Hydrographs for Selected Trent River Subwatersheds

Gull River: The Gull River subwatershed is located in an area that has thin, sparse soil cover underlain by Precambrian bedrock with low permeability. As a result, infiltration is restricted and surface water runoff is dominant. Its hydrologic regime is not typical of watersheds in southern Ontario in the sense that its hydrograph shows little monthly and seasonal variation. This is most likely caused by the number of storage reservoirs located in the subwatershed associated with the Trent-Severn Waterway. Some of the spring runoff is deliberately held back in lakes and reservoirs and then released gradually over the summer months. This activity lowers the peak discharge and augments summer flows in the subwatershed. The same effect was also observed in previous studies (Schroeter & Associates, 2003).

Lower Trent North: The flow in the Lower Trent North subwatershed is the highest in the spring and the second lowest in the summer. There could be a number of reasons for this, such as its smaller catchment size (it has the smallest catchment size) and/or the small degree of anthropogenic control in this subwatershed. All other subwatersheds have several water control structures (dams), but the Lower Trent North subwatershed is relatively uncontrolled, so spring runoff is relatively rapid and summer flows are very low.

Kawartha Lakes West: The Kawartha Lakes West subwatershed, the largest subwatershed, typically has drought conditions from July to September. The main reasons for this drought condition are the wide and shallow structure of the Kawartha Lakes (and Scugog Lake) that promotes extremely high evaporation rates and the presence of Oak Ridges Moraine in the south of the subwatershed. The Moraine is an extensive area of groundwater recharge, but there is a groundwater divide north of the surface water divide in the vicinity of the Moraine that contributes to a loss of groundwater to the adjacent Central Lake Ontario and Ganaraska Region Source Protection Areas. The drought condition is alleviated by the release of water from the Burnt, Gull, and Mississauga Rivers and Nogies and Eel Creeks during the operation of the Trent-Severn Waterway.

The Kawartha Lakes West subwatershed shows a negative flow in late summer; this is because the mean annual inflow to this subwatershed is greater than the mean annual flow out, possibly due to excessive evapotranspiration (the shallow, wide Kawartha Lakes contribute to increased evaporation) and regional groundwater outflow through the Oak Ridges Moraine.

Overburden thickness in this subwatershed is much greater than in the Precambrian area, and as a result more infiltration of precipitation and groundwater storage occurs. Further, due to its larger catchment size, it produces lower flows per unit area and lower peaks in spring and winter than the rest of the subwatersheds.

Kawartha Lakes East: The Kawartha Lakes East subwatershed has a hydrologic regime that is more typical of watersheds in southern Ontario. Its hydrograph shows high flows during spring runoff followed by a moderate decrease during the summer months. In the fall, flows pick up again and then decrease during the winter months when most of the precipitation is frozen in the snow pack.

Lake Ontario & Bay of Quinte Tributaries

Streamflow data in the Lake Ontario and Bay of Quinte tributaries subwatersheds are limited. Long-term streamflow data in the Lake Ontario tributaries subwatershed are only available for the Shelter Valley Creek gauge station, and limited flow data are available for the Butler (Proctor) Creek gauge station. No streamflow data are available for the Bay of Quinte tributaries subwatershed.

Shelter Valley Creek: Shelter Valley Creek has its headwaters in the Oak Ridges Moraine. The streamflow hydrograph for this station (for the time period 1966 to 2004) is shown in Figure 3.2-14. This hydrograph is considered representative of the other creeks in the Lake Ontario tributaries subwatershed that originate in the Moraine. The hydrograph shows a clear spring thaw when flows are the highest due to melting and precipitation in early spring (March to April). Flows are lowest in late summer (August) and then begin to slowly climb throughout the winter months. Flow per unit area is greater than in Precambrian (northern) subwatersheds.

Butler (Proctor) Creek: Butler (Proctor) Creek has its headwaters in the Iroquois Plain. A hydrograph comparing the flows in Shelter Valley Creek and Butler Creek in 2004 is shown in Figure 3.2-15. This hydrograph is considered representative of the other creeks in the Lake Ontario tributaries subwatershed that originate in the Iroquois Plain or South Slope physiographic regions. The flows in Butler Creek are lower than the flows in Shelter Valley Creek; this may be due to the relative area of these subwatersheds (i.e., the Shelter Valley Creek subwatershed is almost three times larger than the Butler Creek subwatershed) and groundwater inflow into the Shelter Valley Creek subwatershed from the Oak Ridges Moraine.

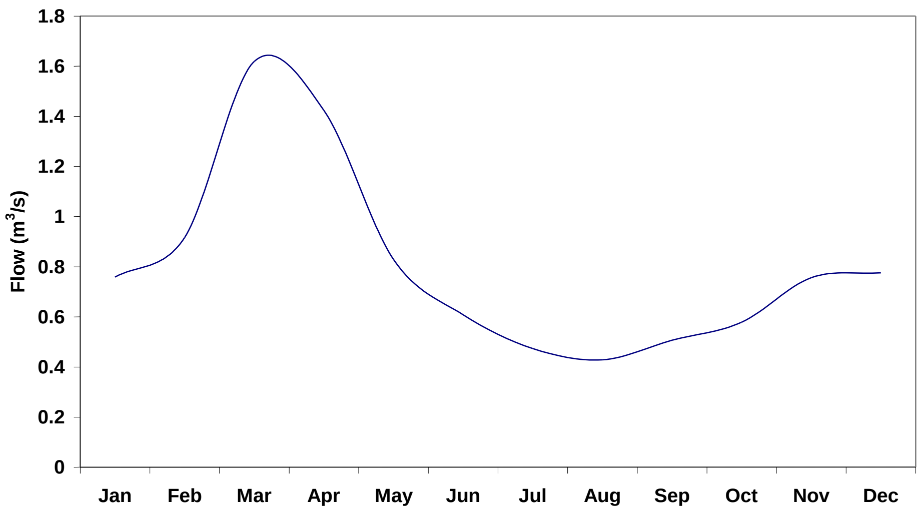


Figure 3.2-14: Hydrograph for Shelter Valley Creek (1966-2004)

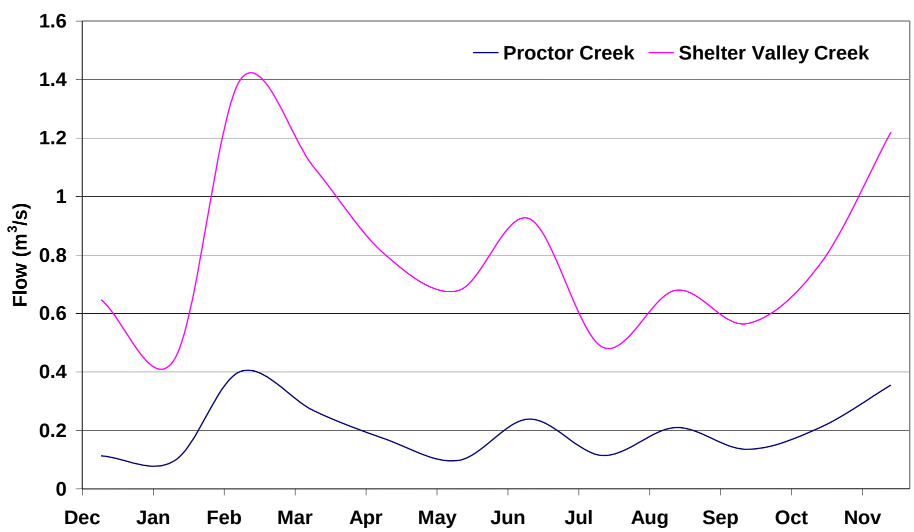


Figure 3.2-15: Hydrographs for Shelter Valley Creek and Butler Creek (2004)

3.2.7.4 AQUATIC HABITAT

Most of the cold water streams in the Paleozoic area originate in the Oak Ridges Moraine and discharge into Lake Ontario or the Trent River. These include Pigeon River, Baxter Creek, and Cavan Creek that flow north, and

Cold Creek, Salt Creek, and Percy Creek that flow east. The streams that flow north start as cold water streams on the north slope of the Oak Ridges Moraine and change into slow-moving warm water streams on the till plain. Stream temperatures in the Trent River watershed are illustrated on Map 3-20.

3.2.8 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 (with 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 (with low hydraulic conductivity) that can store significant quantities of water but does not transmit it readily (an aquitard is distinguished from an aquaclude, 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.

3.2.8.1 GROUNDWATER SURFACES

The water table is the upper limit of the zone of saturation in a groundwater system. Below the water table, the spaces between soil particles and fractures in rocks are completely filled with water (saturated). Above the water table is the vadose (unsaturated) zone, where these spaces are only partially filled. The water table in the Trent River watershed was mapped by applying kriging (interpolation) techniques to water level data from shallow wells in the study area (see Map 3-21).

The potentiometric surface is a theoretical surface that represents the level to which groundwater would rise in a well. In an unconfined aquifer, the groundwater at the water table is not under pressure, so the elevation of the potentiometric surface is equal to the elevation of the water table. In a confined aquifer, the groundwater at the top of the aquifer is under pressure, so the potentiometric surface is higher than the elevation of the top of the aquifer. The potentiometric surface in the Trent River watershed was mapped by applying kriging techniques to water level data from deep wells in the study area (see Map 3-22).

3.2.8.2 AQUIFER SETTINGS

The study area can be divided into three aquifer settings; from oldest to youngest these are the Precambrian Bedrock Aquifer Area, the Paleozoic Bedrock Aquifer Area, and the Quaternary Overburden Aquifer Area (that overlies the Paleozoic Bedrock Aquifer Area). The highest volumes of water are stored in the Quaternary overburden deposits, followed by the Paleozoic bedrock, and then the Precambrian bedrock. The three aquifer settings are described in the following subsections.

3.2.8.2.1 Precambrian Bedrock Aquifer Area

The Precambrian Bedrock Aquifer Area is located in the north of the watershed and is characterized by thin overburden and vast areas of exposed bedrock. The water table in this area is shallow and close to the bedrock surface. Most groundwater supplies in this aquifer setting are from fractures and faults in the Precambrian bedrock, but no large deep regional bedrock aquifer has been identified (Morrison Environmental Ltd., 2004).

There are a limited number of overburden aquifers in this area. There is a general lack of information about the Precambrian Bedrock Aquifer Area.

3.2.8.2.2 Paleozoic Bedrock Aquifer Area

The Paleozoic Bedrock Aquifer Area occupies the area south of the Precambrian Aquifer Area to Lake Ontario. It is a region of Paleozoic limestone that is overlain by Quaternary aged overburden. There are two aquifers in this area: the Paleozoic Bedrock Aquifer, where water is obtained from fractures in bedrock, and the overlying Quaternary Overburden Aquifer (discussed below), where water is obtained from sand and gravel deposits.

Overburden in this area is relatively thin near the transition to the northern Precambrian bedrock. The bedrock at the interface between bedrock and overburden is often highly fractured and weathered, which forms a preferential groundwater flow path (i.e., bedrock surface interflow). The Paleozoic Bedrock Aquifer is the main groundwater source in the area, but both confined and unconfined overburden aquifers exist in the overlying Quaternary aged overburden material.

3.2.8.2.3 Quaternary Overburden Aquifer

The Quaternary Overburden Aquifer occupies much of the same area that is underlain by Paleozoic bedrock. It is made up of saturated sand and gravel deposits. These deposits are thin near the transition zone and thick (approximately 40 m) near Lake Ontario. The Quaternary aquifer provides the greatest volume of groundwater storage of the three aquifer areas in the watershed, since overburden deposits are typically able to store more water than fractured bedrock.

The Quaternary Overburden Aquifer has both unconfined and confined groundwater conditions across the area. On the western side of the area, including the Oak Ridges Moraine, the upper sediments are separated from the lower sediments by the Newmarket Till, which is a fine grained layer that acts as an aquitard (Sharpe et al., 1999). The Newmarket Till tapers out toward the east, and there are areas where the overburden is thin or nonexistent (e.g., south of Rice Lake). The upper sediments consist of glacially deposited sands that store groundwater and make up an unconfined aquifer that sits on top of the Newmarket Till.

3.2.8.3 GROUNDWATER FLOW DIRECTION

Groundwater flow in unconfined aquifers in the Precambrian Bedrock Aquifer Area follows the surface topography above the aquifer, which tends to be in a southwest direction (Morrison Environmental Ltd., 2003) and similar to local surface water drainage patterns. In the Paleozoic Bedrock Aquifer Area (on a regional scale) groundwater flow is south toward Lake Ontario (this pattern is consistent with the slope of the limestone bedrock surface). In the Quaternary Overburden Aquifer, groundwater primarily flows south toward Lake Ontario, following the slope of the underlying Paleozoic bedrock. There is an exception just above the bedrock surface in the area just south of Rice Lake where there is an east-west trending groundwater divide, which is caused by a sediment wedge of subglacial origin. The sediment wedge is aligned with the axis of the Oak Ridges Moraine, with which it is believed to be associated (Barnett et al., 1998). This divide causes the upper aquifer flow patterns to travel north and east into Rice Lake, then towards the Trent River. South of the divide the water continues to flow south towards Lake Ontario (Morrison Environmental Ltd., 2004). Groundwater flow directions in the study area were mapped based on the kriged groundwater surfaces (Maps 3-21 and 3-22).

3.2.8.4 GROUNDWATER RECHARGE AND DISCHARGE AREAS

Recharge occurs when surface water moves downward to become groundwater (downward vertical gradient), and discharge occurs when groundwater discharges to the ground surface (upward vertical gradient). Recharge areas are generally associated with topographically high regions, and discharge areas are associated with lowlands and at abrupt changes in elevation (e.g., escarpments).

Groundwater recharge areas in the source protection region were delineated in a study by the Conservation Authorities Moraine Coalition (discussed in detail in Chapter 6). Discharge areas were identified by subtracting the groundwater surface elevation from the ground surface elevation (discharge areas were delineated where the groundwater surface was close to or above the ground surface). Recharge and discharge areas are illustrated on Map 3-23 (the map also shows open water springs, closed depressions, and hummocky areas).

3.2.8.4.1 Precambrian Bedrock Aquifer Area

The Precambrian region commonly has bedrock exposed at the ground surface. Runoff potential is high: the bedrock acts as an aquitard that causes water to run off and collect in the bedrock valleys where overburden deposits exist. Numerous wetlands, streams, ponds, and lakes exist in these overburden deposit areas (Morrison Environmental Ltd., 2004). Wetlands typically have both recharge and discharge associated with them that fluctuate in response to local and seasonal groundwater levels.

Precambrian bedrock often has interconnected fractures and faults that allow it to act as an aquifer and contribute to groundwater recharge. Deep bedrock wells can be fed by fractures that are hydraulically connected to a nearby lake; in these cases water levels and chemistry will be influenced by the lake water.

3.2.8.4.2 Paleozoic Bedrock Aquifer Area

Recharge waters for the Paleozoic Bedrock Aquifer typically percolate through the overlying overburden materials, especially in upland areas where there are granular deposits (e.g., Oak Ridges Moraine from the west) and areas where overburden aquitards (e.g., Newmarket Till) or other confining layers are absent (e.g., south of Rice Lake). Unlike Precambrian bedrock, Paleozoic bedrock contains soluble carbonate that develops solution channels and karst features that form significant preferential flow paths.

3.2.8.4.3 Quaternary Overburden Aquifer

The recharge areas for this aquifer include the crests of moraines, drumlins, and other glacial deposits in the area (Morrison Environmental Ltd., 2004). In these highland areas, the groundwater surface is deeper than in the lowland areas, where the groundwater surface is close to the ground surface or discharging (Morrison Environmental Ltd., 2004). These upland glacial deposits provide large areas of recharge for local aquifers.

At lower elevations, water flows across the Newmarket Till aquitard and discharges where this layer meets the ground surface, usually in low-lying areas. Many of the local streams have their headwaters located on the slope of the Oak Ridges Moraine and are fed by groundwater discharging to the surface. The deeper confined aquifer, located below the Newmarket Till, exists where basal sand and gravel material and/or bedrock fragments occur, which is above the limestone bedrock surface. It tends to be a lower producing aquifer with a discontinuous occurrence (Morrison Environmental Ltd., 2004).

Hummocky topography is hilly terrain that typically has internal drainage patterns and is usually associated with recessional glacial deposition (i.e., stagnant and/or stranded ice blocks). It is often evident in recessional moraine deposits and/or drumlin fields. Due to its granular nature and internal drainage patterns, hummocky terrain often forms significant areas of recharge for nearby aquifers. Hummocky areas in the study area are concentrated around the Kawartha Lakes and the Oak Ridges Moraine (see Map 3-16).

3.2.8.5 GROUNDWATER MONITORING NETWORK LOCATIONS

The Provincial Groundwater Monitoring Network is a partnership program between the Ministry of the Environment and Climate Change and the Conservation Authorities. Each Conservation Authority has a series of wells across their jurisdiction equipped with Leveloggers that record water level and water temperature readings every hour. The data collected at these stations indicate general groundwater levels at a regional scale and will indicate short or long term variations at a local scale. The data are being added into the Provincial Groundwater Monitoring Information System database to verify current groundwater levels.

The Provincial Groundwater Quality Monitoring Network is relatively new and still expanding. Monitoring stations are sparse in the Precambrian region, but they cover the majority of the Paleozoic region. The locations of monitoring network stations in the study area are illustrated on Map 3-24.

3.2.8.6 GROUNDWATER BASEFLOW

Baseflow is the component of surface water flow that comes from groundwater discharge. The relationship between baseflow and surface water flow typically varies seasonally, with location, and in response to precipitation events. There are no long-term baseflow data available for the study area.

Baseflow in the study area was estimated by calculating the baseflow index (the ratio of baseflow in a stream to its streamflow). An estimate of annual baseflow in a stream can be obtained by multiplying the baseflow index by the annual streamflow. Estimates of the long-term average baseflow index were calculated for subwatersheds in the study area using Ontario Flow Assessment Techniques (OFAT) software and several methods from the literature (Neff et al., 2005; Piggott, A.R., Moin, S., & Southam, C., 2005; McLean & Watt, 2005). The baseflow indices calculated using these methods are listed in Table 3.2-13. Even though the mean basin slope was outside the study parameter range for three of the subwatersheds, the results based on McLean and Watt (2005) were considered the most realistic for the Trent River subwatersheds.

Table 3.2-12: Baseflow Index Estimates for Lake Ontario & Bay of Quinte Tributaries

Creek	Drainage Area (km^2)	Baseflow Index		Mean Annual Baseflow (mm/year)	Mean Annual Streamflow (m^3/s)
		OFAT[1]	Piggot et al. (2005)[2]		
Shelter Valley	69	0.632	0.636	235.5	0.81
Butler (Proctor) Creek	24.00	0.607	NA	151.5	0.19
DND Creek	7.00	0.602	NA	271.2	0.10

[1]Ontario Flow Assessment Techniques
[2]Piggott, A.R., Moin, S. & Southam C. (2005)

Table 3.2-13: Baseflow Index Estimates for Various Subwatersheds in the Trent River Watershed

Subwatershed	Drainage Area (km^2)	Area of Permeable Soil (%)	Mean Basin Slope (%)	Baseflow Index			Mean Annual Baseflow[4] (m^3/sec)	Mean Annual Streamflow[5] (m^3/sec)
				OFAT[1]	USGS (2002)[2]	McLean & Watt (2005)[3]		
Gull River	1296	1.0[a]	8.00[r]	0.670	0.578	0.352	6.69	19
Burnt River	1253	1.0[a]	7.40[r]	0.674	0.585	0.346	6.23	18
Kawartha Lakes West	3494	10.3	2.80	0.627	NA	0.362	7.60	21
Kawartha Lakes East	1292	6.0	2.70	0.630	0.517	0.327	8.83	27
Rice Lake	1808	10.7	2.73	0.627	0.503	0.362	3.26	9
Crowe River	1932	6.0	6.10[r]	0.656	0.551	0.380	9.12	24
Lower Trent River North	936	15.3	2.74	0.633	0.507	0.385	9.24	24
Lower Trent River South	576	28.7	2.78	0.632	0.714	0.430	3.44	8

[1]Ontario Flow Assessment Techniques
[2]U.S. Geological Survey (Neff et al., 2005)
[3]Study parameter range for McLean & Watt (2005):
Mean basin slope 0.73%-5.92% ([r] indicates outside of study range)
Area of permeable soils 2-100% for BFI 0.21 to 0.70 ([a] indicates assumed area of permeable soil)

3.2.9 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 agricultural, municipal (water treatment plants), permitted uses (withdrawals taken under a Permit to Take Water), and unserviced residential and commercial uses that do not require a permit.

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.

3.2.9.1 AGRICULTURAL WATER USE

Agricultural water use includes water used for agricultural activities such as crop irrigation and livestock watering. Since a Permit to Take Water (see Section 3.2.9.4) is not required to take surface or groundwater for agricultural purposes unless the water is stored prior to use, large quantities of water are potentially used for agricultural activities without any record of the volumes extracted. Thus, agricultural water use in the study area had to be estimated. Estimates of agricultural water use were generated for the study area from a spatial database generated by de Löe (2002) for the Ministry of Natural Resources and Forestry, which summarized agricultural water use for all Quaternary watersheds in Ontario. The database was built on the methods of Kreutzwiser and de Löe (1999) and de Löe et al. (2001), who estimated agricultural water use by applying a set of agricultural water use coefficients to agricultural census data (e.g., 90 litres per day (L/day) for each dairy cow on a farm).

The database represents agricultural water use under average climatic conditions and average farming practices. Since climate has a significant effect on irrigation practices from year to year, the accuracy of water use statistics in the database is unclear, and the results should be interpreted with caution. Estimates of agricultural water usage in the study area based on the de Löe (2002) database are listed in Table 3.2-14. The table indicates the number of farms, mean annual agricultural water usage per farm, proportion of water use by agricultural sector, and total agricultural use in each subwatershed. Agricultural water usage in the study area is illustrated on Map 3-25.

Trent River Watershed

Agricultural water use in the Trent River watershed is about 4,665,221 m^3/year (used by about 3,230 farms). This is less than 0.5% of the annual precipitation in the Trent River watershed. About 55% of agricultural water use is attributed to the maintenance of livestock, and the remainder is largely used for irrigation (39%), particularly specialty and greenhouse crops during the summer growing period. Summer water use is about 45% of total annual use (2,077,717 m^3/year). This equates to a summer maximum monthly water use (July to September) of approximately 692,572 m^3/month.

Most of the agricultural water use in the Trent River watershed occurs in the Kawartha Lakes West (38%), Rice Lake (25%), Lower Trent North (21%), and Lower Trent South (8%) subwatersheds. Agricultural water use in the northern subwatersheds (Crowe, Gull, Burnt, and Kawartha Lakes East) is minimal; this can be attributed to poor agricultural conditions.

The mean water use per farm for the entire Trent River watershed is approximately 1,444 m^3/year, but it varies significantly among subwatersheds, ranging from 818 m^3/year in the Gull River subwatershed to 1,854 m^3/year in the Lower Trent South subwatershed. This is likely due to different farming practices between subwatersheds.

Lake Ontario & Bay of Quinte Tributaries

Agricultural water use is about 497,250 m^3/year (about 0.14% of annual precipitation) in the Lake Ontario tributaries subwatershed (used by about 174 farms) and 93,603 m^3/year (about 0.21% of annual precipitation) in the Bay of Quinte tributaries subwatershed (used by about 46 farms).

3.2.9.2 MUNICIPAL WATER USE

Municipal water use includes water supplied by municipal water treatment plants. The locations of municipal water intakes and wells related to these systems are illustrated on Map 3-26. Where available, monthly municipal water usage data for the years 2001 to 2005 were obtained from the municipalities in the study area. Many water treatment plants did not have data for all five years. Further, some plants only collected usage data for a few months per year; in these cases, flows for months with no data were assumed to be equal to the average flows of measured months for a given year. The data were statistically analysed and used to generate estimates of average municipal water usage for each month of the year for each subwatershed. In some cases, the statistical analysis was severely limited by the availability of data, but the results are considered to be the best available estimate of current municipal water use in the study area. Municipal water usage data in the study area are summarized in Table 3.2-15. The locations of municipal drinking water and wastewater treatment plants are shown on Map 3-27.

Trent River Watershed

Total municipal water usage in the Trent River watershed is about 512,473,822 m^3/year (41 mm/year expressed as depth over the surface area of the watershed). Most of this volume was drawn from surface water sources (99.4%) and a small amount was drawn from groundwater sources (0.56%). With the exception of the Kawartha Lakes West subwatershed that is highly dependent on groundwater, most of the major municipal withdrawals are from major surface water sources (e.g., the Trent River).

Municipal water use varies significantly among the subwatersheds of the Trent River watershed as a result of the distribution of settlement areas. Municipal water use is largely concentrated in the Rice Lake, Kawartha Lakes West, and Lower Trent South watersheds, where the largest municipal serviced populations are located (Peterborough, Lindsay, and Trenton). Water use per capita may differ throughout the watershed due to differences in major industrial and institutional uses, system losses (e.g., distribution system losses), and local conservation practices.

Lake Ontario & Bay of Quinte Tributaries

Total municipal water usage in the Lake Ontario and Bay of Quinte tributaries subwatersheds is about 925,275 m^3/year and 1,271,295 m^3/year, respectively (13.1 mm/year and 5.6 mm/year, respectively, expressed as a depth over each subwatershed). These water withdrawals are small with respect to the entire watershed.

3.2.9.3 UNSERVICED WATER USE

A significant portion of residential and commercial property owners in the Trent River watershed obtain water from private supplies; these users are generally referred to as “unserviced” water users. Unserviced use is generally considered to be a minor component of large-scale water budgets, but it can be important at subwatershed or local scales. Most private supplies are assumed to be from groundwater sources, but they can also be from surface water where it is the only reliable water source available. Little information is available regarding the magnitude or efficiency of domestic and commercial uses from distributed water sources in the Trent River watershed. Wells registered with the Ministry of the Environment and Climate Change in the study area are illustrated on Map 3-28.

No actual usage data is available to estimate unserviced water use in the study area. Unserviced water use in the study area was estimated by applying water use coefficients to population data (estimates are provided in Table 3.2-16).

Table 3.2-14: Summary of Agricultural Water Use in the Study Area

	Subwatershed	No. Farms	Mean Annual Usage per Farm (m^3)	Annual Agricultural Water Usage				Agricultural Usage by Usage Type (% Total Agricultural Usage)						
									Irrigation					
				m^3/year	Depth over Trent River watershed (mm/year)	Depth over subwatershed (mm/year)	% Total	Livestock	Field Crops	Fruit Crops	Vegetable Crops	Specialty Crops	Summer Irrigation	Total Irrigation
Trent River Watershed	Burnt River	75	933	69,763	0.06	0.01	1	59	1	0	15	25	38	39
	Crowe	110	1253	137,377	0.07	0.01	3	51	0	2	2	45	46	44
	Gull River	49	818	40,324	0.03	0	1	53	0	0	15	32	43	46
	Kawartha Lakes East	118	986	116,444	0.09	0.01	2	73	0	3	1	22	26	19
	Kawartha Lakes West	1208	1479	1,786,489	0.51	0.14	38	52	1	3	10	34	45	44
	Lower Trent North	570	1679	957,365	1.02	0.08	21	60	1	21	4	14	29	45
	Lower Trent South	206	1854	381,750	0.66	0.03	8	45	1	37	5	12	36	70
	Rice Lake	894	1315	1,175,710	0.65	0.09	25	57	1	8	3	32	38	39
	TOTAL	3230	1444	4,665,221	0.37	0.37	100	55	1	11	6	28	39	45
Bay of Quinte		46		93,603	NA	1.12		40	1	34	3	22	38	38
Lake Ontario		174		497,250	NA	2.17		26	1	33	10	31	59	60

Table 3.2-15: Summary of Average Municipal Water Use and Serviced Population in the Study Area

	Subwatershed	Groundwater		Surface Water		Total Municipal Water Use	
		m^3/year	Serviced Population	m^3/year	Serviced Population	m^3/year	Serviced Population
Trent River Watershed	Burnt	0	45	3,650	20	3,650	65
	Crowe	405,150	1860	245,638	1,300	650,788	3,160
	Gull	199,290	2300	0	0	199,290	2,300
	Kawartha Lakes East	0	0	525,235	2,400	525,235	2,400
	Kawartha Lakes West*	1,529,715	11428	6,263,765	22,281	7,918,675[a]	33,962
	Lower Trent North	0	0	1,164,076	5,087	1,164,076	5,087
	Lower Trent South	370,110	2050	3,061,985	18,850	3,432,095	20,900
	Rice Lake	339,450	2261	500,956,058	80,300	501,295,508	82,561
	TOTAL	2,438,565	19,944	511,974,769	130,238	514,538,529	150,435
Bay of Quinte		0	0	925,275	3,500	925,275	3,500
Lake Ontario		1,271,295	8000	0	0	1,271,295	8000

[a]Includes 125,195 m^3/year in the Kinmount system (serviced population 253) pumped from a groundwater source to a surface water holding pond

Table 3.2-16: Unserviced Water Use in the Study Area

<table>
<tr><th colspan="2" rowspan="2">Subwatershed</th><th rowspan="2">Estimated Unserviced Population</th><th colspan="3">Annual Water Use</th><th rowspan="2">Monthly Maximum Water Use (m³/month)</th><th rowspan="2">% Total</th></tr>
<tr><th>Annual Water Use (m³/year)</th><th>Depth over subwatershed (mm/year)</th><th>Depth over Trent River watershed (mm/year)</th></tr>
<tr><td rowspan="9">Trent River Watershed</td><td>Burnt River</td><td>4,593</td><td>268,223</td><td>0.214</td><td>0.022</td><td>40,233</td><td>3%</td></tr>
<tr><td>Crowe River</td><td>7,497</td><td>437,838</td><td>0.227</td><td>0.035</td><td>65,676</td><td>4%</td></tr>
<tr><td>Gull River</td><td>5,029</td><td>293,694</td><td>0.226</td><td>0.024</td><td>44,054</td><td>3%</td></tr>
<tr><td>Kawartha Lakes East</td><td>9,809</td><td>572,829</td><td>0.440</td><td>0.046</td><td>85,924</td><td>6%</td></tr>
<tr><td>Kawartha Lakes West</td><td>45,080</td><td>2,632,684</td><td>0.793</td><td>0.211</td><td>394,903</td><td>25%</td></tr>
<tr><td>Lower Trent North</td><td>13,227</td><td>772,443</td><td>0.826</td><td>0.062</td><td>115,866</td><td>7%</td></tr>
<tr><td>Lower Trent South</td><td>12,862</td><td>751,135</td><td>1.303</td><td>0.060</td><td>112,670</td><td>7%</td></tr>
<tr><td>Rice Lake</td><td>79,417</td><td>4,637,942</td><td>2.608</td><td>0.372</td><td>695,691</td><td>45%</td></tr>
<tr><td>TOTAL</td><td>177,514</td><td>10,366,789</td><td>NA</td><td>0.832</td><td>1,555,018</td><td>100%</td></tr>
<tr><td colspan="2">Bay of Quinte Tributaries</td><td>19,059</td><td>1,113,784</td><td>15.69</td><td>NA</td><td>5,489</td><td>NA</td></tr>
<tr><td colspan="2">Lake Ontario Tributaries</td><td>10,730</td><td>620,663</td><td>2.71</td><td>NA</td><td>3,094</td><td>NA</td></tr>
</table>

3.2.9.4 PERMITTED WATER USE

Any person, industry, institution, or commercial operation taking more than 50,000 L/day of water from either groundwater or surface water sources must obtain a Permit to Take Water (PTTW) from the Ministry of the Environment and Climate Change. The permit holder is required to report the maximum limit of their prospective water takings. While permits typically require maintaining a record of water taking, reporting of actual water usage under the permit has only recently become a legislated requirement. Permitted water use may vary significantly over the course of the year, especially for seasonal users (e.g., irrigation, snow making, etc.).

Permit information is collected in the PTTW database that includes data on various water use parameters associated with the permits (including location data, purpose of the water taking, maximum water taking per day, days of water taking per year, etc.). A copy of the database was obtained through the Ministry of the Environment and Climate Change for the study area. The data were modified by removing inactive permits, agricultural water uses (accounted for in Section 3.2.9.1), municipal water uses (accounted for in Section 3.2.9.2), and water uses that would not influence the long-term water budget of a subwatershed (e.g., sediment holding ponds for road construction). Permitted water usage in the study area was estimated by assuming that all remaining permit holders take the maximum daily volume for the maximum number of days allowed by the permit. In most cases water use is less than the permitted maximum, so these are overestimates.

Trent River Watershed

There are a total of 117 permits to take water issued in the Trent River watershed that allow a total maximum withdrawal of 24,586,134 m^3/year (1.95 mm/year expressed as depth over the Trent River watershed). These consist of 74 permits to withdraw a total maximum of 13,017,286 m^3/year from groundwater sources, 43 permits to withdraw a total maximum of 11,568,848 m^3/year from surface water sources, and 3 permits to withdraw from both groundwater and surface water sources (permits to take both groundwater and surface water are issued where water is withdrawn from a groundwater source and stored for future use in a surface water holding pond). Maximum permitted water usage in the Trent River watershed is summarized in Table 3.2-17 and illustrated on Maps 3-29 and 3-30.

Permitted water use varies significantly among the subwatersheds in the study area. The highest volumes of permitted water use are found in the Kawartha Lakes West subwatershed (37%), associated largely with the aggregate industry and golf courses; the Rice Lake subwatershed (22%), associated largely with a major aquaculture facility; and the Crowe River subwatershed 19%), associated largely with the aggregate industry. The remainder of permitted water use (22%) is used for drinking water supplies (e.g., campgrounds, communal systems, etc.) and a variety of other commercial and industrial purposes.

In the Trent River watershed, 50% of the total permitted water use is withdrawn for the processes of pit and quarry dewatering and aggregate washing. Other significant permitted water uses include golf courses, aquaculture, and communal well supplies (7%). The remaining 13% of permitted usage is distributed among a variety of other uses. Permitted water usage in the Trent River watershed is summarized by purpose of permit in Figure 3.2-16.

Lake Ontario & Bay of Quinte Tributaries

In the Lake Ontario tributaries subwatershed there are 22 permits to take water that permit a total maximum withdrawal of 2,788,133 m^3/year, and in the Bay of Quinte tributaries subwatershed there are 19 permits to take water that permit a total maximum withdrawal of 4,031,311 m^3/year. The largest permitted water users in these subwatersheds include golf courses, campgrounds, and bottled water suppliers.

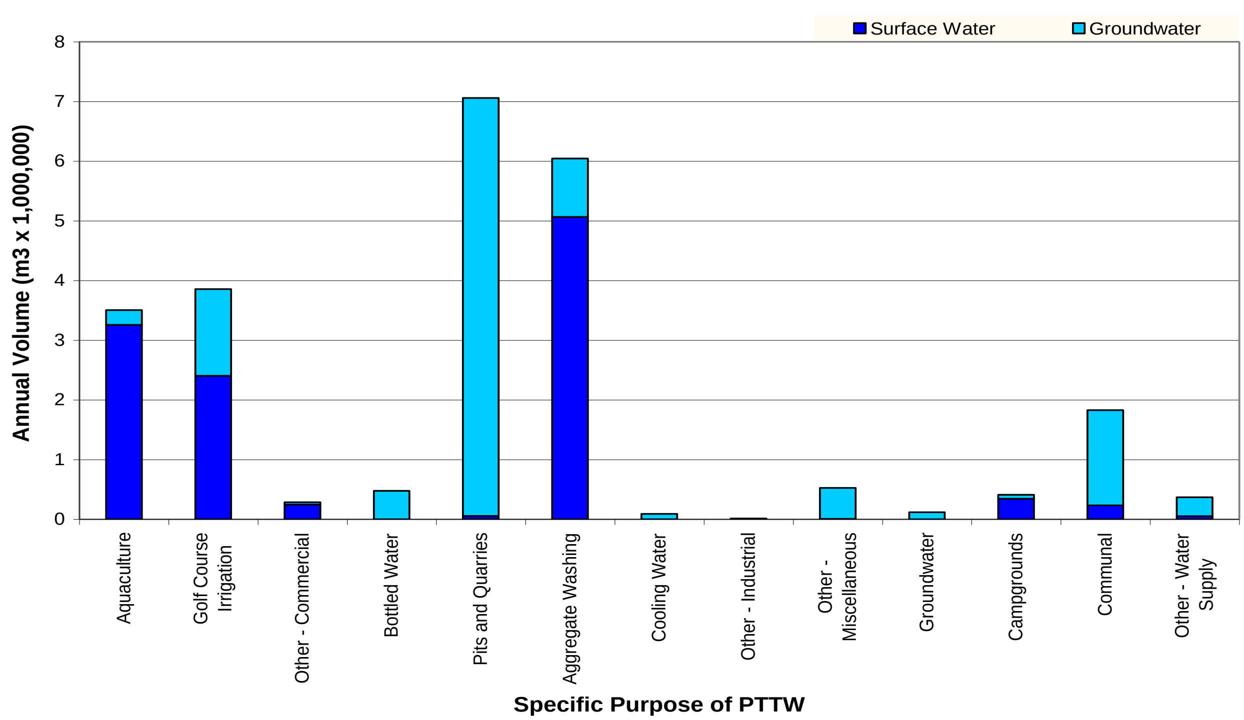


Figure 3.2-16: Permitted water use in the Trent River watershed by purpose of permit

3.2.9.5 WATER USE SUMMARY

Trent River Watershed

The estimates of water uses in the Trent River watershed are summarized in Table 3.2-18. Estimates of the maximum monthly water use for each usage type are listed in Table 3.2-19. The total volume of water potentially withdrawn from the Trent River watershed is about 814,142,632 m^3/year. The largest water use in the watershed is municipal surface water intakes.

Lake Ontario & Bay of Quinte Tributaries

The estimates of water use in the Lake Ontario & Bay of Quinte tributaries are summarized in Table 3.2-20. The total volume of water potentially withdrawn is about 4,920,795 m^3/year from the Bay of Quinte tributaries subwatershed and 6,450,519 m^3/year from the Lake Ontario tributaries subwatershed. The largest water uses in both subwatersheds are water takings made under a Permit to Take Water.

*Table 3.2-17: Maximum Annual Permitted Water Use in the Study Area**

	Watershed	Groundwater				Surface Water				Total			
		No. Permits	Volume (m^3)	Depth[1] (mm)	% Total	No. Permits	Volume (m^3)	Depth[1] (mm)	% Total	No. Permits	Volume (m^3)	Depth[1] (mm)	% Total
Trent River Watershed	Burnt	9	648,312	0.051	31	3	1,418,091	0.112	69	12	2,066,404	0.164	8%
Trent River Watershed	Crowe	7	3,940,980	0.313	84	2	736,420	0.058	16	9	4,677,400	0.371	19%
Trent River Watershed	Gull	0	0	0.000	0	6	412,238	0.033	100	6	412,238	0.033	2%
Trent River Watershed	Kawartha Lakes East[a]	1	1,528,016	0.121	87	3	230,376	0.018	13	6	1,758,392	0.139	7%
Trent River Watershed	Kawartha Lakes West	23	4,036,765	0.320	44	12	5,101,195	0.405	56	35	9,137,959	0.725	37%
Trent River Watershed	Lower Trent North	2	36,500	0.003	28	2	95,462	0.008	72	4	131,962	0.010	1%
Trent River Watershed	Lower Trent South	11	891,193	0.071	94	3	61,598	0.005	6	14	952,791	0.076	4%
Trent River Watershed	Rice Lake[b]	19	1,816,982	0.144	33	11	3,632,004	0.288	67	31	5,448,987	0.432	22%
Trent River Watershed	TOTAL	74	13,017,286	1.023	53	43	11,568,848	0.927	47	117	24,586,134	1.950	100%
Bay of Quinte Tributaries[b]		14	645,437	9.1	14	7	2,142,696	30.2	100	22	2,788,133	39.3	NA
Lake Ontario Tributaries[c]		15	4,061,311	17.7	86	0	0	0.00	0	19	4,061,311	17.7	NA

*Excludes permits for municipal and agricultural uses and uses that do not impact the long-term water budget of the subwatershed

[a,b,c]Volume, depth, and % total fields include (a) two (b) one and (c) four permits to take water from both surface water and groundwater sources (assumed usage was 50% surface water and 50% groundwater)

[1]Indicates volume expressed as a depth over the entire Trent River watershed

Table 3.2-18: Summary of Water Use Estimates in the Trent River Watershed

Water Use	Average Annual Water Use								
	Groundwater			Surface Water			Total (Groundwater + Surface Water)		
	Volume (m^3/year)	Depth[1] (mm/year)	% of Use	Volume (m^3/year)	Depth[1] (mm/year)	% of Use	Volume (m^3/year)	Depth[1] (mm/year)	% Total Water Use
Agriculture[2]	2,332,611	0.19	50	2,332,611	0.19	50	4,665,221	0.37	1%
Municipal Water Supply	5,422,075	0.43	1	769,102,414	61.01	99	774,524,489	61.44	95%
Unserviced[3]	10,366,789	0.82	100	0	0	0	10,366,789	0.82	1%
Permitted	12,898,748	1.02	52	11,687,385	0.93	48	24,586,133	1.95	3%
TOTAL	31,020,223	2.46	4	783,122,410	62.12	96	814,142,632	64.58	100%

[1]Volume of water expressed as a depth over the entire Trent River watershed
[2]Agricultural water use assumed to be 50% groundwater and 50% surface water
[3]Unserviced water use assumed to be primarily groundwater; includes residential and commercial uses

*Table 3.2-19: Summary of Maximum Monthly Water Use in the Trent River Watershed**

Water Use	Monthly Maximum Water Use (m^3/month)		
	Groundwater	Surface Water	Total (Groundwater + Surface Water)
Agriculture[1]	346,286	346,286	692,572
Municipal Water Supply[2]	448,593	64,201,185	64,649,778
Unserviced[3]	1,555,018	-	1,555,018
Permitted	1,364,437	1,638,082	3,002,519
TOTAL	3,714,334	66,185,553	69,899,888

*Indicates water usage during the month with the highest mean monthly usage (typically occurs between July and August)
[1]Agricultural water use assumed to be 50% groundwater and 50% surface water
[3]Maximum Municipal Water Supply is based on actual flow rates where available; Groundwater includes one GUDI system
[3]Unserviced water use assumed to be entirely groundwater

Table 3.2-20: Summary of Water Use Estimates in the Lake Ontario and Bay of Quinte Tributaries Subwatersheds

Water Use	Average Annual Water Use							
	Bay of Quinte tributaries subwatershed				Lake Ontario tributaries subwatershed			
	Groundwater (m^3/year)	Surface Water (m^3/year)	Total (Groundwater + Surface Water) (m^3/year)	Total (Groundwater + Surface Water)[1] (mm/year)	Groundwater (m^3/year)	Surface Water (m^3/year)	Total (Groundwater + Surface Water) (m^3/year)	Total (Groundwater + Surface Water)[2] (mm/year)
Agriculture[A]	46,802	46,802	93,603	1.3	248,625	248,625	497,250	2.37
Municipal Water Supply	0	925,275	925,275	13.1	1,271,295	0	1,271,295	5.60
Unserviced[B]	1,113,784	-	1,113,784	15.7	620,663	-	620,663	2.71
Permitted (PTTW)	645,437	2,142,696	2,788,133	39.3	4,061,311	0	4,061,311	17.70
TOTAL	1,806,022	3,114,773	4,920,795	69.4	6,201,894	248,625	6,450,519	28.38

[1]Expressed as depth over the Bay of Quinte tributaries subwatershed
[2]Expressed as depth over the Lake Ontario tributaries subwatershed

3.2.10 CONCEPTUAL WATER BUDGET RESULTS

Water budgets were calculated for each of the 10 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 Trent River watershed and the Lake Ontario and Bay of Quinte tributaries. The results have not been subjected to statistical analysis, but they were used to inform the Tier 1 water budget process.

3.2.10.1 TRENT RIVER WATERSHED

The conceptual water budget for the Trent River watershed is summarized in Figure 3.2-17, and the water budget components for each of its subwatersheds are listed in Table 3.2-22. Results show that the watershed receives a total of 366 m^3/sec (919 mm/year) of precipitation, of which 206 m^3/sec (518 mm/year) of water is returned back to the atmosphere as evapotranspiration. About 160 m^3/sec of water is available as surplus in the watershed (precipitation minus evapotranspiration). Approximately 1.25 m^3/sec of water is removed every year for agriculture, municipal water supply, unserviced uses, and permitted uses. An average of about 150 m^3/sec of water is recorded as streamflow at the final outlet (Trenton).

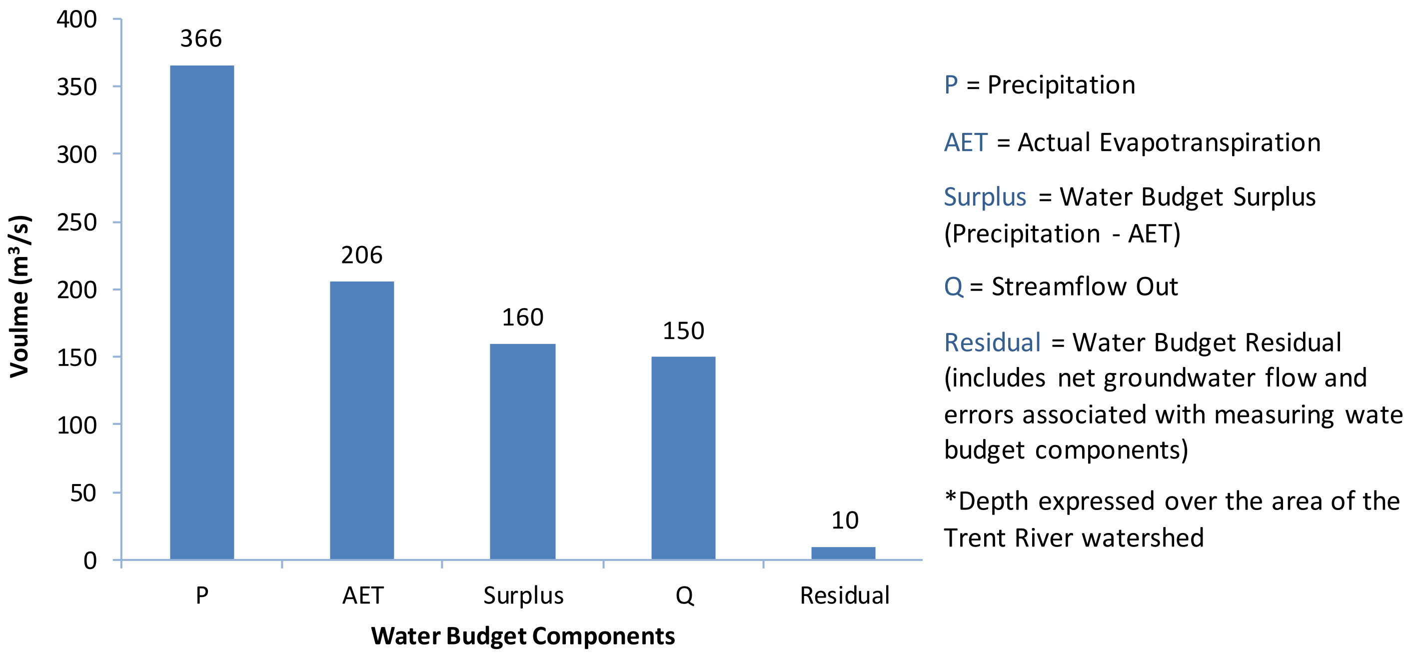


Figure 3.2-17: Water Budget for the Trent River Watershed

Results show that surplus water (precipitation minus evapotranspiration) is higher in the subwatersheds located in the Precambrian Area (Gull, Burnt, and Crowe Rivers) because they have higher precipitation and lower evapotranspiration rates. In these subwatersheds, evapotranspiration accounts for 48% to 55% of the mean annual precipitation; in comparison, in the Rice Lake and Lower Trent North subwatersheds it accounts for 61% of the mean annual precipitation. Factors that may contribute to lower evapotranspiration rates in the Precambrian subwatersheds are fewer daylight hours, the shielding effects of large forest covers, and the narrow and deep structure of the Haliburton Lakes, which reduces evaporation. Significant infiltration of precipitation is unlikely in the Precambrian Area subwatersheds because of the low permeability of the bedrock. More infiltration of precipitation occurs in the relatively permeable glacial deposits and sedimentary rock underlying the southern catchments (Cope, D.M., 2003).

Some subwatersheds have a large water budget residual leftover in the water budget equation. Since the water budget residual includes net groundwater flow (GW_{out} - GW_{in}), this suggests that they are potentially gaining or losing water to adjacent watersheds (i.e., there is a net influx or outflux or groundwater into or out of some of the subwatersheds). This assumption is supported by several independent studies (Singer, 1981; Hinton, 2005; GRCA, 2006). These studies noted that a significant amount of groundwater from outside of some of these watersheds discharges into several streams that have headwaters in the Oak Ridges Moraine. The watersheds that have a potential influx or outflux of groundwater, and the potential causes of the influx or outflux, are listed in Table 3.2-23.

At a broad scale, there appears to be a sufficient quantity of water available in the basin to meet anthropogenic water use and ecosystem requirement needs for the Trent River and for the eight subwatersheds (based on the current operational practices of the Trent-Severn Waterway).

3.2.10.2 LAKE ONTARIO & BAY OF QUINTE TRIBUTARIES

There is only one gauge station in the Lake Ontario & Bay of Quinte tributaries subwatersheds – Shelter Valley Creek – that provides long-term, reliable streamflow data. For this reason, a water budget was completed for this location only. The water budget for the Shelter Valley Creek gauge station is presented in Table 3.2-21.

Table 3.2-21: Water Budget Components for Shelter Valley Creek

Subwatershed	Area (km^2)	Mean Annual Flow (m^3/s)	Precipitation (mm/year)	Evapot-transpiration (mm/year)	Surplus Water (mm/year)	Streamflow (mm/year)	Residual (mm/year)
Shelter Valley Creek	69.0	0.81	871	532	339	370	-31

Results show that the subwatershed receives a sum of 871 mm/year water flux as precipitation, of which 532 mm/year (61% of the precipitation) of water is returned back to the atmosphere as evapotranspiration. Another 370.21 mm/year is lost via streamflow. Water use in the Lake Ontario region is expected to be a small portion of the total available surplus water.

This leaves a negative residual of 31.1 mm/year. This residual includes the net regional groundwater flow (GW_{out} -GW_{in}) and the combined errors and uncertainties associated with measurements and assumptions. This negative value could be caused by an influx of groundwater into the watershed (GW_{in}). This assumption is supported by several independent studies (Singer, 1981; Hinton, 2005; GRCA, 2006). These studies noted that a significant amount of groundwater from outside of the watershed discharges into several streams having their headwaters in the Oak Ridges Moraine and draining to Lake Ontario (i.e., Shelter Valley Creek). Since the negative value is significant, it is likely that the creek is receiving groundwater discharge.

Lake Ontario Tributaries Subwatershed

It is expected that the creeks that have their headwaters originating in the Oak Ridges Moraine (Shelter Valley and Barnum House) are groundwater dominated. These creeks are relatively fast flowing, in comparison to others in the region. It is possible that the region has a net influx of groundwater from some of the surrounding watersheds due to the presence of the Oak Ridges Moraine.

For the creeks that have their headwaters in the South Slope, it is not possible at this time to determine whether they will be surface water or groundwater dominated. Limited flow data available from the Butler (Proctor) Creek gauge station show that the flows in this area are smaller than those found in the creeks originating in the Oak Ridges Moraine. However these watercourses are cold water streams, which suggests that there is significant groundwater discharge to the creeks originating in the South Slope.

It is expected that water use in the Lake Ontario region will make up a small portion (about 3% in the Shelter Valley Creek watershed) of the total surplus water available. However, there still may be occurrences of local drought conditions.

Bay of Quinte Tributaries Subwatershed

Creeks found in the Bay of Quinte region originate in the clay plains, and should therefore be relatively fast flowing. This is because the area provides very little storage, and during precipitation events the peak flows will be experienced quite rapidly. There are no gauge stations found in this subwatershed. This region is surface water dominated with very little influence from groundwater expected. For this reason, some of the creeks are often found dry during the summer months. The fact that these creeks are warm water streams supports the conclusion that there is very little groundwater discharge to the streams.

Municipal water use in this area is from surface water sources (Bay of Quinte) and it is expected that there is enough surplus water in the area to meet the needs of the population.

3.2.11 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 Haliburton County and northern Peterborough County
- Evapotranspiration data for the Trent River Basin
- Additional wind data for use in the Penman model for evapotranspiration.

Geology

- Soil data for Haliburton County
- Edge matching of soils maps (including attribute classification among the soil maps of different counties)
- Additional borehole information to help describe bedrock geology in the Precambrian area
- Stratigraphy and hydrostratigraphy.

Land Cover

- Comprehensive list of the locations of active and abandoned pits and quarries as well as active and abandoned mining locations
- Good quality land cover data for the Lower Trent, Crowe Valley, and Otonabee-Peterborough source protection areas, and the northern portion of the Kawartha-Haliburton Source Protection Area
- Land use data detailing anthropogenic use classifications.

Surface Water

- Increased density of gauge stations on the Trent system.

Groundwater

- Properly geo-referenced wells in the Water Well Information System
- Additional baseflow monitoring data
- Accurate, verified geological stratification information for the Paleozoic region
- Accurate mapping of overburden deposits in the Precambrian area
- Increased density of Provincial Groundwater Monitoring Network wells in the Precambrian area
- Information on stream and lake temperatures, as related to groundwater discharge in the Precambrian area.

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 the amount of water returned to surface water tributaries, evaporated in sewage lagoons, etc.)
- 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 the aquatic habitat dependent on water depth
- Assessment of the aquatic habitat dependent on water flow.

Table 3.2-22: Summary of Water Budget Components for Trent River Subwatersheds

Water Budget Components		Subwatershed								Trent River Watershed	
Component	Unit	Gull River	Burnt River	Kawartha Lakes West	Kawartha Lakes East	Rice Lake	Crowe River	Lower Trent North	Lower Trent South	Total	Average
Drainage Area	km^2	1,280	1,270	3,495	1,292	1,730	1,990	920	577	12554	-
Precipitation	m^3/sec	42	42	96	39	46	60	25	15	366	46
	mm/year	1,045	1,045	869	940	840	957	841	841	919	922
Actual Evapotranspiration	m^3/sec	20	20	58	22	28	33	15	9	206	26
	mm/year	504	504	526	528	511	523	511	514	518	515
	% of precip.	48	48	60	56	61	55	61	61	56	56
Surplus Water[1]	m^3/sec	22	22	76	76	104	27	128	148	160	85
	mm/year	541	541	343	412	329	434	329	327	-	407
	% of precip.	52	52	40	44	39	45	39	39	-	44
Surface Water In	m^3/sec	0	0	38	59	86	0	118	142	-	-
Surface Water Out	m^3/sec	19	18	59	86	95	24	142	150	-	-
	% of surplus	88	84	78	113	91	86	111	101	-	-
Water Budget Residual	m^3/sec	2.6	3.5	16.4	-9.8	9.4	3.8	-14.3	-1.5	10	-
	mm/year	63	87	148	-240	172	60	-489	-83	25	-
Anthropogenic Removal	m^3/sec	0.024	0.076	0.43	0.078	0.357	0.187	0.059	0.066	1.27	-
	mm/year	0.583	1.893	3.879	1.894	6.510	3.06	2.023	3.614	-	-
	% of precip.	0.06	0.18	0.45	0.20	0.78	0.31	0.24	0.44	0.35	-

[1]Surplus water is the difference between precipitation and actual evapotranspiration (i.e. Surplus = P - AET)

Table 3.2-23: Trent River Subwatersheds with a Potential Influx or Outflux of Groundwater

Subwatershed	Surface Water Flow Distribution (L/s/km^2)	Watershed Characteristics	Comments
Kawartha Lakes West	6	Regional Groundwater outflow (Singer, 1981; Hinton, 2005) Surface water flow yield is low	• Losing water to adjoining subwatersheds (e.g. Lake Ontario tributaries in CLOCA) via recharge/infiltration taking place in Oak Ridges Moraine. • Losing water to Severn River basin through infiltration taking place in Balsam Lake area and through flow regulation at Balsam Lake.
Kawartha Lakes East	21	Regional Groundwater flow Surface water flow yield is high	• Regional groundwater flow due to infiltration/recharge taking place in karst deposits (Warsaw Caves) within the head waters of Indian River. • The comparatively high surface water flow distribution (flow per unit area) may be an indication of the subwatershed gaining water from outside.
Rice Lake	5	Regional Groundwater outflow (Singer, 1981; Hinton, 2005; GRCA, 2006) Surface water flow yield is low	• Losing water via recharge/infiltration taking place in karst deposits (Warsaw Caves) within the head waters of Indian River. • Losing water to adjoining subwatersheds (e.g. Lake Ontario tributaries in GRCA, such as Wilmot Creek).
Lower Trent North	26	Regional Groundwater flow Surface water flow yield is high	• Regional groundwater low due to recharge/infiltration in Oak Ridges Moraine and Dummer Moraine. • The comparatively high surface water flow distribution (flow per unit area) may be an indication of the subwatershed gaining water from outside.

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3.3 TIER 1 WATER BUDGET & WATER QUANTITY STRESS ASSESSMENT

The Tier 1 water budget expands on the findings of the conceptual water budget by calculating water budgets at smaller spatial scales and by assigning water quantity stress levels to each subwatershed in the study area. The uncertainty associated with calculating water budgets and assigning water quantity stress levels is also evaluated. The Tier 1 was completed by XCG Consultants Ltd. and documented in the following report:

- *Tier 1 Water Budget and Water Quantity Stress Assessment: Trent River Basin, Lake Ontario and Bay of Quinte tributaries (March 2010).*

This section is a summary of that report.

3.3.1 SUBWATERSHEDS

For the purposes of the Tier 1 water budget, the study area was divided into 47 subwatersheds based on provincial Quaternary subwatershed mapping. The delineation of subwatersheds used for the conceptual water budget was also used for part of the Tier 1 analysis. The Tier 1 and conceptual subwatershed delineations are shown on Map 3-31.

3.3.2 METHODOLOGY

The objective of the Tier 1 water budget is to develop water budgets and calculate existing and future water quantity stresses. The Tier 1 analysis included the following four major tasks:

1. Estimation of water budgets (long-term annual and long-term monthly)
2. Estimation of surface water stress by subwatershed and by intake-defined watershed
3. Estimation of groundwater stress by subwatershed

As far as possible, existing data sources were used to develop water budgets and to calculate water supply and reserve, particularly Water Survey of Canada (WSC) flow data records. Where these data were not available, computer models were used to estimate water supply.

3.3.3 WATER BUDGETS

Water budgets were developed for all of the Tier 1 subwatersheds in the study area. A long-term streamflow record is an important input to a water budget, so water budgets were calculated for all subwatersheds in the study area with gauged flow data available. For subwatersheds that are not gauged, streamflow was estimated using a simulation model.

3.3.3.1 GAUGED SUBWATERSHEDS

Water budgets for gauged subwatersheds were performed at both long-term annual and long-term monthly time scales. "Long term" is a time period that is long enough to accurately determine mean values for the components of the water budget (typically 15 to 20 years). For gauged subwatersheds, the following assumptions were made to simplify the water budget equation:

1. Where the basin of interest is a headwater basin (i.e., there is no streamflow into the basin), the net streamflow out term (Q_{net}) is taken as the streamflow out of the basin.
2. There are no diversions into or out of the watershed, so the net diversions out term (D_{net}) is zero and can be deleted from the water budget equation.
3. The net withdrawals are small and of the order of uncertainty in the other terms of the water budget equation. Hence, the "net withdrawals and returns" term (W_{net}) is negligible and can be deleted from the equation.

After these simplifications, the water budget equation was:

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

P = precipitation
G_{net} = net groundwater in
ET = evapotranspiration
Q_{net} = net streamflow out
ΔS = change in storage

This equation was used to calculate long-term annual and long-term monthly water budgets for gauged subwatersheds. The sources of data used to estimate each of the terms of the equation are discussed below.

Precipitation

Long-term mean annual precipitation (P) was taken from the Natural Resources Canada database for the period 1971 to 2000. The climate surfaces referenced in this database were developed by Bill Hogg of Environment Canada and Dan McKenney of the Great Lakes Forest Research Centre (Hogg, 2008). The thin plate smoothing spline technique was used to interpolate climate station data. All of the climate data in the Environment Canada archives were included in the analysis. The technique used all data in the area of analysis to include effects due to elevation in the spatial interpolation, as well as the effects due to distance from major waterbodies such as the Great Lakes.

Evapotranspiration

Long-term mean annual evapotranspiration (ET) was taken from the Agriculture Canada database (Penman's method) for the period 1961 to 1990. This database is organized by eco-district; the entire study area falls within five eco-districts. For each eco-district, the database gives potential evapotranspiration and water deficit on a mean monthly basis. Actual evapotranspiration is the difference between potential evapotranspiration and water deficit. Water deficit (the difference between potential evapotranspiration and actual evapotranspiration) is given for various values of soil water-holding capacity. Actual evapotranspiration is dependent on the amount of moisture held by the soils and in the root zone (i.e., if the amount of moisture is below the potential evapotranspiration, then there will be a water deficit).

Streamflow

Long-term mean annual net streamflow (Q_{net}) was taken from the Water Survey of Canada database for the available period of record to 2005. It was assumed that the time series of annual streamflow and monthly streamflow is stationary (i.e., free of trends, shift, or periodicity). This implies that the statistical parameters of the series, such as the mean and variance, remain constant through time (see Maidment, 1993).

Groundwater flow

Long-term mean annual net groundwater in (G_{net}) was taken as zero unless there was information available from a calibrated groundwater model. Generally, all the subwatersheds in the Paleozoic region (south of the Kawartha Lakes) are included in a groundwater flow model developed by the Conservation Authorities Moraine Coalition. For these subwatersheds, annual net groundwater inflow was obtained from the model. Model coverage did not include the northern (Precambrian) part of the source protection region. For these subwatersheds, it was assumed that annual net groundwater inflows are negligible.

Residual

The long-term mean annual residual was calculated from the water budget equation for each subwatershed. The results were well within the range of uncertainty in the estimates of precipitation, evapotranspiration, and streamflow.

3.3.3.1.1 Long-term Annual Water Budgets

For a long-term annual water budget analysis, it is typically assumed that the positive and negative changes in storage (ΔS) will tend to cancel out (i.e., the sum of the annual values of ΔS will be negligible compared to the sum of the annual values of the other water budget components). Thus, for the long-term annual water budget, the change in storage term (ΔS) was assumed zero and removed from the water budget equation.

The long-term annual water budgets for all of the gauged subwatersheds in the study area are given in Table 3.3-1, and Figure 3.3-1 and Figure 3.3-2 (northern and southern/central basins are shown on separate figures).

Table 3.3-1: Long-term Annual Water Budgets for Gauged Subwatersheds

Gauged Subwatershed	WSC[1] Station #	Water Budget Components[2] (mm)				
		P	ET	G_{net}	Q	Residual
Gull River @ Norland	02HF002	1068	580	0	480	9
Burnt River near Burnt River	02HF003	1023	570	0	452	1
Eels Creek below Apsley	02HH001	943	569	50	461	-38
Mississagua River below Mississauga Lake	02HH002	955	579	0	420	-43
Crowe River @ Marmora	02HK003	900	572	-6	372	-50
Crowe River near Glen Alda	02HK005	935	572	0	455	-91
Beaver Creek near Marmora	02HK006	893	570	50	429	-56
Shelter Valley Creek near Grafton	02HD010	878	553	15	392	-52
Mariposa Brook near Little Britain	02HG001	922	587	-4	289	42
Nonquon River near Port Perry	02HG002	878	581	-81	260	-43
Jackson Creek @ Peterborough	02HJ001	900	546	-24	318	12
Otonabee River @ Lakefield	02HJ002	975	571	0	363	41
Ouse River near Westwood	02HJ003	878	559	1	326	-6
Trent River @ Healey Falls	02HK002	957	570	0	328	59
Trent River @ Glen Ross	02HK004	942	570	0	373	-2
Cold Creek @ Orland	02HK007	885	553	-41	394	-103
Rawdon Creek near West Huntingdon	02HK008	904	555	-13	361	-25
Burnley Creek above Warkworth	02HK009	880	553	-19	324	-15
Mayhew Creek near Trenton	02HK011	907	555	9	382	-21

[1]Water Survey of Canada
[2]Expressed as depth over the watershed area

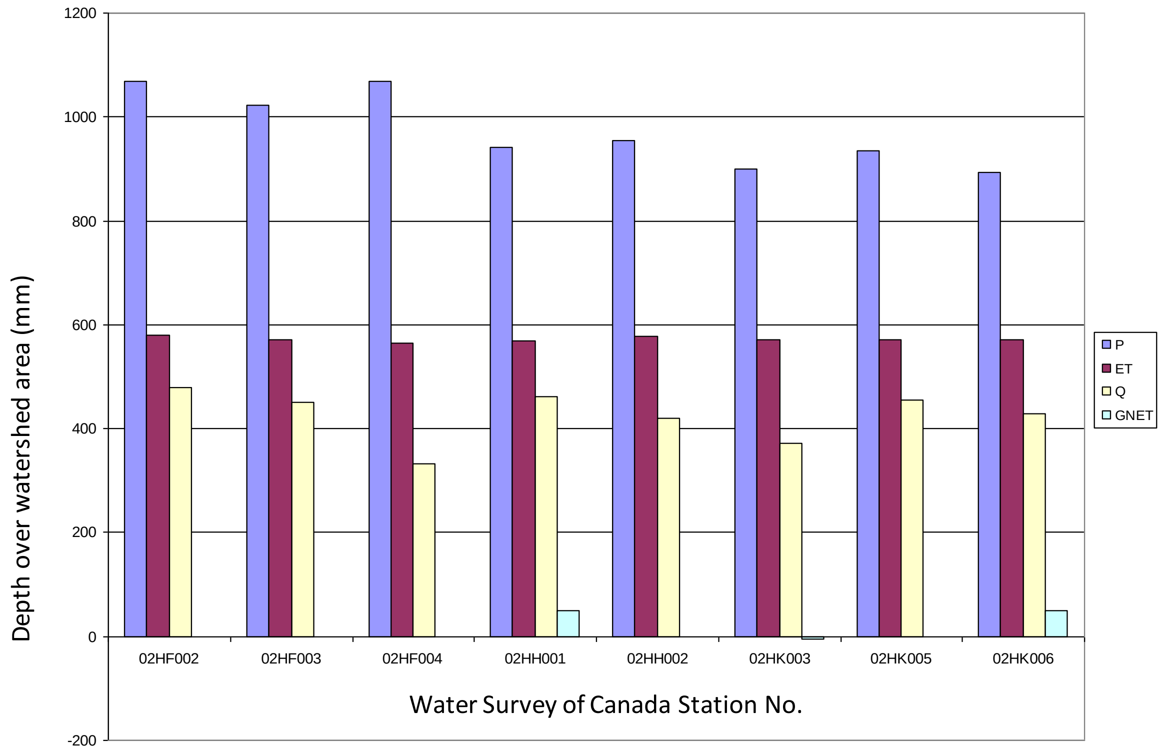

Figure 3.3-1: Long-term Annual Water Budgets for Northern Basins (Gauged)

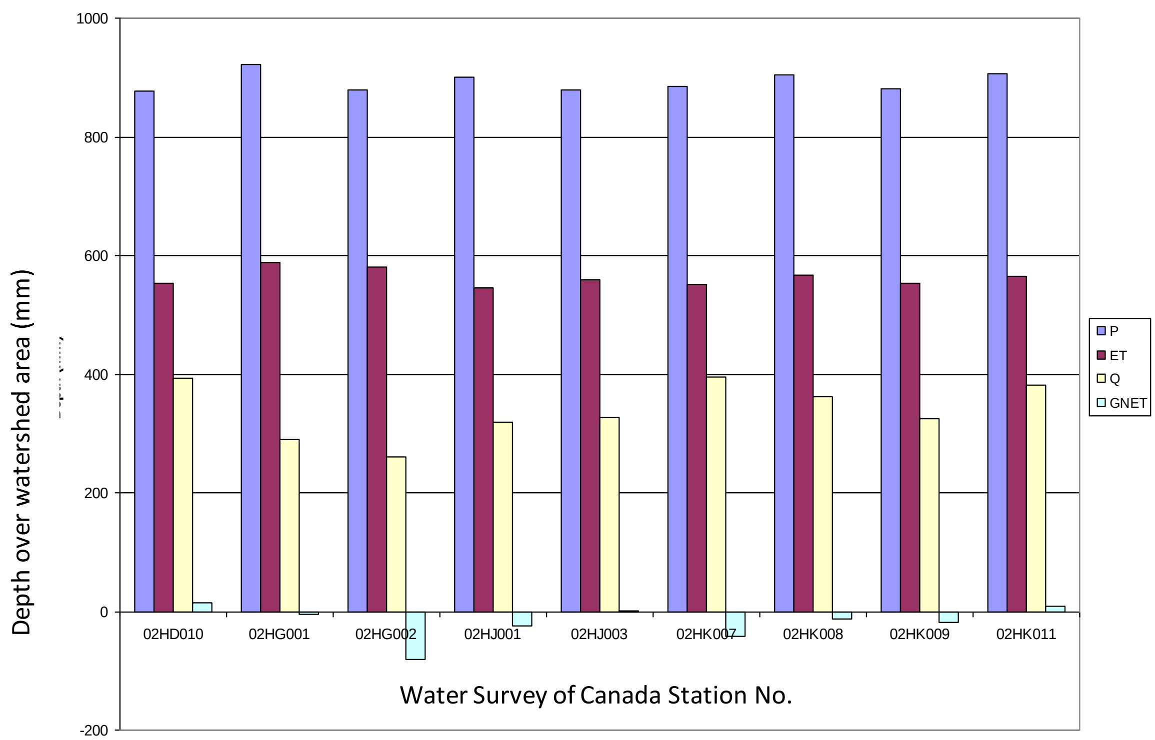

Figure 3.3-2: Long-term Annual Water Budgets for Southern/Central Basins (Gauged)

3.3.3.1.2 Long-Term Monthly Water Budgets

In a long-term monthly water budget, the change in storage (ΔS) cannot be ignored because it varies throughout the year. Except in special cases, the change in storage (ΔS) cannot be estimated and must be determined as the difference between the inputs and outputs of the water budget equation. Accordingly, in the long-term average monthly case, the change in storage term (ΔS) was taken to include both the change in storage and the water budget residual.

3.3.3.2 UNGAUGED SUBWATERSHEDS

Water budgets for ungauged subwatersheds were estimated using a simulation model that was set up and calibrated to gauged data. The model results obtained from the calibration of the gauged subwatersheds were then extrapolated to ungauged subwatersheds. The model used for this purpose was a hydrological model based on the CANWET model platform. CANWET v.3 is a GIS-based, water balance, nutrient, and sediment modeling tool based on the Generalized Watershed Loading Function (Haith et al., 1992) and adapted from the ArcView Generalized Watershed Loading Function model platform (Evans et al., 2002), with numerous enhancements and customizations for use in Canadian conditions.

The simulation objective was to apply the findings from the model calibration on a case-by-case basis to the ungauged subwatersheds. The results of the simulation were then compared against the regional streamflow normal (average) for verification purposes (described below). In a case of significant difference, the results from the streamflow normal were used for the water budget analysis.

3.3.3.2.1 Comparison of Flows

Comparison of flows from the available gauges suggested regional trends in flow characteristics. The gauges used in the verification were divided into categories based on location and degree of regulation: southern less regulated, central less regulated, northern regulated, and northern less regulated. The long-term average flows (hydrographs) from stream gauges in the study area are shown in Figures 3.3-3 to 3.3-5. It can be seen from these figures that there are distinct differences in the hydrograph shapes among different regions of the study area. Each simulated subwatershed was evaluated to determine the most appropriate category of gauges to use for verification. The classification of subwatersheds into one of three regions is also supported by the regional geology, regional climate, and regional ecological zones.

The hydrographs were used to verify the simulation results for the ungauged subwatersheds. The intent was that if the simulated annual hydrographs fell between the 10^{th} and 90^{th} percentiles for each month, the simulation was more likely to represent the flow regime of the subwatershed on an average annual basis. Using the average data from multiple gauges allowed for the smoothing of any errors in the gauge records.

3.3.3.2.2 Development of Monthly Water Budgets for Ungauged Subwatersheds

The model calibration provided a set of model parameters for each of the 11 conceptual water budget subwatersheds (which are further broken up into the 47 tier 1 subwatersheds). The parameter sets included groundwater recession coefficients, unsaturated leakage factor, snow melt factor, curve number adjustment factors, and evapotranspiration adjustment factors. These parameters influence the shape of the hydrograph and the distribution of flow between direct runoff and groundwater flow.

In general, the parameter set generated for a conceptual water budget subwatershed was applied to the Tier 1 subwatersheds located within it. In many cases, minor adjustments were made to the parameter set for each Tier 1 subwatershed to bring evapotranspiration amounts generated by the model into agreement with the target evaporation for each subwatershed as determined in the conceptual water budget (see Section 3.2.2.5). For Tier 1 subwatersheds where Conservation Authority Moraine Coalition model coverage was available, groundwater seepage was set to the annual value from the model and judgment was made on its monthly distribution.

The base parameter sets used, the adjustments made to each Tier 1 subwatershed model, and the validation data used to check the resulting simulations are summarized in Table 3.3-2. For each ungauged subwatershed, the table indicates the gauged subwatersheds used for the selection of model parameters and the regional hydrograph used to verify the results.

Simulated results were used to generate water budgets for all subwatersheds except the highly regulated subwatersheds in the Gull River watershed and the Mississauga River subwatershed in Kawartha Lakes East. For these subwatersheds, regional flow relations that were developed based on basins of a similar nature (i.e., highly regulated or natural/less regulated) in southern, central, and northern regions of the study area were used. Long-term monthly water budgets for all ungauged (Tier 1) subwatersheds are given in Appendix C.

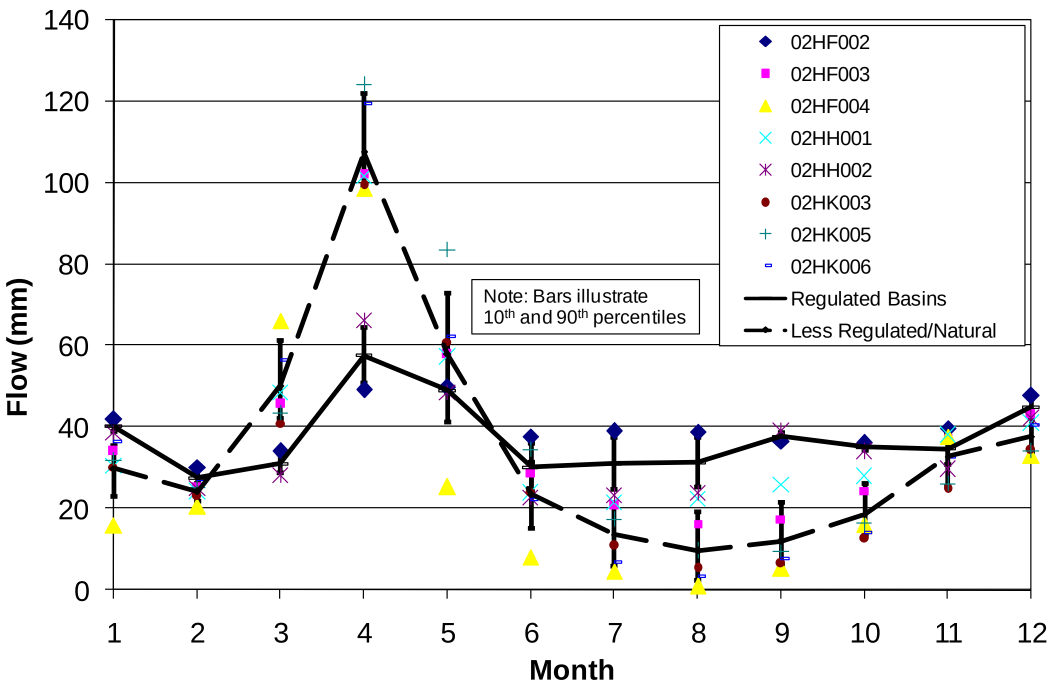

Figure 3.3-3: Long-term Mean Monthly Flow (Northern Basins)

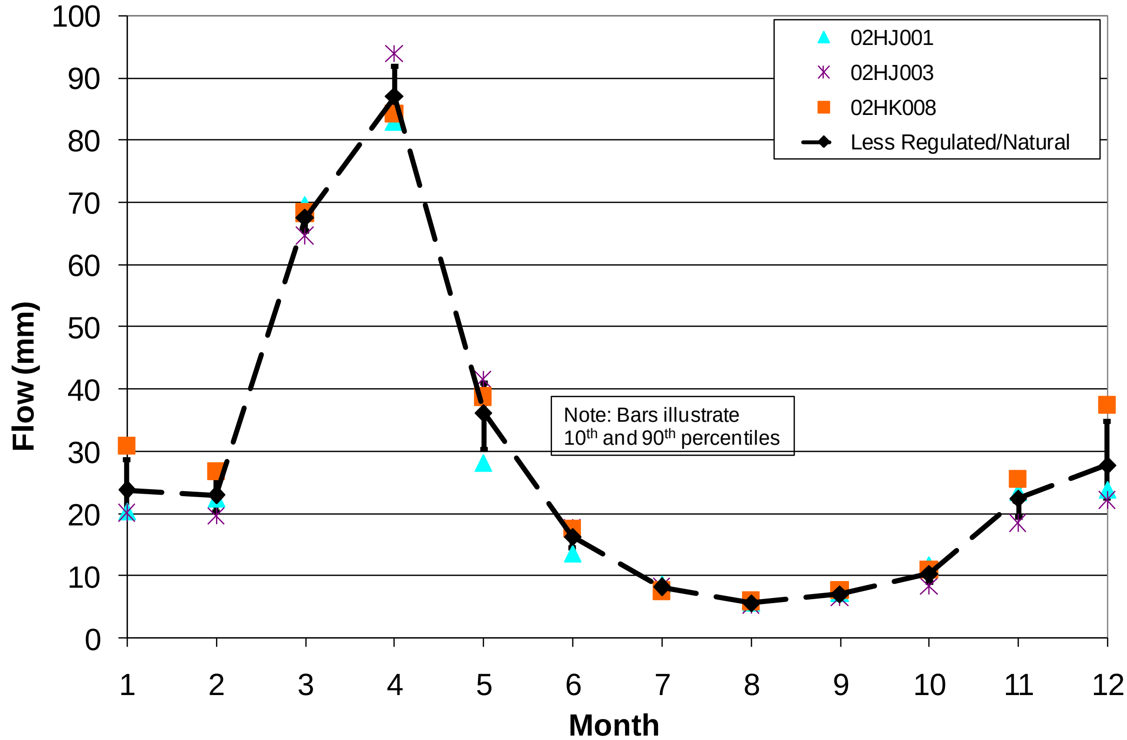

Figure 3.3-4: Long-term Mean Monthly Flow (Central Basins)

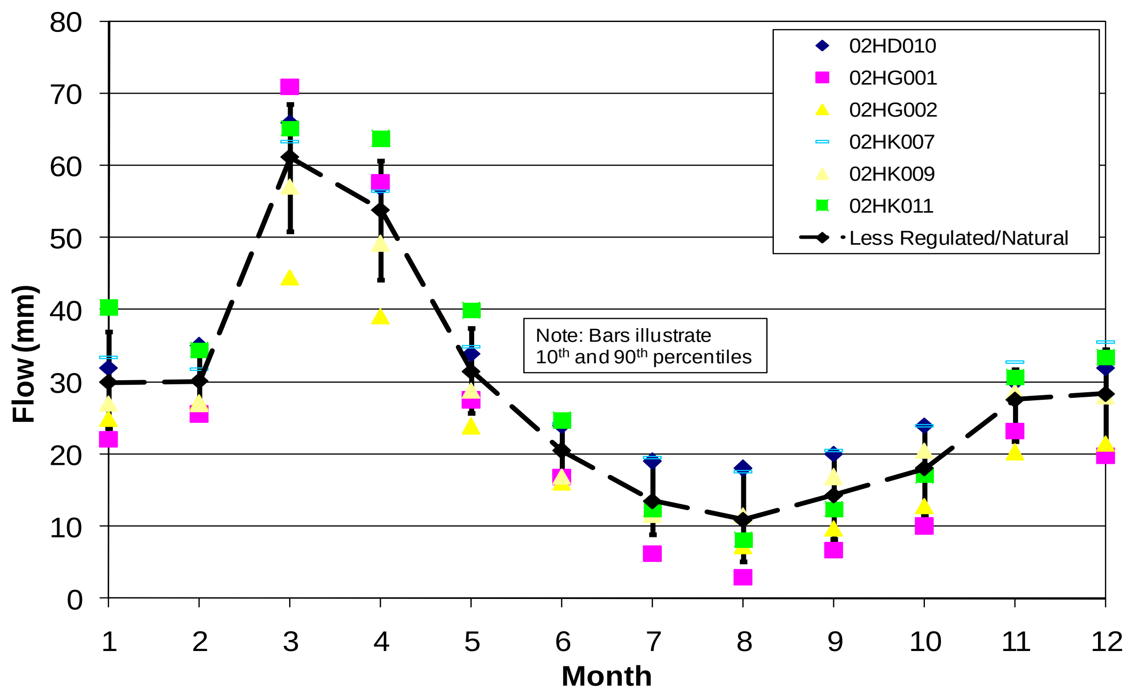

Figure 3.3-5: Long-term Mean Monthly Flow (Southern Basins)

Table 3.3-2: Summary of Simulations for Tier 1 Subwatersheds

Conceptual Subwatershed	Tier 1 Subwatershed	Subwatersheds used for Parameter Selection and Modifications to Base Parameter Set	Regional Hydrograph for Interdecile Range Check[3]
Gull River	Gull1 Gull2 Gull3 Gull4 Gull5 Gull6	-Northern regulated basins; regional streamflows applied	
Burnt River	Burnt1 Burnt2 Burnt3 Burnt4 Burnt5 Burnt6	-Burnt River near Burnt River (02HF003)	Northern less regulated/natural basins.
Kawartha Lakes East	KLE1 KLE2	-Eels Creek Below Apsley (02HH001)	Northern less regulated/natural basins.
	KLE3 KLE5	-Averages for central basins[1] -Reduced water taking from Peterborough and Lakefield WTPs by distributing it over the upstream subwatershed area	Central less regulated/natural basins.
	KLE4	-Northern regulated basin; regional streamflow applied	
Crowe River	Crowe1 Crowe4 Crowe5	-Crowe River at Marmora (02HK003) -Small modifications were made on CN Adj. for April and May by decrease of 0.1	Central less regulated/natural basins.
	Crowe2 Crowe3	-Crowe River at Marmora (02HK003) -Small modifications were made for CN Adj. in April and May by decrease of 0.1	Northern less regulated/natural basins.
Northern Kawartha Lakes West	N-KLW2 N-KLW3 N-KLW5 N-KLW6	-Averages for central basins[1]	Central less regulated/natural basins.
	N-KLW4	-Northern regulated basin; regional streamflow applied	
	N-KLW1	-Eels Creek Below Apsley (02HH001)	Northern less regulated/natural basins
Rice Lake	Rice1	-Averages for central basins[1]	Central less regulated/natural basins.
Ouse River	Ouse1 Ouse2 Ouse3	-Averages for central basins[1]	Central less regulated/natural basins.
Southern Kawartha Lakes West	S-KLW1 S-KLW2 S-KLW3	-Averages for southern basins[2] -Small modifications were made on GW recession values for Jan. and Feb. by increase of 0.01	Southern less regulated/natural basins.
Lower Trent	LT1 LT2 LT3 LT4	-Averages for southern basins[2] -Small modifications were made on GW recession values for Jan. and Feb. by increase of 0.01	Southern less regulated/natural basins.
Lake Ontario Tributary - Shelter Valley Brook	SVC1 SVC2 SVC3	-Averages for southern basins[2]	Southern less regulated/natural basins.
Lake Ontario Tributary - Proctor Creek	PROCTOR1 PROCTOR2 PROCTOR3	-Averages for southern basins[2] -Small modifications were made on GW recession values for Jan. and Feb. by increase of 0.01	Southern less regulated/natural basins.
Bay of Quinte Tributaries	BQ1 BQ2	-Averages for southern basins[2] -Small modifications were made on CN Adj. Jan, Feb and Dec. CN Adj. were decreased by 0.03, Mar. and Apr. CN Adj. were decreased by 0.05 and 0.09, respectively.	Southern less regulated/natural basins.

[1]Ouse River near Westwood (02HJ003); Jackson Creek at Peterborough (02HJ001)

[2]Nonquon River near Port Perry (02HG002); Mariposa Brook near Little Britain (02HG001); Cold Creek at Orland (02HK007); Burnley Creek above Warkworth (02K009); Shelter Valley Brook near Grafton (02HD010)

[3]The interdecile range is the difference between the 90th and 10th percentiles of the average monthly streamflow values for th e subwatersheds in a particular sub region/class (e. g., "northern/natural")

3.3.3.3 UNCERTAINTY IN WATER BUDGETS

The calculation of water budget demand and assignment of water quantity stress levels involved several sources of uncertainty. The values given for the individual components of the water budget are estimates. There is more than one method that can be used to estimate any given component and the uncertainty generally varies from method to method.

The sources of uncertainty for the various methods used to estimate the components of the water budget equation are listed in Table 3.3-3. A qualitative estimate of the uncertainty for each method is also provided: qualitative uncertainty is assigned an integer value from 1 to 5, where 1 corresponds to low uncertainty, 3 to average uncertainty, and 5 to high uncertainty.

Table 3.3-3: Uncertainty in Water Budget Components

Component	Estimation Method	Uncertainty Sources	Uncertainty Scores	
			Average Annual Water Budget	Average Monthly Water Budget
Precipitation (P)	Areally gridded	Gauge bias, sampling error	2	3
	Model-single station	Gauge bias and areal variation, sampling error	3	3
Evapotranspiration (ET)	Model-gridded, Penman	Model error, parameter error, sampling error	2	3
	Model-single station, Hamon	Model error, parameter error and areal variation, sampling error	3	3
Streamflow (Q)	Measured - WSC hydrometric station	Occasional rating curve bias, sampling error	1	2
	Measured - other hydrometric station	Rating curve bias, sampling error	2	2
	Streamflow simulation model	Model error, parameter error, sampling error	3	3
Net Groundwater (G_{net})	Groundwater model	Model error and parameter error	4	5
	Assumed to be zero	Assumption	5	5

3.3.4 SUPPLY AND RESERVE

Water quantity stress in the subwatersheds in the study area was evaluated on the basis of percent water demand. The percent water demand is the ratio of demand to supply in a subwatershed, given by the following equation:

$$\text{Percent Water Demand} = \frac{Q_{Demand}}{Q_{Supply} - Q_{Reserve}} \times 100$$

Where: Q_{Demand} = consumptive water demand (sum of all anthropogenic water takings in the subwatershed)
Q_{Supply} = water supply (amount of water flowing through a subwatershed)
$Q_{Reserve}$ = water reserve (amount excluded from supply for anthropogenic and ecological needs).

The difference of supply and reserve (i.e., Q_{Supply} - $Q_{Reserve}$) is termed the available water. The calculation of water supply and reserve for surface and groundwater is discussed below. Demand (Q_{Demand}) is discussed in Section 3.3.5, and the calculation of percent water demand and assignment of water quantity stress levels are discussed in Section 3.3.6.

3.3.4.1 SURFACE WATER

For surface water, water supply (Q_{Supply}) was defined as the 50th percentile flow (i.e., the median flow: the flow expected 50% of the time), and reserve ($Q_{Reserve}$) was defined as the 10th percentile flow (i.e., the flow exceeded on average 90% of the time). Water supply and reserve for surface water were determined using non-parametric statistics generated from monthly streamflow data or estimated from a hydrological model. A conservative estimate of total available surface water was calculated by subtracting the reserve from the supply.

There are 19 subwatersheds in the study area that have sufficiently long streamflow records to directly calculate monthly supply and reserve. Supply and reserve for these subwatersheds are provided in Appendix C.

*The **Nash–Sutcliffe statistic** is used to assess the predictive power of hydrological models. Nash–Sutcliffe efficiencies can range from negative infinity to 1. An efficiency of 1 corresponds to a perfect match of modeled discharge to the observed data. An efficiency of 0 indicates that the model predictions are as accurate as the mean of the observed data. An efficiency less than zero occurs when the observed mean is a better predictor than the model. Essentially, the closer the model efficiency is to 1, the more accurate the model is.*

For ungauged subwatersheds, monthly values of supply and reserve were determined using a combination of a CANWET simulation model and the regional streamflow normal.

Two summary statistics were used to assess the reliability of the mean monthly flows simulated by the CANWET model for gauged subwatersheds:

- Ratio of simulated mean monthly flow to observed monthly flow for each month for each subwatershed
- Nash-Sutcliffe statistic for each month for each subwatershed.

The ratio statistic showed that, except for highly regulated subwatersheds such as the Gull River, the CANWET model provided a satisfactory estimate of long-term monthly mean streamflow. However, the Nash-Sutcliffe statistic showed that, in general, the CANWET model could not simulate the variation in monthly flows sufficiently to provide reliable estimates of supply and reserve values. Accordingly, supply and reserve were not calculated directly from the CANWET model. Rather, the estimates provided by the model were corrected using an adjustment factor. Based on the summary statistics, ungauged subwatersheds were divided into the following two categories, and the adjustment factor supply was calculated differently for each category:

- **Type A:** Ungauged subwatersheds where the ratio statistic for most months indicated that the model could not simulate monthly mean values of streamflow. For these cases, the CANWET model was used to estimate the long-term annual streamflow. The CANWET estimate was then divided by the regional long-term annual streamflow normal to develop an adjustment factor (in percent).
- **Type B:** Ungauged **s**ubwatersheds where the Nash-Sutcliffe statistic indicated that the model could simulate monthly mean values of streamflow, but not percentiles. For these cases, the CANWET model was used to estimate the mean monthly streamflow. The CANWET estimates were then divided by the regional monthly streamflow normal to develop a monthly adjustment factor.

The supply and reserve for ungauged subwatersheds were calculated by multiplying the adjustment factors by the regional streamflow normal. The monthly supply and reserve calculations and their difference (i.e., supply minus reserve) for each subwatershed are provided in Appendix C.

Municipal Surface Water Intakes

There are 15 municipal surface water intakes in the study area. For each of these intakes, a stress assessment was completed for the entire watershed draining to that intake (hereafter referred to as "intake-defined watershed"). In most cases, intakes were sufficiently close to a hydrometric station that the supply and reserve values (i.e., the 50th and 10th percentile flows) for the gauged watersheds could be taken, without adjustment, as the estimates for the intake. In one case (Lindsay), data from a non-WSC (Water Supply of Canada) hydrometric station were used to calculate supply and reserve. In the remaining three cases (Fenelon Falls, Southview Estates, and Bobcaygeon), supply and reserve were taken as weighted estimates of hydrometric station values and Lindsay estimates. Gauges and gauge weights for these three systems are listed in Table 3.3-4. The resulting monthly supply and reserve calculations for intake-defined watersheds are provided in Appendix C.

Table 3.3-4: Gauges used for Municipal Surface Water Intakes at Fenelon Falls, Southview Estates & Bobcaygeon

Municipal Intake	Gauge Used for Supply and Reserve	Gauge Weight (%)
Fenelon Falls	Gull River at Norland	40
	Burnt River near Burnt River	60
Southview Estates	Gull River at Norland	29
	Burnt River near Burnt River	49
	Estimates from Lindsay Dam	22
Bobcaygeon	Gull River at Norland	27
	Burnt River near Burnt River	53
	Estimates from Lindsay	20

3.3.4.2 GROUNDWATER

For groundwater, water supply (Q_{Supply}) was defined as the sum of groundwater recharge and lateral groundwater flow into a subwatershed. Groundwater recharge was estimated by reviewing several independent estimates, including those from baseflow estimation and from a calibrated groundwater model. Previous work on recharge considered for this groundwater supply assessment is summarized in Table 3.3-5. The table includes estimates of recharge and baseflow index from various sources.

Recharge values for gauged subwatersheds were estimated in two ways: using the Conservation Authorities Moraine Coalition groundwater flow model and a baseflow index method (i.e., multiplying the best available estimate of baseflow index by the mean annual runoff). Where available, estimates obtained from a groundwater flow model were used as the final recharge values. Otherwise, the baseflow index method was used. The estimates of recharge and the final values selected for ungauged subwatersheds are identified in Table 3.3-6. The table also includes estimates of groundwater inflow.

Annual groundwater supply was calculated for each subwatershed as the sum of the final recharge estimate and the groundwater inflow for that subwatershed. Monthly groundwater supply was estimated by dividing the annual value by 12. Groundwater reserve ($Q_{Reserve}$) was calculated as 10% of the monthly supply. The monthly supply and reserve calculations are provided by subwatershed in Appendix C.

Table 3.3-5: Regional Recharge and Baseflow Information

Tertiary Drainage[1]	USGS 2005 Name[2]	WSC Station #	Station Name	Recharge[3]	Baseflow Index		
				Neff et al. (2005b)	Neff et al. (2005a)	Moin & Shaw[4] (1986)	Morrison (2004)
2HD	Central Lake Ontario Tributaries	02HD010	Shelter Valley Brook near Grafton	277	0.52	N/A	0.70
2HF	Haliburton	02HF002	Gull River at Norland	300	0.56	0.86	0.80
		02HF003	Burnt River near Burnt River			0.66	0.66
		02HF004	Bob Creek near Minden			0.32	0.62
2HG	Scugog	02HG001	Mariposa Brook near Little Britain	191	0.43	N/A (0.46)	0.54
		02HG002	Nonquon River near Port Perry			N/A	N/A
2HH	Kawarthas	02HH001	Eels Creek below Apsley	246	0.49	0.64	0.72
		02HH002	Mississagua River below Mississagua Lake			0.65	0.64
2HJ	Otonabee	02HJ001	Jackson Creek at Peterborough	196	0.43	0.40 (0.45)	0.66
		02HJ002	Otonabee River at Lakefield			0.70	0.66
		02HJ003	Ouse River near Westwood			0.62	0.65
2HK	Crowe-Trent	02HK002	Trent River at Healey Falls	264	0.53	0.70	0.65
		02HK003	Crowe River at Marmora			0.66	0.60
		02HK004	Trent River at Glen Ross			0.74	0.66
		02HK005	Crowe River near Glen Alda			0.76	0.67
		02HK006	Beaver Creek near Marmora			0.62	0.69
		02HK007	Cold Creek at Orland			0.69 (0.62)	0.62
		02HK008	Rawdon Creek near West Huntington			N/A	0.75
		02HK009	Burnley Creek above Warkworth			N/A	0.64
		02HK011	Mayhew Creek near Trenton			N/A	0.58

[1] Tertiary subwatershed designation per federal (Water Survey of Canada) standards
[2] Name assigned to drainage area by Neff et al. (2005a, b)
[3] Converted from inches to millimeters
[4] Values in parentheses are updates by McLean (2002)

Table 3.3-6: Recharge and Groundwater Inflow Estimates for Tier 1 Subwatersheds

CANWET Major Drainage	Tier 1 Subwatershed	Recharge (Neff et al. 2005b) (mm)	Baseflow Index Method			Model Recharge[4] (mm)	Lateral Groundwater Inflow[5] (mm)	Final Recharge Estimate (mm)
			Selected Baseflow Index[1]	Mean Annual Runoff[2] (mm)	BFI Recharge[3]			
Gull	Gull 1	300	0.32	508	**163**		0	165
	Gull 2			497	**159**		0	160
	Gull 3			497	**159**		0	160
	Gull 4			484	**155**		0	155
	Gull 5			496	**159**		0	160
	Gull 6			488	**156**		0	155
Burnt	Burnt 1	300	0.32	424	**136**		0	135
	Burnt 2			455	**146**		0	145
	Burnt 3			397	**127**		0	130
	Burnt 4			457	**146**		0	145
	Burnt 5			467	**149**		0	150
	Burnt 6			463	**148**		0	150
Crowe	Crowe 1	264	0.32	364	**116**		0	115
	Crowe 2			398	**127**		0	130
	Crowe 3			428	**137**		0	140
	Crowe 4			364	**116**		0	115
	Crowe 5			384	**123**		0	125
Kawartha Lakes West (North & Central)	KLW-N 1	191	0.43	382	**164**		0	165
	KLW-N 2			351	**121**		0	120
	KLW-N3			344	**148**		0	150
	KLW-N4			370	159	**61**	4	60
	KLW-N5			353	152	**57**	4	60
	KLW-N6			321	138	**36**	3	35
Kawartha Lakes West (South)	KLW-S 1	246	0.43	326	**140**	193	14	140
	KLW-S 2			300	129	**119**	47	120
	KLW-S 3			365	157	**159**	42	160
Kawartha Lakes East	KLE 1	246	0.32	369	**118**		0	120
	KLE 2			412	**132**		0	130
	KLE 3			378	**121**		4	120
	KLE 4			396	**127**		0	130
	KLE 5			328	105	**56**	0	55
Rice Lake	Rice Lake	196	0.43	328	141	**111**	13	110
Ouse	Ouse 1	196	0.43	329	142	**88**	18	90
	Ouse 2			344	148	**61**	10	60
	Ouse 3			295	127	**47**	16	50
Lower Trent	Lower Trent 1	264	0.53	311	165	**107**	9	110
	Lower Trent 2			319	169	**60**	19	60
	Lower Trent 3			359	190	**77**	12	80
	Lower Trent 4			332	176	**101**	16	100
Lake Ontario (Drains from Lake Iroquois Plain)	Lake Ontario 1	277	0.52	397	207	**101**	80	100
	Lake Ontario 2			431	224	**72**	84	70
	Lake Ontario 3			346	180	**64**	27	65
Shelter Valley (Drains off Oak Ridges Moraine/South Slope)	Shelter Valley 1	277	0.52	319	166	**143**	110	145
	Shelter Valley 2			362	188	**178**	96	180
	Shelter Valley 3			326	169	**138**	85	140
Bay of Quinte (Drains to Bay of Quinte)	Bay of Quinte 1	277	0.52	360	187	**56**	13	55
	Bay of Quinte 2			344	179	**56**	11	55

*Bold values indicate the representative recharge value selected for the subwatershed (note that final recharge values were rounded)
[1] Indicates the baseflow index value selected as representative of the subwatershed
[2] Estimated from CANWET model
[3] Calculated as the product of Selected Baseflow Index and Mean Annual Runoff
[4] Estimated from CAMC-YPDT model
[5] Long-term average annual lateral groundwater inflow (calculated from groundwater model where available, assumed to be zero, or based on professional judgement)

3.3.5 DEMAND

Water demand includes water takings that require a permit and those that do not require a permit. Both existing and future demands were also estimated.

3.3.5.1 PERMITTED WATER TAKINGS

All water takings exceeding 50,000 L/day are required to obtain a Permit to Take Water from the Ministry of the Environment and Climate Change. The Ministry maintains a database of all permit holders throughout the province. The quantities in the database are generally presented as maximum permitted takings and therefore generally overestimate the actual usage. In many cases (particularly for municipal water supplies) there are data on actual pumping rates; where these data exist, existing permitted demand was represented by the actual taking. Permitted takings are partitioned into ground and surface water sources in the database. The October 2006 Permit to Take Water database as provided by the Ministry of Natural Resources and Forestry was used for this analysis.

Existing permitted demands in the study area were estimated for each subwatershed based on the Permit to Take Water database values multiplied by the appropriate consumptive and seasonal use factors (discussed below). Permitted water takings used for the Tier 1 water budget are summarized in Appendix C.

3.3.5.1.1 Consumptive Use

The intent of the stress assessment is to consider only consumptive use of water. For commercial uses such as water bottlers, the takings are 100% consumptive (i.e., none of the water is returned to the source). However, for most other types of takings, the use is not 100% consumptive (i.e., in a municipal water supply, water is withdrawn from the source but returned again after treatment in a municipal sewage treatment facility).

Default consumptive use factors were provided in the 2006 Permit to Take Water database. In some cases (e.g., wetlands, wildlife conservation, hydro power generation, etc.), professional judgment was applied to override the default consumptive use factors.

3.3.5.1.2 Seasonal Use

Many permit holders, such as golf course operators, do not require water at the same rate throughout all months of the year. For these cases, seasonal use factors were applied to reflect the seasonal distribution of the water use (adjustments were provided in the provincial guidance module for water budgets (Ministry of the Environment and Climate Change, 2007) as a series of monthly values set to either zero or one). The total annual permitted taking was divided by the number of months of takings to more accurately estimate monthly demand.

3.3.5.2 UNPERMITTED WATER TAKINGS

There are two major categories of non-permitted water use, which must also be considered in the calculation of total demands. These are non-serviced residential demand and agricultural demand (less than 50,000 L/day). The approach for estimating these types of water use is discussed below.

3.3.5.2.1 Unserviced Residential Demand

Unserviced residential demand includes domestic water use by people living in unserviced areas. To determine the extent of this demand by subwatershed, the delineation of serviced and non-serviced land areas was determined based on available servicing mapping provided by municipalities. Population data from the 2006 census were available from Statistics Canada. Using GIS mapping techniques, the unserviced population was estimated by subwatershed and multiplied by a conservative per-capita water use rate given in the provincial guidance module for water budgets (335 litres/day/person) (Ministry of the Environment and Climate Change, 2007).

3.3.5.2.2 Agricultural Demand

Estimates of agricultural water use were generated for the study area from a spatial database generated by de Löe (2002) for the Ministry of Natural Resources and Forestry, which summarized agricultural water use for all Quaternary watersheds in Ontario. As this database contains all agricultural takings, any permitted agricultural takings in a subwatershed were subtracted from this total to determine the unpermitted takings.

The attributes in the spatial database were generally used as follows:

- LIVESTOCK demand was evenly distributed across all months
- SEASONAL or IRR_SUM was evenly distributed across June, July, and August.

3.3.5.2.3 Sources and Consumptive Factors for Unpermitted Water Takings

Unpermitted takings must be assigned to either a groundwater or surface water source. The sources for domestic and agricultural takings were distributed as follows:

- Gull, Burnt, North Kawartha Lakes West, Kawartha Lakes East, Ouse, and Crowe River subwatersheds were assumed to have a source split of 50% - 50% (surface water/groundwater source)
- All takings in the southern subwatersheds were assumed to have a 100% groundwater source.

Further, unpermitted takings were adjusted with consumptive factors (the consumptive factor of a water taking indicates the proportion of water that is not returned to the source). The following consumptive factors were used for unpermitted takings:

- Domestic demand: 0.2 (consistent with the consumptive factor for municipal supplies)
- Agricultural demand: 0.8 (rounded up from the 0.78 as suggested by de Löe (2002).

3.3.5.3 FUTURE CONDITIONS

Water demands in the future were also estimated as part of the water quantity stress assessment. Future water demand was estimated by scaling up existing demand in proportion to the estimated future population. Future population was estimated from population projection data by county provided by the Ministry of Finance. The existing and future demand calculations are provided in full by Tier 1 subwatershed in Appendix C.

3.3.6 WATER QUANTITY STRESS

Water quantity stress in the subwatersheds in the study area is evaluated on the basis of percent water demand. The percent water demand is the ratio of demand to supply in a subwatershed, which is given by:

$$\text{Percent Water Demand} = \frac{Q_{Demand}}{Q_{Supply} - Q_{Reserve}} \times 100$$

Where: Q_{Demand} = consumptive water demand (sum of all anthropogenic water takings in the subwatershed)
Q_{Supply} = water supply (amount of water flowing through a subwatershed)
$Q_{Reserve}$ = water reserve (amount excluded from supply for anthropogenic and ecological needs).

The percent water demand was calculated for each subwatershed in the study area and compared to stress thresholds provided in the *Technical Rules*. Stress thresholds are different for groundwater and surface water. The assignment of water quantity stress levels to surface water and groundwater is discussed below. Subwatersheds with moderate or high water quantity stress levels are shown on Maps 3-33 and 3-34.

3.3.6.1 SURFACE WATER

For surface water, the calculation of percent water demand was done on a monthly basis. The maximum monthly percent water demand was then determined (expected to almost exclusively fall within the late summer or early fall months) and assigned a water quantity stress level in accordance with the surface water stress thresholds given in Table 3.3-7. The percent water demand and surface water stress levels under both current and future demand conditions for all subwatersheds are listed in Table 3.3-9. The stress results for intake-defined watersheds are listed in Table 3.3-10.

3.3.6.2 GROUNDWATER

For groundwater, the calculation of percent water demand was done on an average annual and average monthly basis. The annual average and maximum monthly percent water demand were then assigned a water quantity stress level in accordance with the groundwater stress thresholds given in Table 3.3-8. The percent water demand and groundwater stress levels under both current and future demand conditions for all Tier 1 subwatersheds are listed in Table 3.3-11.

Table 3.3-7: Surface Water Stress Thresholds

Surface Water Stress Level	Maximum Monthly Percent Water Demand
Low	< 20
Moderate	20 – 50
Significant	> 50

Table 3.3-8: Groundwater Stress Thresholds

Groundwater Stress Level	Percent Water Demand	
	Average Annual	Max. Monthly
Low	< 10	< 25
Moderate	10 - 25	25 - 50
Significant	> 25	> 50

3.3.6.3 UNCERTAINTY IN WATER QUANTITY STRESS

The calculation of percent water demand and assignment of water quantity stress levels involved several sources of uncertainty. The uncertainty of the stress assessment for each subwatershed was characterized as either high or low. The uncertainty of surface water stress levels is indicated for all subwatersheds in Table 3.3-9 and for intake-defined watersheds in Table 3.3-10. The uncertainty of groundwater stress levels is indicated for all subwatersheds in Table 3.3-11. The assignment of uncertainty in water quantity stress levels is discussed below.

Uncertainty is particularly important where a subwatershed has been assigned a low stress level and the percent water demand estimate is near the threshold for moderate stress.

Two cases were considered for the assignment of uncertainty:

- **Case 1**: Subwatersheds with a moderate stress level that could be low due to uncertain demand values
- **Case 2**: Subwatersheds with a low stress level that could be moderate due to uncertain supply, reserve, and demand values.

The cases differ in that the first case can easily be identified but the second case cannot. Accordingly, uncertainty was identified using different methods for each case.

3.3.6.3.1 Case 1 Uncertainty

For Case 1, all subwatersheds with moderate or high stress levels were identified. For each of these subwatersheds, the estimates of available water ($Q_{Supply} – Q_{Reserve}$) and demand (Q_{Demand}) were checked for uncertainty. Those cases of high uncertainty are identified and the subwatershed or intake-defined watershed is assigned an uncertainty score of high.

3.3.6.3.2 Case 2 Uncertainty

For Case 2, different methodologies were used for surface water and groundwater sources, as discussed below.

Surface Water Sources

A sensitivity analysis was conducted in which percent water demand was recalculated under five scenarios:

- **Scenario 1**: Q_{Demand} for subwatersheds was doubled for existing conditions
- **Scenario 2**: Q_{Demand} for intake locations was doubled for future conditions
- **Scenario 3**: Q_{Supply} - $Q_{Reserve}$ for subwatersheds and for intake locations was reduced by 50%
- **Scenario 4**: Scenario 1 + Scenario 3
- **Scenario 5**: Scenario 2 + Scenario 3.

For all subwatersheds and/or intake-defined watersheds where any one scenario resulted in a change in stress level from low to moderate, calculations of Q_{Demand} and Q_{Supply} - $Q_{Reserve}$ were checked to determine whether the estimates were deemed reasonable or not. The uncertainty level was assigned accordingly.

Groundwater Sources

A sensitivity analysis was conducted in which percent water demand was recalculated under three scenarios:

- **Scenario 1**: Q_{Demand} for subwatersheds was doubled for existing conditions
- **Scenario 2**: Q_{Demand} for withdrawal locations was doubled for future conditions
- **Scenario 3**: Q_{Supply} - $Q_{Reserve}$ for all subwatersheds was reduced by 50 %.

For all subwatersheds where any one scenario resulted in a change in stress level from low to moderate, calculations of Q_{Demand} and Q_{Supply} - $Q_{Reserve}$ were checked to determine whether the estimates were deemed reasonable or not. The uncertainty level was assigned accordingly.

Table 3.3-9: Surface Water Stress Summary: Tier 1 Subwatersheds

Tier 1 Subwatershed	Critical Stress					Uncertainty
	Month	Current Demand Scenario		Future Demand Scenario		
		% Water Demand	Stress Level	% Water Demand	Stress Level	
Gull 1	August	0	Low	0	Low	Low
Gull 2	August	0.1	Low	0.1	Low	Low
Gull 3	August	0	Low	0	Low	Low
Gull 4	August	0.01	Low	0.01	Low	Low
Gull 5	August	4	Low	4	Low	Low
Gull 6	August	0.4	Low	0.5	Low	Low
Burnt 1	August	2	Low	2	Low	Low
Burnt 2	August	19	Low	23	Moderate	Low
Burnt 3	August	0.2	Low	0.3	Low	Low
Burnt 4	Sept	2	Low	3	Low	Low
Burnt 5	August	0.2	Low	0.2	Low	Low
Burnt 6	August	0.2	Low	0.2	Low	Low
Crowe 1	Sept	5	Low	6	Low	Low
Crowe 2	August	0.03	Low	0.03	Low	Low
Crowe 3	Sept	2	Low	3	Low	Low
Crowe 4	August	3	Low	3	Low	Low
Crowe 5	August	9	Low	11	Low	Low
KLW-N 1	August	0.2	Low	0.2	Low	Low
KLW-N 2	August	2	Low	2	Low	Low
KLW-N3	August	5	Low	6	Low	Low
KLW-N4	August	9	Low	11	Low	Low
KLW-N5	August	2	Low	2	Low	Low
KLW-N6	August	12	Low	15	Low	Low
KLW-S 1	August	6	Low	7	Low	Low
KLW-S 2	August	5	Low	5	Low	Low
KLW-S 3	August	2	Low	2	Low	Low
KLE 1	August	3	Low	4	Low	Low
KLE 2	August	0.01	Low	0.01	Low	Low
KLE 3	August	1	Low	1	Low	Low
KLE 4	August	0.4	Low	0.4	Low	Low
KLE 5	August	4	Low	5	Low	Low
Rice Lake	August	7	Low	8	Low	Low
Ouse 1	August	5	Low	6	Low	High
Ouse 2	Sept	4	Low	5	Low	Low
Ouse 3	August	9	Low	10	Low	Low
Lower Trent 1	August	0.2	Low	0.3	Low	Low
Lower Trent 2	August	6	Low	7	Low	Low
Lower Trent 3	August	2	Low	2	Low	Low
Lower Trent 4	August	2	Low	3	Low	Low
Lake Ontario 1	August	0	Low	0	Low	Low
Lake Ontario 2	August	0	Low	0	Low	Low
Lake Ontario 3	August	18	Low	22	Moderate	Low
Shelter Valley 1	August	0	Low	0	Low	Low
Shelter Valley 2	August	0	Low	0	Low	Low
Shelter Valley 3	August	0	Low	0	Low	Low
Bay of Quinte 1	August	32	Moderate	39	Moderate	Low
Bay of Quinte 2	August	0	Low	0	Low	Low

Table 3.3-10: Surface Water Stress Summary: Intake-Defined Watersheds

Intake-Defined Watershed	Critical Stress					Uncertainty
	Month	Current Demand Scenario		Future Demand Scenario		
		% Water Demand	Stress Level	% Water Demand	Stress Level	
Norland	August	0	Low	0.3	Low	Low
Kinmount	August	0.01	Low	1	Low	Low
Fenelon Falls	August	4	Low	4	Low	Low
Lindsay	Sept	28	Moderate	33	Moderate	Low
Southview Estates	August	4	Low	4	Low	Low
Bobcaygeon	August	4	Low	5	Low	Low
Lakefield	August	0.06	Low	1	Low	Low
Peterborough	August	2	Low	3	Low	Low
Hastings	August	0.03	Low	1	Low	Low
Marmora	August	0.1	Low	2	Low	Low
Campbellford	August	0.1	Low	1	Low	Low
Warkworth	Nov	2	Low	2	Low	Low
Frankford	Sept	0.04	Low	1	Low	Low
Batawa	August	0.04	Low	1	Low	Low
Trenton	Sept	1	Low	2	Low	Low

Table 3.3-11: Groundwater Stress Summary: Tier 1 Subwatersheds

Subwatershed	Critical Stress								Uncertainty
	Current Demand Scenario				Future Demand Scenario				
	Max. Month	Annual	Max. Month Stress Level	Annual Stress Level	Max. Month	Annual	Max. Month Stress Category	Annual Stress Category	
Gull 1	0	0	Low	Low	0	0	Low	Low	Low
Gull 2	0	0	Low	Low	0	0	Low	Low	Low
Gull 3	0	0	Low	Low	0	0	Low	Low	Low
Gull 4	0	0	Low	Low	0	0	Low	Low	Low
Gull 5	1	1	Low	Low	1	1	Low	Low	Low
Gull 6	0	0	Low	Low	0	0	Low	Low	Low
Burnt 1	0	0	Low	Low	0	0	Low	Low	Low
Burnt 2	2	1	Low	Low	3	1	Low	Low	Low
Burnt 3	0	0	Low	Low	0	0	Low	Low	Low
Burnt 4	0	0	Low	Low	0	0	Low	Low	Low
Burnt 5	0	0	Low	Low	0	0	Low	Low	Low
Burnt 6	0	0	Low	Low	0	0	Low	Low	Low
Crowe 1	3	2	Low	Low	3	2	Low	Low	Low
Crowe 2	0	0	Low	Low	0	0	Low	Low	Low
Crowe 3	0	0	Low	Low	0	0	Low	Low	Low
Crowe 4	5	4	Low	Low	6	5	Low	Low	High
Crowe 5	0	0	Low	Low	0	0	Low	Low	Low
KLW-N 1	1	1	Low	Low	1	1	Low	Low	Low
KLW-N 2	0	0	Low	Low	1	0	Low	Low	Low
KLW-N3	0	0	Low	Low	0	0	Low	Low	Low
KLW-N4	5	3	Low	Low	6	3	Low	Low	Low
KLW-N5	2	1	Low	Low	3	1	Low	Low	Low
KLW-N6	1	1	Low	Low	2	1	Low	Low	Low
KLW-S 1	7	4	Low	Low	8	5	Low	Low	Low
KLW-S 2	3	1	Low	Low	3	1	Low	Low	Low
KLW-S 3	5	4	Low	Low	7	4	Low	Low	Low
KLE 1	0	0	Low	Low	0	0	Low	Low	Low
KLE 2	0	0	Low	Low	0	0	Low	Low	Low
KLE 3	1	0	Low	Low	1	0	Low	Low	Low
KLE 4	1	0	Low	Low	1	1	Low	Low	Low
KLE 5	22	11	Low	Moderate	26	13	Moderate	Moderate	Low
Rice Lake	3	2	Low	Low	4	2	Low	Low	Low
Ouse 1	1	0	Low	Low	1	0	Low	Low	Low
Ouse 2	2	2	Low	Low	3	2	Low	Low	Low
Ouse 3	1	1	Low	Low	2	1	Low	Low	Low
Lower Trent 1	3	1	Low	Low	3	2	Low	Low	Low
Lower Trent 2	6	4	Low	Low	7	5	Low	Low	Low
Lower Trent 3	2	1	Low	Low	2	1	Low	Low	Low
Lower Trent 4	5	3	Low	Low	6	4	Low	Low	Low
Lake Ontario 1	17	13	Low	Moderate	20	16	Low	Moderate	Low
Lake Ontario 2	8	3	Low	Low	10	3	Low	Low	Low
Lake Ontario 3	56	40	Significant	Significant	67	48	Significant	Significant	Low
Shelter Valley 1	4	1	Low	Low	5	1	Low	Low	Low
Shelter Valley 2	1	0	Low	Low	2	1	Low	Low	Low
Shelter Valley 3	8	5	Low	Low	10	6	Low	Low	Low
Bay of Quinte 1	4	2	Low	Low	5	2	Low	Low	Low
Bay of Quinte 2	4	2	Low	Low	5	2	Low	Low	Low

3.3.7 CONCLUSIONS

Surface Water Stress

The Tier 1 water budget and stress assessment summary found that 3 of the 47 Tier 1 subwatersheds in the study area have a moderate or significant stress level (Burnt 2, Lake Ontario 3, and Bay of Quinte 1). These 3 stressed subwatersheds were assigned a low uncertainty. Further, 1 of the 15 intake-defined watersheds was found to have moderate stress level (Lindsay). This intake-based watershed was assigned a low uncertainty.

Groundwater Stress

Most Tier 1 subwatersheds in the study area were found to have a low stress level. The exceptions were the KLE-5 (Kawartha Lakes East-5), Lake Ontario 1, and Lake Ontario 3 subwatersheds, which were found to be either moderate or significant. The uncertainty rating for all groundwater subwatersheds was identified as low, except for the Crowe 4 subwatershed, which was assigned a high uncertainty due to uncertainty in supply.

Subwatersheds for Tier 2 Study

Only subwatersheds that contain a municipal drinking water system require a Tier 2 water budget and water quantity stress assessment. The Tier 1 subwatersheds that were assigned moderate or high stress levels and contain a municipal drinking water system are listed below:

- Lindsay intake-defined watershed (includes all subwatersheds located upstream of the Lindsay dam: KLW-S1, KLW-S2, and KLW-N4)
- Crowe 4 (associated with Havelock municipal wellfield)
- Lake Ontario 1 (associated with Colborne municipal wellfield)
- Lake Ontario 3 (associated with Brighton municipal wellfield).

3.3.8 REFERENCES

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3.4 TIER 2 WATER BUDGET & WATER QUANTITY STRESS ASSESSMENT

The Tier 2 water budget and water quantity stress assessment is intended to look in more detail at the subwatersheds that were assigned a significant or moderate water quantity stress level in the Tier 1 assessment that contain a municipal drinking water system. This is achieved by using complex surface and groundwater flow models to refine the estimates of the water budget components for these subwatersheds. The model predictions are used to reevaluate the water quantity stress levels for these subwatersheds under various demand and drought scenarios, and to assign a final water quantity stress level to each subwatershed.

The Tier 1 assessment flagged the following subwatersheds for a Tier 2 assessment:

- Subwatershed draining to the Lindsay surface water intake
- Subwatershed containing the Havelock municipal wells
- Subwatershed containing the Brighton municipal wells
- Subwatershed containing the Colborne municipal wells.

The boundaries of these subwatersheds are shown on Maps 3-35 to 3-39. The Tier 2 water budgets and water quantity stress assessments for these subwatersheds are discussed in the following sections.

3.4.1 LINDSAY

The Tier 2 water budget and water quantity stress assessment for the subwatershed draining to the Lindsay intake was completed by XCG Consultants Ltd. and documented in the following report:

- *Technical Memorandum 3: Tier 2 Water Budget: Part 1 Lindsay Subwatershed (March 2010).*

This section is a summary of that report.

3.4.1.1 STUDY AREA

The Lindsay subwatershed includes lands that drain to the Lindsay surface water intake. This area includes the Kawartha Lakes West catchments KLW-S1, KLW-S2, and the portion of KLW-N4 located upstream (south) of the Lindsay dam. The Lindsay intake is located in the Scugog River upstream of a dam operated by the Trent-Severn Waterway. The Lindsay subwatershed is shown on Map 3-35.

3.4.1.2 MODEL DEVELOPMENT

A daily hydrological model representing the subwatersheds contributing to the Lindsay intake was developed for the Tier 2 study. The model represented inputs and withdrawals, log settings at the Lindsay dam, outflows, precipitation, evapotranspiration, and groundwater recharge and discharge. For modeling purposes, the Lindsay subwatershed was divided into several discrete areas shown on Map 3-36. The model was configured as a series of linked watershed, channel, and reservoir model elements following the guidelines in the *Hydrology of Floods in Canada-A Guide to Planning and Design* (Watt et al., 1989). The configuration of model elements is shown in Figure 3.4-1 (each element corresponds to one of the discrete areas shown on Map 3-36). Watershed and channel elements were modeled using the hydrologic model HSPF, maintained by the United States Environmental Protection Agency, and the water levels at the Lindsay dam were modeled using RESCOM, a custom reservoir model developed by XCG. Model nodes were placed at the downstream end of each element and at junctions. In consultation with Kawartha Conservation staff, eight watershed elements and one reservoir element were selected. The model nodes are illustrated schematically in Figure 3.4-1.

Data inputs for the models included meteorological data (precipitation and temperature) and log setting. The meteorological data used was an in-filled dataset for the Environment Canada Lindsay Frost meteorological station (#6164433). Model parameters were selected based on flow and snowpack calibration, and professional judgment was made based on available land use, geology, and topography.

The HSPF model was calibrated to flow data from hydrometric stations and snowpack water equivalents measured at Emily Park. The RESCOM model was calibrated to reservoir water level data measured at Caesarea. The level of calibration achieved for Mariposa Brook and the Nonquon River was superior to that in the Tier 1 assessment.

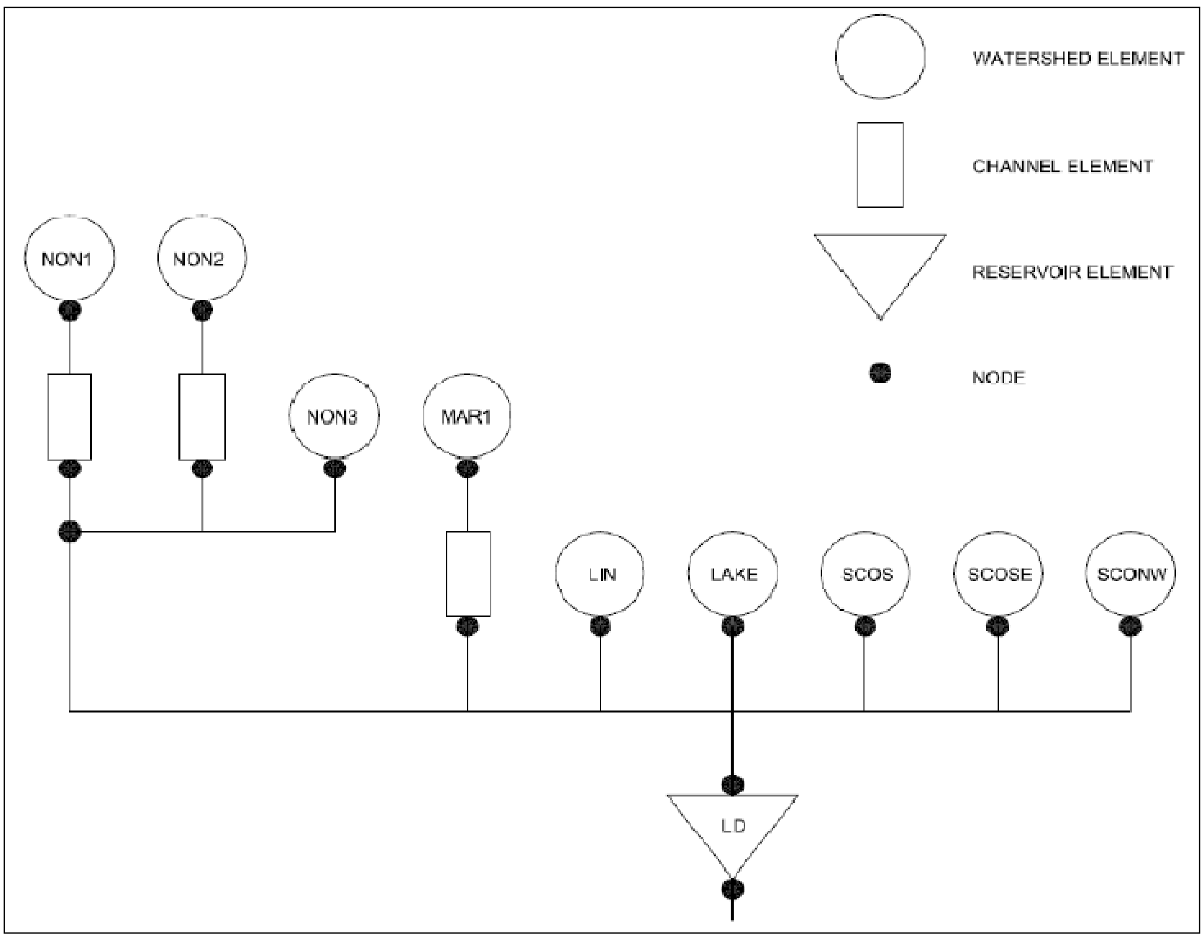

Figure 3.4-1: Schematic of HSPF-RESCOM Model used for Tier 2 Assessment of Lindsay Subwatershed

3.4.1.3 WATER BUDGET

Long-term monthly water budgets were calculated for the Lindsay subwatershed and its catchments using the outputs generated by the HSPF model. The same water budget equation used in the Tier 1 assessment was used for the Tier 2 assessment:

$$P + G_{net} = ET + Q_{net} + \Delta S$$

Where : P = precipitation
G_{net} = net groundwater in
ET = evapotranspiration
Q_{net} = streamflow out
ΔS = change in storage

Long-term monthly water budgets for the Lindsay subwatersheds are shown in Table 3.4-1 to Table 3.4-4. The annual sums are given to the nearest millimetre; the true value for the annual change in storage term (ΔS) is zero (non-zero values are the result of rounding).

3.4.1.4 WATER QUANTITY STRESS ASSESSMENT

The Tier 2 water quantity stress assessment assigns water quantity stress levels to subwatersheds on the basis of the percent water demand and the water level at the Lindsay intake. Percent water demand is given by the following equation:

$$\text{Percent Water Demand} = \frac{Q_{Demand}}{Q_{Supply} - Q_{Reserve}} \times 100$$

Where: Q_{Demand} = consumptive water demand (sum of all anthropogenic water takings in the subwatershed)
Q_{Supply} = water supply (amount of water flowing through a subwatershed)
$Q_{Reserve}$ = water reserve (amount excluded from supply for anthropogenic and ecological needs).

The percent water demand was calculated for the Lindsay subwatershed and its catchments under existing conditions, future conditions, and several drought scenarios. Each scenario was evaluated in accordance with the data restrictions prescribed in the *Technical Rules*, listed in Table 3.4-5.

The *Technical Rules* requires that the calculation of percent water demand be performed using data for the calendar year immediately before the year in which the Terms of Reference was required to be submitted to the Minister (2007, in this case). However, for the Lindsay subwatershed, the data available for 2008 were more comprehensive and accurate than the data for 2007. Thus, the 2008 data were considered to provide a better representation of water usage in the area and were used in the calculation of percent water demand. Director's Approval was obtained for this approach (see Appendix A).

The HSPF-RESCOM model was used to calculate the supply and reserve terms under non-drought scenarios (A & B) and to estimate the water levels at the Lindsay intake for the drought scenarios (D, E, G, & H). The calculation of supply, reserve, and demand, and the assignment of water quantity stress levels in the Lindsay subwatershed are discussed in the following sections.

Table 3.4-1: Long-term Monthly Water Budget: KLW-S1

Month	Water Budget Components (mm)				
	P	ET	G_{net}	Q	ΔS
Jan	35	0.2	-0.9	26.4	7.5
Feb	41	0.2	-1.3	23.5	16
Mar	112	4.5	-3.8	59.9	43.8
Apr	97	37.8	-2.7	61.1	-4.6
May	85	94.5	-1.4	26.6	-37.5
Jun	79	115.4	-0.7	16.1	-53.2
Jul	80	122.6	-0.4	10.8	-53.8
Aug	85	98.9	-0.3	5.5	-19.7
Sep	80	63.8	-0.4	5.1	10.7
Oct	74	29.1	-0.9	9.6	34.4
Nov	79	7.3	-1.8	21.3	48.6
Dec	42	0.8	-1.1	28.9	11.2
Annual	889	575	-16	295	3

Table 3.4-2: Long-term Monthly Water Budget: KLW-S2

Month	Water Budget Components (mm)				
	P	ET	G_{net}	Q	ΔS
Jan	35	0.2	-3.8	19.2	11.8
Feb	41	0.2	-5.7	17.7	17.4
Mar	112	4.5	-17.1	40.7	49.7
Apr	97	39.3	-12.6	45.3	-0.2
May	85	94.6	-5.9	27.7	-43.2
Jun	79	123.4	-2.5	17.2	-64
Jul	80	124	-0.9	12.1	-57
Aug	85	97.3	-0.5	8.6	-21.4
Sep	80	65.4	-0.9	7.2	6.5
Oct	74	29.7	-2.5	8.3	33.5
Nov	79	7.2	-6.8	12.7	52.3
Dec	42	0.8	-4.5	19.1	17.6
Annual	889	587	-64	236	2

Table 3.4-3 Long-term Monthly Water Budget: KLW-N4

Month	Water Budget Components (mm)				
	P	ET	G_{net}	Q	ΔS
Jan	35	0.2	-0.3	15.7	18.8
Feb	41	0.2	-0.4	18	22.4
Mar	112	4.5	-1.4	63.1	43
Apr	97	41.9	-0.9	70.4	-16.2
May	85	103.4	-0.3	27.8	-46.5
Jun	79	130.8	-0.2	13.8	-65.8
Jul	80	126.9	-0.1	8.6	-55.6
Aug	85	97.1	0	3.5	-15.6
Sep	80	65.6	-0.1	3.9	10.4
Oct	74	30.1	-0.2	9.7	34
Nov	79	7.3	-0.6	18.4	52.7
Dec	42	0.8	-0.3	20.4	20.5
Annual	889	609	-5	273	2

Table 3.4-4: Long-term Monthly Water Budget: Lindsay Subwatershed*

Month	Water Budget Components (mm)				
	P	ET	G_{net}	Q	ΔS
Jan	35	0.2	-1	22.3	11.5
Feb	41	0.2	-1.4	22	17.4
Mar	112	4.6	-4.3	61.7	41.4
Apr	97	39.6	-3.1	62.1	-7.8
May	85	97.4	-1.5	25	-38.9
Jun	79	121.6	-0.7	12.1	-55.4
Jul	80	124.3	-0.3	6.6	-51.2
Aug	85	98.3	-0.2	3.6	-17.1
Sep	80	64.8	-0.3	5.4	9.5
Oct	74	29.8	-0.8	11.5	31.9
Nov	79	7.3	-1.9	22.5	47.3
Dec	42	0.8	-1.2	25.6	14.4
Annual	889	589	-17	280	3

*Includes KLW-S1, KLW-S2, and the portion of KLW-N4 located upstream (south) of the Lindsay dam

Table 3.4-5: Tier 2 Subwatershed Stress Level Scenarios

Scenario[1]	Data Restrictions		
	Demand	Land Cover	Climate & Stream Flow
A	Existing	Existing conditions	Historical data set
B	Future	Reflective of future development in subwatershed	Historical data set
D	Existing	Existing conditions	Reflective of 2-year drought period
E	Future	Reflective of future development in subwatershed	Reflective of 2-year drought period
G	Existing	Existing conditions	Reflective of 10-year drought period
H	Future	Reflective of future development in subwatershed	Reflective of 10-year drought period

[1]Scenarios C, F, and I are not listed because they refer to planned systems

3.4.1.4.1 Supply and Reserve

Supply (Q_{Supply}) was calculated for each scenario as the monthly median flow as generated by the HSPF model for the period of 1950 to 2005. For the Lindsay subwatershed, the monthly median inflow to the reservoir as calculated from the RESCOM model was used for the supply.

Reserve ($Q_{Reserve}$) was calculated as the 10th percentile monthly flow as generated by the HSPF model for the period of 1950 to 2005. For the Lindsay subwatershed, the reserve value was taken as the greater of the monthly 10th percentile inflow to the reservoir (obtained from the RESCOM model) and the amount of water required for lockages.

3.4.1.4.2 Demand

Demand (Q_{Demand}) was calculated as the sum of four components: permitted demands, domestic demand that does not require a Permit to Take Water, agricultural demands, and lockage requirements. The same methodologies used to estimate demands for the Tier 1 assessment (see Section 3.3.5) were used for the Tier 2 assessment, with the following exceptions:

Permitted Water Takings

Actual permitted water takings were used to represent permitted usage (rather than the maximum permitted volumes used in the Tier 1 study). These data were obtained from the Water Taking Reporting System provided by the Ministry of the Environment and Climate Change (MOECC). Actual water takings from municipal water supplies were obtained from the municipalities (the Region of Durham and City of Kawartha Lakes). Consumptive demand was calculated in most cases by multiplying by the consumptive use factors defined in the provincial guidance module for water budgets (Ministry of the Environment and Climate Change, 2007). Special attention was required for groundwater supplies that had wastewater facilities discharging to surface water; in these cases, the groundwater consumptive use factor was set to 1 (i.e., all of the water is removed from the aquifer), and the surface water consumptive use factor was set to negative 1 (i.e., all of the water removed from the aquifer is discharged to the receiving surface water).

Lockage Requirements

Lockage requirements were not calculated for any subwatersheds in the Tier 1 water budget. Water required for lockages from Lake Scugog to Sturgeon Lake were determined by estimating the number of lockages in a month multiplied by the plan area of the lock (40.5 m x 9.8 m), and then multiplied by the difference in stage between Lake Scugog and Sturgeon Lake. Approximate lock dimensions, lake levels, and number of lockages per month were provided by the Trent-Severn Waterway. Long-term average monthly differences in stage between Lake Scugog and Sturgeon Lake were used to estimate the difference in stage.

Future Scenarios

Future scenarios (B, E, and H) were evaluated by scaling up the demands for municipal water supplies and unpermitted residential demands. Future demand was estimated using the latest projections available: for the Region of Durham, the projected water treatment plant flows and population data by subwatershed were used; for the City of Kawartha Lakes, water use was increased by 20% as provided for in the Ministry of Finance projected population by county/separated city.

The data restrictions for the future scenarios require adjustments to land cover that are reflective of future development in the watershed, which could in turn affect supply. Given the size of the subwatersheds in question there would have to be significant changes to the landscape to result in large-scale changes in monthly streamflow. Such changes are not anticipated by the concerned municipalities, so model adjustments to reflect land use changes were not found to be necessary.

Drought Scenarios

Drought scenarios (D, E, G, and H) were evaluated by running a continuous model simulation for the 1950 to 2005 period using data that reflected the 2-year and 10-year drought periods. Based on the in-filled records at the Lindsay Frost meteorological station, the 2-year drought period occurred during 1963 and 1964, and the 10-year drought period occurred between 1961 and 1970.

The water levels predicted by the RESCOM model near the Lindsay intake were found to be above the low water level in the wet well at the Lindsay water treatment plant (249.26 m) during all of the required drought scenarios. Water levels predicted for 2-year and 10-year drought scenarios for the existing system are shown in Figure 3.4-2 and Figure 3.4-3, respectively. Water levels predicted for the 2-year and 10-year drought scenarios for future conditions are shown in Figure 3.4-4 and Figure 3.4-5, respectively.

Water Quantity Stress Levels

Tier 2 water quantity stress levels were assigned in accordance with criteria that reflect the percent water demand calculated during the various scenarios and the water levels at the Lindsay intake. The criteria for assigning water quantity stress levels for surface water are summarized in Table 3.4-6. The final water quantity stress levels assigned to the Lindsay subwatersheds are given in Table 3.4-7. The calculation of percent water demand for the Lindsay subwatersheds is summarized in Table 3.4-8 to Table 3.4-11.

Table 3.4-6: Criteria for Assigning Water Quantity Stress Levels (Surface Water)

Stress Level	Criteria for Assigning Stress Level (per Technical Rule 34)				
Significant	Percent water demand is greater than 50% during Scenario A or B (existing system)				
Moderate	Percent water demand less than 50% but greater than 20%	*OR*	At any time after January 1, 1990 or under Scenarios D, E, G, H i) Any part of a surface water intake was not below the water's surface during normal operation of the intake ii) The operation of a surface water intake pump was terminated because of an insufficient quantity of water being supplied to the intake	*OR*	All of the following are true: i) The result of one or more maximum percent water demand calculations is between 18 - 20% ii) The uncertainty associated with the percent demand calculations is high iii) A sensitivity analysis of the data used to prepare the Tier 2 water budget suggests that the stress level for the subwatershed could be moderate
Low	If none of the criteria for Significant or Moderate water quantity stress levels are met				

Table 3.4-7: Subwatershed Stress Levels for Lindsay Subwatershed and Catchments

Scenario	Description	Lindsay Catchments			Lindsay Subwatershed (includes all catchments)
		KLW-S1	KLW-S2	KLW-N4[1]	
A	Existing system	Low	Low	Low	Low
B	Future system	Low	Low	Low	Low
D	Existing system, 2-year drought	N/A	N/A	N/A	Low
E	Future system, 2-year drought	N/A	N/A	N/A	Low
G	Existing system, 10-year drought	N/A	N/A	N/A	Low
H	Future system, 10-year drought	N/A	N/A	N/A	Low
	Final Subwatershed Stress Level	Low	Low	Low	Low

[1] Includes the portion of KLW-N4 located upstream (south) of the Lindsay dam

Table 3.4-8: Subwatershed Surface Water Quantity Stress: KLW-S1

Month	Supply (mm)	Reserve (mm)	Supply - Reserve (mm)	Demand (mm)		Percent Water Demand	
				Current	Future	Current	Future
Jan	24.8	5.2	19.6	-0.20	-0.27	0	0
Feb	16.9	6.4	10.5	-0.15	-0.21	0	0
Mar	58.5	21.9	36.6	-0. 20	-0.27	0	0
Apr	50.7	24.4	26.3	-0.23	-0.31	0	0
May	23.9	13.2	10.7	-0.06	-0.08	0	0
Jun	12.6	7.5	5.1	-0.11	-0.14	0	0
Jul	8.2	4.0	4.2	0.00	0.00	0	0
Aug	4.3	2.6	1.7	0.00	0.00	0	0
Sep	3	1.5	1.5	-0.11	-0.14	0	0
Oct	5.3	1.6	3.7	-0.22	-0.30	0	0
Nov	15.5	2.8	12.7	-0.44	-0.60	0	0
Dec	27	7.1	19.9	-0.35	-0.47	0	0

Note: All takings are groundwater. Negative demand results from municipal wastewater discharge (groundwater to surface water). These negative values are assigned to zero for the percent water demand

Table 3.4-10: Subwatershed Surface Water Quantity Stress: KLW-N4

Month	Supply (mm)	Reserve (mm)	Supply - Reserve (mm)	Demand (mm)		Percent Water Demand	
				Current	Future	Current	Future
Jan	12.5	4.0	8.5	0.04	0.05	0	1
Feb	11.6	4.0	7.6	0.04	0.04	1	1
Mar	62.5	21.9	40.6	0.04	0.05	0	0
Apr	51.6	29.8	21.8	0.04	0.05	0	0
May	21.8	13.1	8.7	0.04	0.05	0	1
Jun	10.4	6.3	4.1	0.1	0.11	2	3
Jul	5.9	3.1	2.8	0.11	0.11	4	4
Aug	2.8	1.8	1.0	0.11	0.11	10	10
Sep	1.8	1.0	0.8	0.08	0.08	9	9
Oct	4.6	0.9	3.7	0.08	0.09	2	2
Nov	12	1.7	10.3	0.04	0.05	0	0
Dec	17.8	4.3	13.5	0.04	0.05	0	0

Table 3.4-9: Subwatershed Surface Water Quantity Stress: KLW-S2

Month	Supply (mm)	Reserve (mm)	Supply - Reserve (mm)	Demand (mm)		Percent Water Demand	
				Current	Future	Current	Future
Jan	15.9	4.7	11.2	0.00	0.00	0	0
Feb	12.2	5	7.2	0.00	0.00	0	0
Mar	37.3	12.4	24.9	0.00	0.00	0	0
Apr	40.9	20.1	20.8	0.00	0.00	0	0
May	23.1	13.1	10	0.00	0.00	0	0
Jun	15.8	9.8	6	0.00	0.00	0	0
Jul	11.4	7.5	3.9	0.00	0.00	0	0
Aug	8.7	6.1	2.6	0.00	0.00	0	0
Sep	7.0	5.0	2.0	0.00	0.00	0	0
Oct	6.7	4.8	1.9	0.00	0.00	0	0
Nov	9.4	4.8	4.6	0.00	0.00	0	0
Dec	17.4	5.6	11.8	0.00	0.00	0	0

Table 3.4-11: Subwatershed Surface Water Quantity Stress: Lindsay subwatershed

Month	Supply (mm)	Reserve* (mm)	Supply - Reserve (mm)	Demand (mm)		Percent Water Demand	
				Current	Future	Current	Future
Jan	20.6	5.0	15.6	0.19	0.21	1	1
Feb	14.9	6.3	8.6	0.17	0.19	2	2
Mar	59	24.7	34.3	0.18	0.2	1	1
Apr	47.2	25.3	21.9	0.19	0.21	1	1
May	20.5	9.6	10.9	0.33	0.39	3	3
Jun	9.0	2.9	6.1	0.27	0.31	4	5
Jul	4.4	0.50	4.9	0.35	0.41	8	10
Aug	3	0.49	3.5	0.32	0.38	11	13
Sep	4	0.40	3.6	0.32	0.37	8	9
Oct	7.7	2.1	5.6	0.25	0.28	4	5
Nov	17.2	5.5	11.7	0.03	0.06	0	1
Dec	22.9	7.4	15.5	0.1	0.1	1	1

* Reserve was calculated as the larger of the 10th percentile or water required for lock operation.

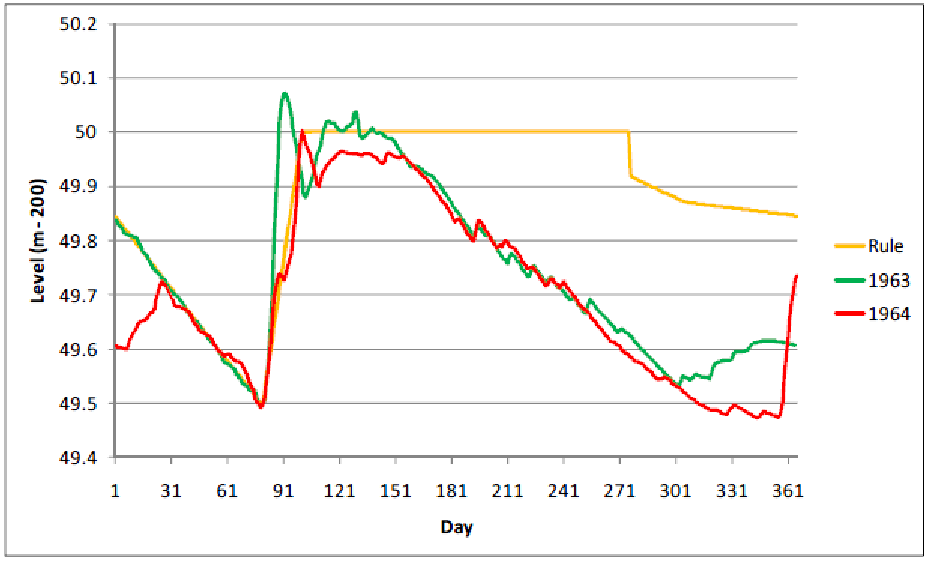

Figure 3.4-2: Modeled water levels at Lindsay intake (Scenario D)

Existing system under 2-year drought (1963-1964)

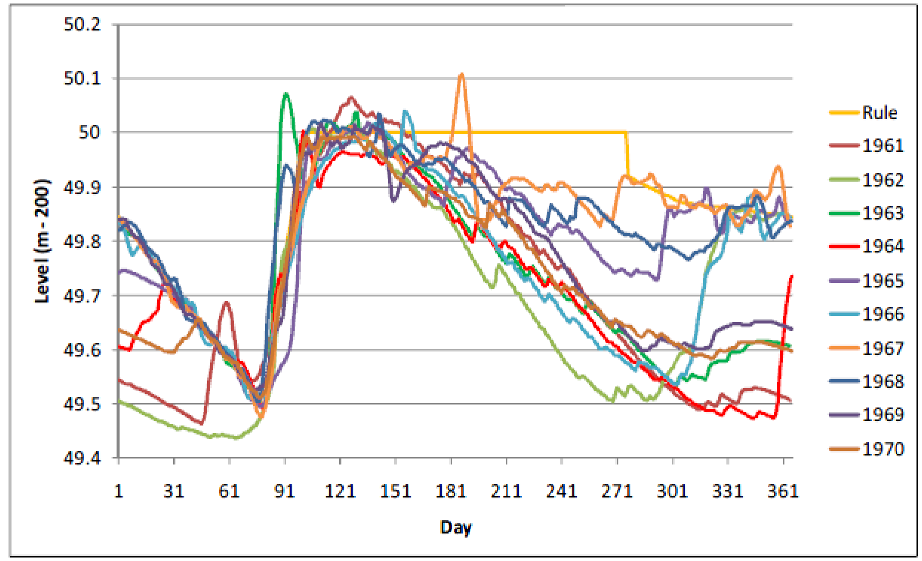

Figure 3.4-3: Modeled water levels at Lindsay intake (Scenario G)

Existing system under 10-year drought (1961-1970)

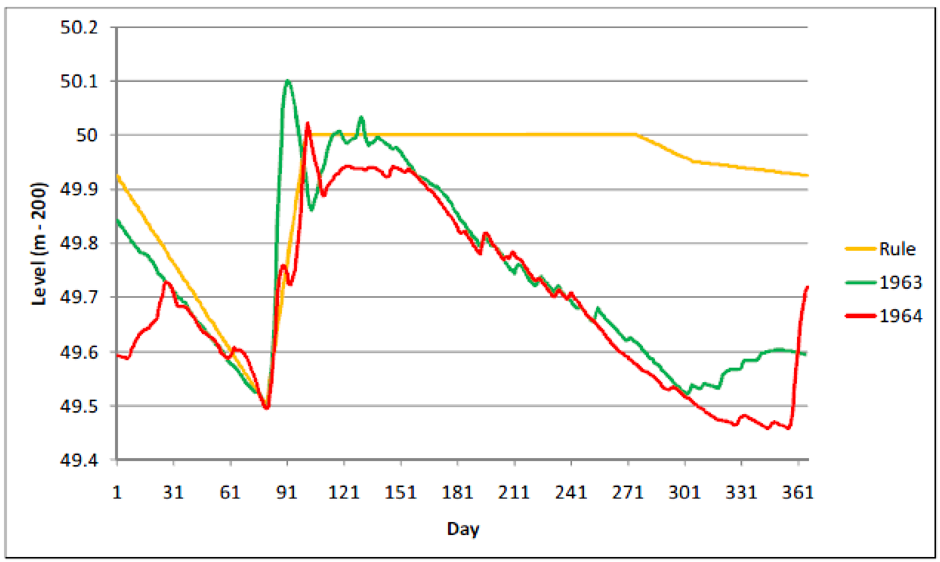

Figure 3.4-4: Modeled water levels at Lindsay intake (Scenario E)

Future system under 2-year drought (1963-1964)

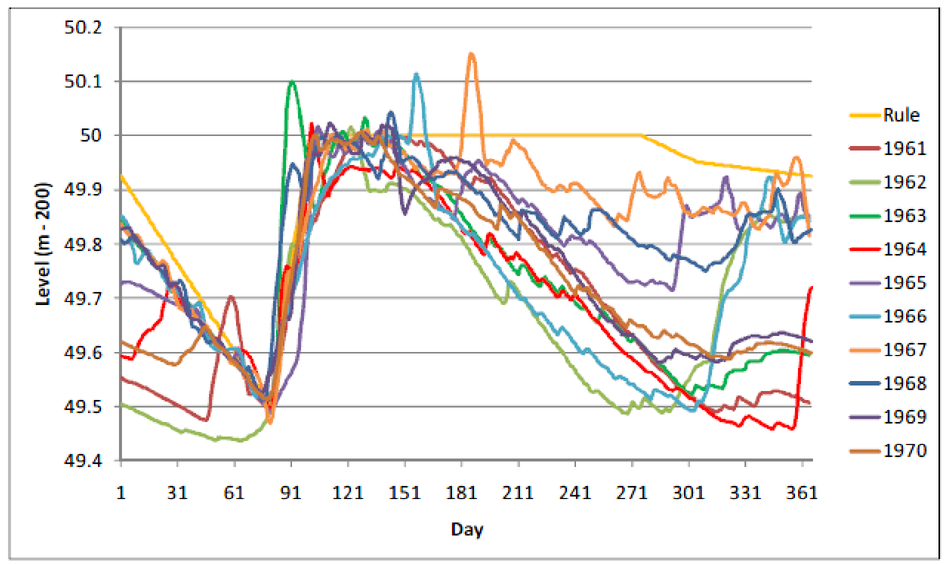

Figure 3.4-5: Modeled water levels at Lindsay intake (Scenario H)

Future system under 10-year drought (1961-1970)

3.4.1.5 UNCERTAINTY

Overall, the modelers assigned a low level of uncertainty to the Tier 2 water budget and percent demand calculations. The modelers felt that the input data used for the Tier 2 ranged from satisfactory to good and that the level of calibration attained was satisfactory based on the available data. The modelers also felt that the hydrologic system was represented satisfactorily for the purposes of this study. The sources of uncertainty are discussed below.

Meteorological data: Approximately half of the Lindsay Frost meteorogical dataset was composed of in-filled data; any bias in these data (especially that of temperature around the freezing mark) could lead to problems in long-term simulated results. The in-filling process was completed province-wide and was independently peer reviewed. These data were considered of sufficient quality for the monthly analysis required for the Tier 2 assessment.

Log setting data: Where a log setting change was not recorded, this could lead to significant error depending on the duration of the log setting applied. Further, this dataset was developed from a review of old paper records; conventions and recording methods applied by different individuals led to some confusion in transcribing the correct setting data.

Demand data: The current estimates of demand as reported in the Water Taking Reporting System database are considered to be of superior quality compared to those applied in the Tier 1 water budget.

Calibration: The level of calibration achieved for Mariposa Brook and the Nonquon River was superior to that in the Tier 1 water budget. In addition to the Water Survey of Canada flow stations, snow water equivalents measured at Emily Park Snowcourse and regional groundwater flows as predicted from the CAMC regional groundwater flow models were used as additional calibration points. The overall model was loosely calibrated to the Lake Scugog levels measured at Caesarea (the statistical analysis was not performed due to the uncertainty attributed to the dam leakage term).

3.4.1.6 OPERATIONAL CONSTRAINTS

The Tier 2 study identified operational constraints regarding the operation of the Lindsay dam. The critical water level to avoid pump vortexing at the Lindsay water treatment plant is at an elevation of approximately 249.5 m (1.3 m above the elevated sill of the wet well). This elevation coincides directly with the lower end of the Lindsay dam operational rule curve. A review of water level records showed that, in March, it is not uncommon for Lake Scugog Levels to fall below this critical water level during the reservoir drawdown period (when the reservoir is lowered to prepare for the spring freshet), which hits its low level in mid-March. Although the quantity of water during this period is more than sufficient to provide for all demands, the operation of the dam may cause water levels to drop below the critical level.

An effective communication protocol between the City of Kawartha Lakes and the Trent-Severn Waterway would ensure that the water level at the Lindsay intake is kept above the critical level required for operation of the water treatment plant.

3.4.1.7 CONCLUSIONS

The Tier 2 water budget and water quantity stress assessment assigned a low stress level to KLW-S1, KLW-S2, KLW-N4, and the Lindsay intake-defined watershed. The uncertainty of the Tier 2 analyses was assessed to be low. The subwatersheds that contribute to the Lindsay intake do not require a Tier 3 water budget and water quantity stress assessment based on the stress levels assigned for the required six scenarios. Therefore, there are no water quantity threats in the subwatersheds that contribute to the Lindsay intake.

3.4.2 HAVELOCK

The Tier 2 water budget and water quantity stress assessment for the subwatershed containing the Havelock municipal wellfield was completed by XCG Consultants Ltd. and is discussed in detail in the following reports:

- *Final Report - Tier 2 Water Budget Report: Part 2 Havelock Subwatershed* (April 2010),
- *Addendum Memo – Tier 2 Water Budget Update for Crowe-4 Subwatershed*

This section is a summary of the above reports.

3.4.2.1 STUDY AREA

The Havelock subwatershed (Crowe 4) is located in the southern region of the Crowe River watershed. The subwatershed was defined as the reach of the Crowe River between the outlet of Belmont Lake and the outlet of Crowe Lake and all contributing streams into this reach of the Crowe River. There are three active wells in the Havelock municipal wellfield, Well #1, Well #3, and Well #4. All three wells obtain groundwater from a shallow limestone aquifer and are drilled between 13.7 and 15.2 metres below ground surface. The Havelock subwatershed is shown on Map 3-37.

3.4.2.2 MODEL DEVELOPMENT

A numerical groundwater model representing the Havelock subwatershed was developed for the Tier 2 study. The model represented the geologic system, including overburden geology and bedrock geology as well as the groundwater system, including water levels from groundwater wells and surface waterbodies. The model also simulates groundwater recharge that accounts for precipitation, evapotranspiration, and runoff.

To ensure the entire subwatershed was modeled, a rectangular grid was delineated with boundaries beyond the subwatershed boundaries (Figure 3.4-6). This rectangular grid was divided into 200-metre by 200-metre cells. The numerical model simulates the groundwater flow system in the entire rectangular grid by calculating the groundwater levels in each of the geologic units in each of the 200-metre by 200-metre cells.

The geologic system was represented by a 3-layer system as illustrated in Figure 3.4-7. The top layer, Layer 1, represents the overburden deposits. Layer 2 underlies Layer 1, and represents weathered limestone and Precambrian bedrock. Layer 2 represents the aquifer where the municipal wells are located. Layer 3, the bottom layer of the model, represents unweathered limestone and Precambrian bedrock. The depths of each of the 3 layers were determined using the Ministry of the Environment and Climate Change Water Well database.

The properties of the geologic units, including hydraulic conductivity, porosity, and storativity, for each of the 3 layers were assigned based on literature values that are summarized in Freeze and Cherry (1979).

Groundwater flow boundaries are included in all groundwater flow models to account for water moving into and out of the sides of the model area, and to account for water moving in from the ground surface (i.e., recharge). Constant head boundaries are used in areas where the changes in groundwater levels are expected to be minimal (these are shown on Figure 3.4-6). This is typically the case for areas near large surface waterbodies such as lakes and rivers. No-flow boundaries represent areas where groundwater flow is not expected to cross the boundary. The north-west to north and south-east to south boundaries of the model were constant head boundaries. The southern boundary of the numerical model was consistent with a larger regional model of the Oak Ridges Moraine. The north-east and south-west model boundaries were no-flow boundaries.

Groundwater withdrawals were included in the model for each of the six permitted groundwater takings. The withdrawal rates were calculated based on the actual pumping rates that were obtained from the Ministry of the Environment and Climate Change Permit to Take Water database.

The numerical modeling was completed in the popular groundwater model MODFLOW. The initial water levels were input into the model based on data from the Trent Conservation Coalition, based on data from the Ministry of the Environment and Climate Change Water Well Information System and the Ministry of Natural Resources and Forestry Digital Elevation Mapping. Groundwater recharge values for each model cell were obtained from the Tier 1 water budget.

Model calibration is the final step for completing a model. The goal of model calibration is to adjust the model inputs (geologic properties, recharge, etc.) to try to reproduce the observed groundwater levels. The model was calibrated by arbitrarily adjusting the average groundwater recharge rate into the model and comparing the groundwater levels calculated in the model to measured groundwater levels in the Ministry of the Environment and Climate Change Water Well Record database. Once the model was calibrated with the average groundwater recharge rate, the model was used to carry out the drought analyses as discussed below.

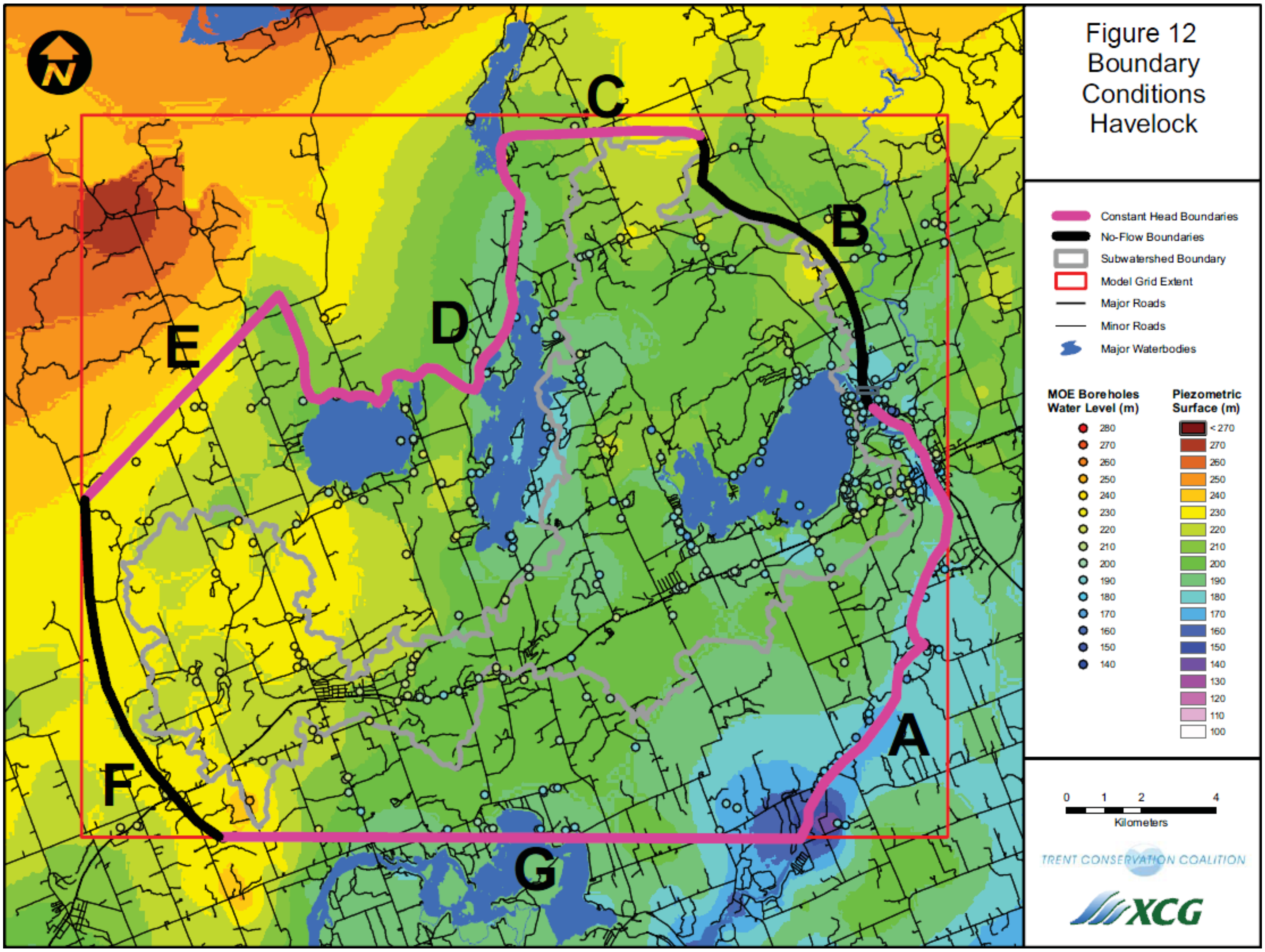

Figure 3.4-6: Model Boundaries for the Havelock Subwatershed

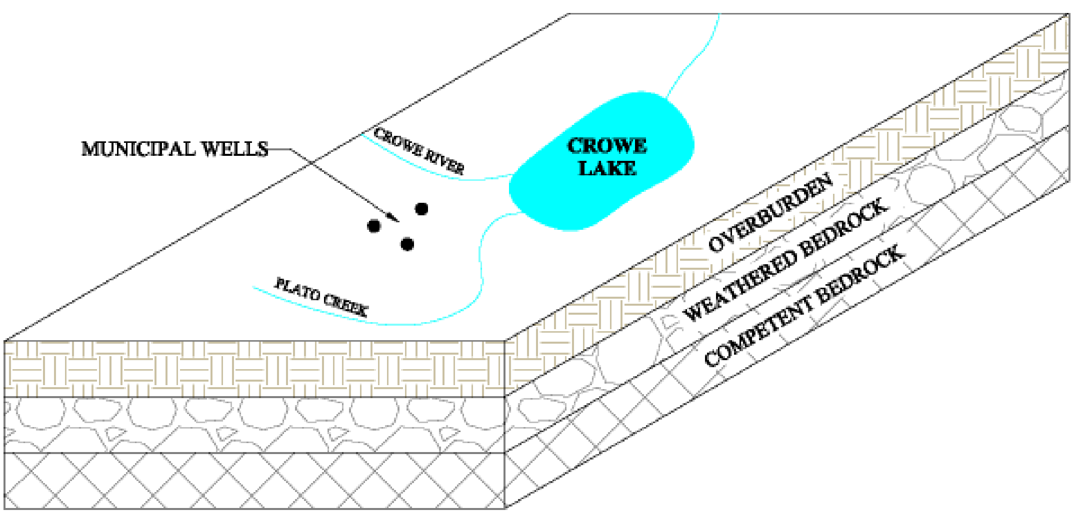

Figure 3.4-7: 3-Layer Conceptual Model for Havelock Subwatershed

3.4.2.3 WATER BUDGET

The Tier 2 long-term monthly water budget for the Havelock subwatershed was calculated for the groundwater system using the results from the MODFLOW model. The Tier 1 water budget included surface processes (e.g., precipitation and evapotranspiration), which is a separate water budget from the groundwater budget presented here. The Tier 2 groundwater budget solved for the Havelock subwatershed was:

$$R + G_{net} = BF + W + \Delta S$$

Where: R = groundwater recharge
G_{net} = net groundwater flow
BF = baseflow
W = groundwater extracted by pumping wells
ΔS = change in storage

The net groundwater flow was calculated as the difference between the groundwater inflow and the groundwater outflow ($G_{net} = G_{in} - G_{out}$) from the MODFLOW model. The results for the calculated long-term groundwater budgets for the Havelock subwatershed are shown in Table 3.4-12.

Table 3.4-12: Long-term Annual Groundwater Budget for Havelock Subwatershed

Water Budget Components (mm/year)				
R	G_{net}	BF	W	ΔS
102.4	63.9	21.8	2.3	0.2

3.4.2.4 WATER QUANTITY STRESS ASSESSMENT

The Tier 2 water quantity stress assessment assigns water quantity stress levels to subwatersheds on the basis of the percent water demand and the groundwater levels in the Havelock wells. Percent water demand is given by the following equation:

$$\text{Percent Water Demand} = \frac{Q_{Demand}}{Q_{Supply} - Q_{Reserve}} \times 100$$

Where: Q_{Demand} = consumptive water demand (sum of all anthropogenic water takings in the subwatershed)
Q_{Supply} = water supply (amount of water flowing through a subwatershed)
$Q_{Reserve}$ = water reserve (amount excluded from supply for anthropogenic and ecological needs).

The percent water demand was calculated for the Havelock subwatershed under existing conditions, future conditions, and several drought scenarios. Each scenario was evaluated in accordance with the data restrictions prescribed in the *Technical Rules*, listed in Table 3.4-13.

The *Technical Rules* requires that the calculation of percent water demand be performed using data for the calendar year immediately before the year in which the Terms of Reference was required to be submitted to the Minister (2007, in this case). However, a review of the data for 2005 to 2008 indicated that 2006 showed the maximum water taking during the period. Thus, the data for 2006 was considered to be a better representation of water use in the area and was used for the percent water demand calculation. Director's Approval was obtained for this approach (see Appendix A).

The MODFLOW model results were used to calculate the supply and reserve terms under non-drought scenarios (A & B) and to estimate the groundwater levels in the wells for the drought scenarios (D, E, G, & H). The calculation of supply, reserve, and demand and the assignment of water quantity stress levels in the Havelock subwatershed are discussed in the following sections.

Table 3.4-13: Tier 2 Subwatershed Stress Level Scenarios

Scenario[1]	Data Restrictions		
	Demand	Land Cover	Climate & Stream Flow
A	Existing	Existing Conditions	Historical data set
B	Future	Reflective of future development in subwatershed	Historical data set
D	Existing	Existing Conditions	Reflective of 2-year drought period
E	Future	Reflective of future development in subwatershed	Reflective of 2-year drought period
G	Existing	Existing Conditions	Reflective of 10-year drought period
H	Future	Reflective of future development in subwatershed	Reflective of 10-year drought period

[1]Scenarios C, F, and I are not listed because they refer to planned systems

3.4.2.4.1 Supply and Reserve

The annual groundwater supply (Q_{Supply}) was calculated as the estimated annual groundwater recharge rate plus the annual estimated groundwater flow into the Havelock subwatershed. The monthly supply was calculated by dividing the annual supply by 12.

Groundwater reserve ($Q_{Reserve}$) was calculated as 10% of the estimated average annual groundwater discharge rate. The annual groundwater discharge rate was calculated from the model results as the sum of the groundwater flow out and the groundwater that discharged to surface waterbodies. The monthly reserve was calculated by dividing the annual reserve by 12.

3.4.2.4.2 Demand

Demand (Q_{Demand}) was calculated as the sum of three components: permitted demands, domestic demands that do not require a Permit to Take Water, and agricultural demands.

Permitted Water Takings

Actual permitted water takings were used to represent permitted usage rather than the maximum permitted volumes used in the Tier 1 study. These data were obtained from the Water Taking Reporting System provided by the Ministry of the Environment and Climate Change. Actual water takings from the Havelock wells were obtained from the Township of Havelock. Consumptive demand was calculated by multiplying the actual water use by the consumptive factors listed in the provincial guidance module for water budgets (Ministry of the Environment and Climate Change, 2007).

Special attention was required for groundwater supplies that had wastewater facilities discharging to surface water, such as the Havelock municipal system. In these cases, the groundwater consumptive use factor was set to 1 (i.e., all of the water is removed from the aquifer).

Unpermitted Agricultural Demand

Agricultural demand was estimated using estimated agricultural water use (de Löe, 2002). Livestock water demand was assumed to be constant throughout the year, but seasonal agricultural uses (e.g., irrigation) were assumed to occur in June, July, and August only. The source of water for the agricultural water takings was assumed to be 50% groundwater and 50% surface water, consistent with the Tier 1 analysis. Finally, a consumptive use factor of 0.8 was applied to the agricultural demand.

Unpermitted Domestic Demand

Unpermitted domestic demand is primarily residences not serviced by municipal systems. The Ministry of the Environment and Climate Change Water Well Records database indicated there were 349 active domestic wells in the subwatershed. The water demand per well was calculated by assuming 2.6 people per well and 335 litres/person/day (MOECC, 2007).

3.4.2.4.3 Future Scenarios

Future scenarios (B, E, and H) were evaluated by scaling up the demands for municipal water supplies and unpermitted residential demands. Future demand was estimated using the latest projections available. For municipal demand, the Township of Havelock-Belmont-Methuen provided a future growth rate of 10.3% in the next twenty five years for the township. This growth rate was applied to both permitted municipal water takings and unpermitted domestic water takings.

The data restrictions for the future scenarios require adjustments to land cover that are reflective of future development in the watershed, which could in turn affect supply. Given the size of the subwatersheds in question, there would have to be significant changes to the landscape to result in large-scale changes in monthly streamflow. Such changes are not anticipated by the concerned municipalities, so model adjustments to reflect land use changes were not found to be necessary.

3.4.2.4.4 Drought Scenarios

Drought scenarios (scenarios D, E, G, and H) were evaluated using the MODFLOW model to simulate both the 2-year and 10-year drought conditions. The 2-year drought scenario was simulated by using zero recharge to the model.

The 10-year drought scenario was simulated using a historical 10-year drought scenario. The daily climate data from the Norwood precipitation gauge (10 km west of the subwatershed) from January 1950 to December 2005 were used to select the representative historical drought. The 10-year period with the least amount of precipitation was from June 1960 to June 1970, which had 17% precipitation compared to the average annual precipitation for the area. Average annual groundwater recharge in the MODFLOW model was decreased by 17%. Also, frozen ground in the winter and high evapotranspiration (that decreases groundwater recharge) in the summer were assumed to inhibit groundwater recharge in the summer and winter months. It is accepted that the majority of recharge in the region occurs in spring and fall. The annual average groundwater recharge (reduced by 17%) was evenly distributed for three months in the spring and three months in the fall.

The MODFLOW model was used to calculate the groundwater levels in the wells for the 2-year and 10-year drought scenarios (Table 3.4-14).

Communications with the system operators (Ontario Clean Water Association) indicated that Well #1 and Well #4 have lower level lockout elevations associated with these wells. This elevation defines the safe operating level for the well (i.e. the elevation at which the pumps associated with the well are shut off to avoid overdrawing from the well). There is no documented lower level lockout for Well #3.

The lower level lockout elevations were used to determine whether the groundwater levels dropped below a safe operating level for Wells #1 and #4, while the top of screen level was used for Well #3. The bold values in Table 3.4-14 show where the predicted groundwater levels are below the safe operating level. Due to the simulated groundwater level dropping below the safe operating level in well #4 during the 2-year drought conditions, a moderate stress level was assigned to Scenario D and Scenario E. However, the calculated water levels for the 10-year drought were above the safe operating level, and a low stress was assigned to Scenario G and Scenario H. Since a low stress was assigned to the 10-year drought scenario, the final stress assignment for the drought scenarios was low.

Table 3.4-14: Calculated Groundwater Elevations in Municipal Wells

Measurement of Interest	Groundwater Elevation (m above sea level)		
	Well #1	Well #3	Well #4
Ground Surface	213.74	212.50	213.52
Top of Well Screen (Well 3) Low Level Lockout (Wells 1&4)	203.70	205.18	206.70
Static Water Level	209.18	208.60	209.18
Scenario A	209.18	208.60	209.18
Scenario B	208.88	208.20	208.88
Scenario D	206.58	205.90	**206.61**
Scenario E	206.56	205.88	**206.59**
Scenario G	207.07	206.35	207.05
Scenario H	207.05	206.31	207.03

3.4.2.4.5 Water Quantity Stress Levels

Tier 2 water quantity stress levels were assigned in accordance with criteria that reflect the percent water demand calculated during the various scenarios and also the water levels in the Havelock wells. The criteria for assigning water quantity stress levels for surface water are summarized in Table 3.4-16. The final water quantity stress levels assigned to the Havelock subwatershed are given in Table 3.4-15. The calculated percent water demands for the Havelock subwatershed are summarized in Table 3.4-17.

The monthly supply values were obtained from the MODFLOW model and were near 10 mm/month (Table 3.4-17). The monthly reserve values (Table 3.4-17) are near 1 mm/month. The variability in Q_{Supply} and $Q_{Reserve}$ among months is due to the different number of days in each month. The sum of the permitted demands, unpermitted agricultural demands, and unpermitted domestic demands for the current and future demands is also shown in Table 3.4-17.

The maximum monthly percent water demand does not exceed 9% in either the future or existing conditions. Therefore the monthly percent water demands do not trigger a moderate stress.

As the annual percent water demands are under 10%, a moderate stress is not automatically triggered for either the future or existing scenario (see Table 3.4-16). For the annual percent water demand, the future scenario is slightly above 8%. The existing annual percent water demand is less than 8% and does not trigger moderate stress. Therefore, uncertainty and sensitivity for the annual percent water demand need to be evaluated to determine whether a low or moderate stress is triggered. The uncertainty and sensitivity assessments are discussed below in Sections 3.4.2.5 and 3.4.2.6, respectively. Despite a high level of uncertainty assessed for the percent water demand calculations, the sensitivity analysis of the data used to prepare the water budget suggests that the stress level for the subwatershed could not be moderate. Therefore a low stress was assigned to the Havelock subwatershed.

The drought scenario analysis showed that the stress level was also low. Because of these two low stress levels, the criteria for assigning water quantity stress levels indicate that the final stress level for the Havelock subwatershed is low.

Table 3.4-15: Scenario and Final Stress Levels for Havelock Subwatershed

Scenario	Stress Level	Scenario	Stress Level
A	Low	G	Low
B	Low	H	Low
D	Moderate	Uncertainty	High
E	Moderate	Sensitivity	Low
		Final Level	Low

Table 3.4-16: Criteria for Assigning Water Quantity Stress Levels (Groundwater)

Stress Level	Criteria for Assigning Stress Level (per Technical Rule 34)								
Significant	Annual percent water demand is greater than 25% during Scenario A or B					Or	Monthly percent water demand is greater than 50% during Scenario A or B		
Moderate	Annual percent water demand less than 25% but greater than 10% during Scenario A or B	Or	Monthly percent water demand less than 50% but greater than 25% during Scenario A or B	Or	At any time after January 1, 1990 or under Scenarios D, E, G, H: i) The groundwater level in the vicinity of the well was not at a level sufficient for the normal operation of the well. ii) The operation of a well pump was terminated because of an insufficient quantity of water being supplied to the well.	Or	All of the following are true: i) The result of one or more annual percent water demand calculations is between 8-10% ii) The uncertainty associated with the demand calculation is high iii) A sensitivity analysis of the data used to prepare the Tier 2 water budget suggests that the stress level for the subwatershed could be moderate	Or	All of the following are true: i) The result of one or more monthly maximum percent water demand calculations is between 18-20% ii) The uncertainty associated with the percent demand calculation is high iii) A sensitivity analysis of the data used to prepare the Tier 2 water budget suggests that the stress level for the subwatershed could be moderate
Low	If none of the criteria for Significant or Moderate water quantity stress levels are met								

Table 3.4-17: Calculated Annual and Monthly Percent Water Demand

Month	Supply (mm)	Reserve (mm)	Supply - Reserve (mm)	Demand (mm)		Percent Water Demand	
				Current	Future	Current	Future
January	10.55	1.03	9.52	0.28	0.68	2.94%	7.17
February	9.53	0.93	8.60	0.26	0.70	3.07%	8.16
March	10.55	1.03	9.52	0.29	0.78	3.07%	8.16
April	10.21	1.00	9.21	0.28	0.75	3.07%	8.16
May	10.55	1.03	9.52	0.29	0.78	3.07%	8.16
June	10.21	1.00	9.21	0.29	0.76	3.11%	8.21
July	10.55	1.03	9.52	0.30	0.78	3.11%	8.21
August	10.55	1.03	9.52	0.30	0.78	3.11%	8.21
September	10.21	1.00	9.21	0.28	0.75	3.07%	8.16
October	10.55	1.03	9.52	0.29	0.78	3.07%	8.16
November	10.21	1.00	9.21	0.28	0.75	3.07%	8.16
December	10.55	1.03	9.52	0.28	0.68	2.94%	7.17
Annual	124.22	12.13	112.09	3.42	8.19	3.07%	8.00

3.4.2.5 UNCERTAINTY

Overall, the modelers assigned a high level of uncertainty to the Tier 2 water budget and percent demand calculations. The input data used for the MODFLOW model were estimates based on literature values, not based on direct measurement. The modelers felt that the hydrogeologic system was satisfactorily represented for the purposes of this study. The sources of uncertainty are discussed below.

Model Inputs: The parameters assigned to each of the three model layers were based on literature values, and were not based on actual field tests. The estimated parameters include groundwater recharge, hydraulic conductivity, and storativity. The uncertainty associated with these data is high.

Demand data: The current estimates of demand as reported in the Water Taking Reporting System database are considered to be of superior quality compared to those applied in the Tier 1 water budget.

Model Calibration: The overall model was calibrated to the measured groundwater levels recorded in the Ministry of the Environment and Climate Change Water Well Record database. There is no expected improvement on this data but there are acknowledged limitations of this data. Also, a measured surface water flow rate would provide a second calibration measure, in addition to the groundwater levels in the Ministry of the Environment and Climate Change Water Well Record database, and this would improve the confidence in the model calibration. The level of calibration achieved for the groundwater model was deemed acceptable by the modelers and the peer reviewers. To improve the overall calibration, significant additional data resources would be required. The subwatershed water budget assessment was superior to that in the Tier 1 water budget.

Despite the high uncertainty associated with the model inputs, the calculated low stress levels for Scenario A, B, G, and H result in a low final stress assignment for the subwatershed.

3.4.2.6 SENSITIVITY ANALYSIS

As discussed in 3.4.2.4.5, where the uncertainty is assessed to be high, a sensitivity analysis of the data used to prepare the Tier Two Water Budget should be completed to determine if the stress level for the subwatershed could be moderate. Therefore, because the uncertainty is considered high and the percent water demand for future conditions is 8%, a sensitivity analysis was completed on the parameters that could be modified for the water budget calculations.

This analysis included modifying the predicted future growth rates (modified up to 20%), groundwater takings for both unregulated residential and unregulated agricultural takings (modified up to 100%), and modification of consumptive use factors.

The majority of the takings in this subwatershed are from the regulated sources. Therefore, specific attention was spent to review the factors that would affect the regulated takings for the sensitivity analysis. The maximum regulated taking was used for the regulated takings for the future conditions, while the data supplied in the Water Taking Reporting System by MOECC was used for the assessment of existing conditions.

For a worst case scenario, all consumptive use factors on regulated takings were increased to 100% and the maximum Percent Water Demand remained below 10%; this indicates that the stress level for the Water Budget could not be moderate (>10%).

3.4.2.7 CONCLUSIONS

The Tier 2 water budget and water quantity stress assessment assigned a low stress level to the Havelock subwatershed. The uncertainty of the Tier 2 analyses was assessed to be high. The Havelock subwatershed does not require a Tier 3 water budget and water quantity stress assessment based on the stress levels assigned for the required scenarios. Therefore, there are no water quantity threats in the Havelock subwatershed.

3.4.3 COLBORNE AND BRIGHTON

The Tier 2 water budget and water quantity stress assessment for the subwatershed containing the Colborne and Brighton municipal wells was completed by Earthfx Inc. and is documented in the following report:

- *Final Report - Tier 2 Water Budget Analysis and Water Quantity Stress Assessment for Lake Ontario Subwatersheds 1 and 3 in the Brighton and Colborne Area* (April 2010).

This section is a summary of that report.

3.4.3.1 STUDY AREA

The subwatersheds containing the Colborne and Brighton municipal wells (Lake Ontario subwatersheds 1 and 3, respectively) are located along Highway 2 north of the Lake Ontario shoreline and south of the Oak Ridges Moraine. Both subwatersheds drain directly into Lake Ontario. The two subwatersheds were grouped together for the Tier 2 analysis because of the similarity of their geologic and hydrogeologic settings. The subwatersheds that contain the Colborne and Brighton municipal wells are shown on Maps 3-38 and 3-39, respectively.

The Colborne system draws water from one well and has a standby well. The Brighton system includes three wells located north of the community of Brighton (pumping is rotated among the three wells). The community of Grafton operates two municipal wells west of subwatershed 1.

3.4.3.2 MODEL DEVELOPMENT

A numerical groundwater model representing the Colborne and Brighton subwatersheds and the surrounding area was developed for the Tier 2 study. The model represents the geologic system including overburden geology and bedrock geology, as well as the groundwater system including water levels from groundwater wells and surface waterbodies. The model also simulates groundwater recharge, which accounts for precipitation, evapotranspiration, and runoff. The study area for the Tier 2 model is shown in Figure 3.4-8.

The model covered an area in Northumberland County extending from the crest of the Oak Ridges Moraine south to Lake Ontario and included the municipal wells for Grafton, Colborne, and Brighton. A single sub-regional model was used for the Colborne and Brighton subwatersheds. The model area was divided into 100-metre by 100-metre cells, except for the area around the municipal wells that had a cell size of 25 m by 25 m. The numerical model simulates the groundwater flow system in the entire grid by calculating the groundwater levels in each of the geologic units in each of the cells. The numerical modeling was completed in the popular groundwater model MODFLOW.

The geologic system was represented by a six-layer model as illustrated in Figure 3.4-9 for the Colborne subwatershed and Figure 3.4-10 for the Brighton subwatershed. The overburden layers are the top six layers in the model and include recent deposits (e.g., soils and organic deposits) combined with the Oak Ridges Aquifer Complex (ORAC), the Upper Newmarket Till, inter-till sediments, the Lower Newmarket Till, and the Thorncliffe formation. The two underlying layers are bedrock layers that consist of upper weathered bedrock and an underlying unweathered bedrock. The depths of each of the layers were determined using the Ministry of the Environment and Climate Change Water Well Information System.

The properties of the geologic units, including hydraulic conductivity, porosity, and storativity, for each of the layers were assigned based on literature values (Freeze & Cherry, 1979) and from previous hydrogeological investigations (Kassenaar & Wexler, 2006).

Initial estimates of groundwater recharge rates were based on those rates determined through calibration of the Conservation Authorities Moraine Coalition models, as outlined in Kassenaar and Wexler (2006). Groundwater recharge was adjusted in the process of model calibration to better match observed groundwater levels and estimated groundwater discharge to streams.

Groundwater flow boundaries are included in all groundwater flow models to account for water moving into and out of the sides of the model area, and to account for water moving in from the ground surface (i.e., recharge). Constant head boundaries are used in areas where the changes in groundwater levels are expected to be minimal. This is typically the case for areas near large surface waterbodies such as lakes and rivers. No-flow boundaries represent areas where groundwater flow is not expected to cross the boundary. A no-flow boundary condition was applied along the northern, eastern, and western boundaries of the model where natural flow divides are believed to exist. The southern boundary, Lake Ontario, was represented as a constant head discharge boundary.

Groundwater discharge to streams was simulated using water-level dependent discharge boundaries, commonly referred to as rivers and drains. The drains were used to simulate groundwater discharging into rivers. Drains do not allow surface water to recharge groundwater; groundwater can only discharge into the surface water.

Groundwater withdrawals were included in the model for all of the permitted groundwater takings in the model. The withdrawal rates were calculated based on the actual pumping rates that were obtained from the Ministry of the Environment and Climate Change Permit to Take Water database.

The initial water levels were input into the model based on the data from the Ministry of the Environment and Climate Change Water Well Information System and the Ministry of Natural Resources and Forestry Digital Elevation Mapping.

The model was calibrated by adjusting the hydraulic conductivities in each of the model layers in order to minimize the difference between the groundwater levels calculated by the model and the actual water levels reported in the Ministry of the Environment and Climate Change Water Well Information System. A second calibration target was to compare the calculated surface water flows created by the “drains” in the model to measured surface water flow data from Environment Canada stream gauges.

Once the model was calibrated, the model was used to calculate the groundwater budget and the groundwater stress analyses, presented in the following sections.

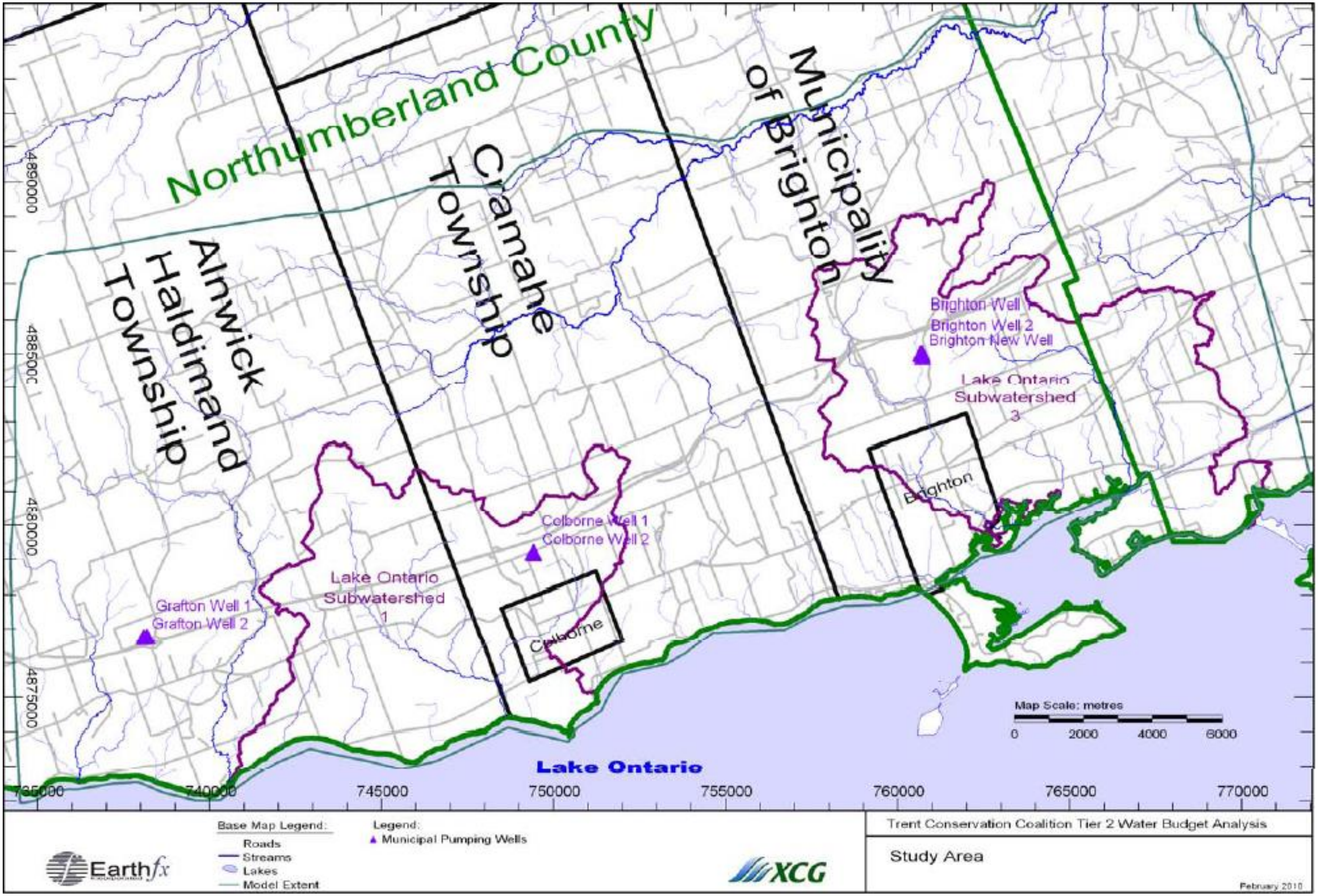

Figure 3.4-8: Study Area for Colborne and Brighton Tier 2 Water Budget

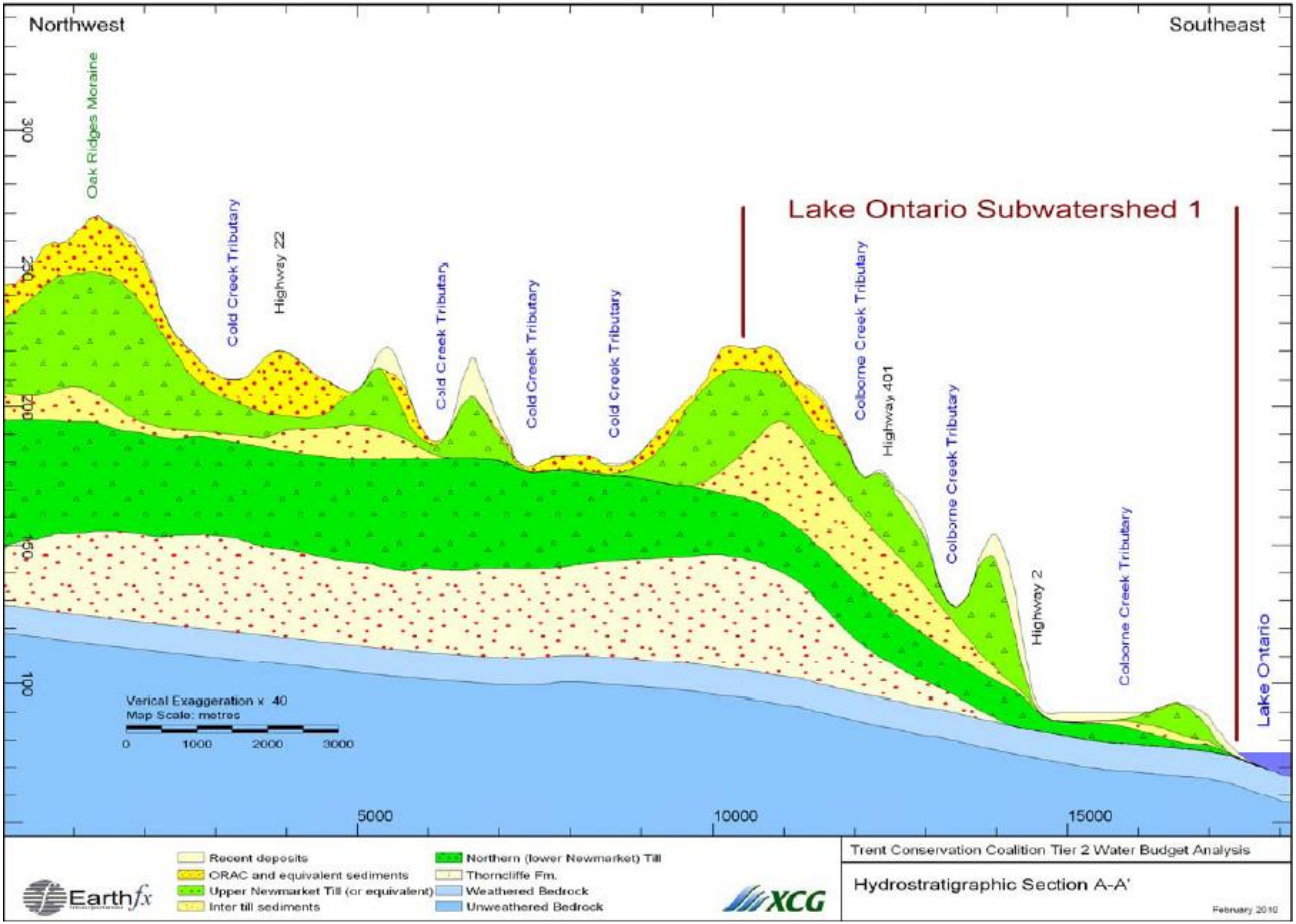

Figure 3.4-9: Conceptual Model for Subwatershed Containing Colborne Wells

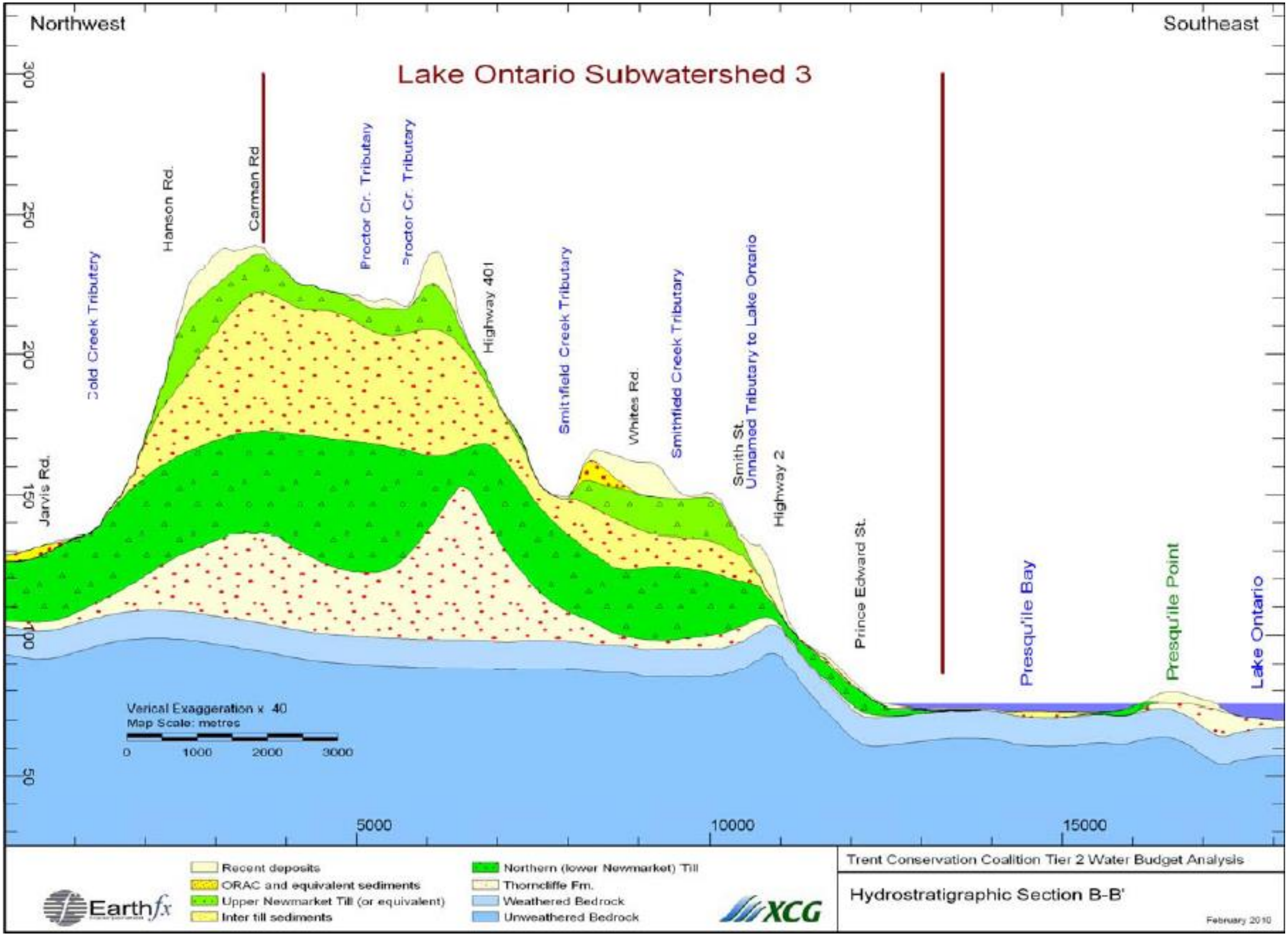

Figure 3.4-1: Conceptual Model for Subwatershed Containing Brighton Wells

3.4.3.3 WATER BUDGET

The Tier 2 long-term monthly water budgets for the Colborne and Brighton subwatersheds were calculated for the groundwater system using the results from the groundwater model. The Tier 1 water budget included surface processes (e.g., precipitation and evapotranspiration), which is a separate water budget from the groundwater budget presented here. The Tier 2 groundwater budget solved for the Colborne and Brighton subwatersheds was as follows:

$$R + GW_{in} = GW_{out} + BF + W + V$$

Where : R = groundwater recharge
G_{in} = groundwater inflow
G_{out} = groundwater outflow
BF = groundwater discharge (including drain leakage and net river leakage)
Q_{net} = streamflow out
W = groundwater extracted by pumping wells
V = private well and agricultural takings

The results for the calculated groundwater budgets for the Colborne and Brighton subwatersheds are shown in Table 3.4-18.

Table 3.4-18: Long-Term Groundwater Budget for Colborne and Brighton Subwatersheds

Inflows and Outflows	Lake Ontario Subwatershed 1 (Colborne) (m^3/s)	Lake Ontario Subwatershed 3 (Brighton) (m^3/s)
Recharge	0.49	0.69
Groundwater Inflow	0.33	0.18
Groundwater Outflow	0.27	0.23
Drain Leakage Out	0.52	0.55
Net River Leakage Out	0.021	0.1
Wells	0.024	0.033
Private Use/Agriculture	0.0004	0.004

3.4.3.4 WATER QUANTITY STRESS ASSESSMENT

The Tier 2 water quantity stress assessment assigns water quantity stress levels to subwatersheds on the basis of the percent water demand and the groundwater levels in the Colborne and Brighton municipal wells. Percent water demand is given by the following equation:

$$\text{Percent Water Demand} = \frac{Q_{Demand}}{Q_{Supply} - Q_{Reserve}} \times 100$$

Where: Q_{Demand} = consumptive water demand (sum of all anthropogenic water takings in the subwatershed)
Q_{Supply} = water supply (amount of water flowing through a subwatershed)
$Q_{Reserve}$ = water reserve (amount excluded from supply for anthropogenic and ecological needs).

The percent water demand was calculated for the Colborne and Brighton subwatersheds under existing conditions, future conditions, and several drought scenarios. Each scenario was evaluated in accordance with the data restrictions prescribed in the *Technical Rules*, listed in Table 3.4-19.

The *Technical Rules* requires that the calculation of percent water demand be performed using data for the calendar year immediately before the year in which the Terms of Reference was required to be submitted to the Minister. In accordance with this requirement, data for the 2007 calendar year were used for the percent water demand calculations for the subwatersheds containing the Brighton and Colborne municipal wells. However, for the subwatershed containing the Colborne municipal wells, a review of the data for 2005 to 2008 indicated that the year 2006 showed the maximum taking during the period. Thus, the data for 2006 was considered to be the best representation of water usage and was used for the percent water demand calculations for the subwatershed containing the Colborne municipal wells. The data for 2007 was used for the subwatershed containing the Brighton wells. Director's Approval was obtained for this approach (see Appendix A).

The results from the groundwater model were used to calculate the supply and reserve terms under non-drought scenarios (A & B) and to estimate the groundwater levels in the wells for the drought scenarios (D & E). The calculation of supply, reserve, and demand and the assignment of water quantity stress levels in the Colborne and Brighton subwatersheds are discussed in the following sections.

Table 3.4-19: Tier 2 Subwatershed Stress Level Scenarios

Scenario[1]	Data Restrictions		
	Demand	Land Cover	Climate & Stream Flow
A	Existing	Existing Conditions	Historical data set
B	Future	Reflective of future development in subwatershed	Historical data set
D	Existing	Existing Conditions	Reflective of 2-year drought period
E	Future	Reflective of future development in subwatershed	Reflective of 2-year drought period
G	Existing	Existing Conditions	Reflective of 10-year drought period
H	Future	Reflective of future development in subwatershed	Reflective of 10-year drought period

[1]Scenarios C, F, and I are not listed because they refer to planned systems

3.4.3.4.1 Supply and Reserve

The annual groundwater supply (Q_{Supply}) was calculated for the Colborne and Brighton subwatersheds individually. The supply was calculated as the estimated annual groundwater recharge rate plus the annual estimated groundwater flow into each of the subwatersheds. The monthly supply was calculated by dividing the annual supply by 12.

Groundwater reserve ($Q_{Reserve}$) was calculated as 10% of the estimated average annual groundwater discharge rate. The annual groundwater discharge rate was calculated from the model results as the groundwater that discharged to surface waterbodies. The monthly reserve was calculated by dividing the annual reserve by 12.

3.4.3.4.2 Demand

Demand (Q_{Demand}) was calculated as the sum of three components: permitted demands, domestic demands that do not require a Permit to Take Water, and agricultural demands.

Permitted Water Takings

Actual permitted water takings were used to represent permitted usage rather than the maximum permitted volumes used in the Tier 1 study. These data were obtained from the Water Taking Reporting System provided by the Ministry of the Environment and Climate Change. Estimates of actual water use were available for all permits except a water-bottling operation in which the maximum permitted rate was used for the analysis. Consumptive demand was calculated by multiplying the actual water use by the consumptive factors listed in the provincial guidance module for water budgets (Ministry of the Environment and Climate Change, 2007).

Special attention was required for groundwater supplies that had wastewater facilities discharging to surface water, such as the Colborne and Brighton municipal systems. In these cases, the groundwater consumptive use factor was set to 1 (i.e., all of the water is removed from the aquifer).

Unpermitted Agricultural Demand

Agricultural demand was estimated using estimated agricultural water use (de Löe, 2002). The agricultural demand estimates given by de Löe (2002) were reported on an annual basis. Although it is quite likely that agricultural demand for the summer season exceeds winter demands, there was no information available to allocate seasonal water taking using the data provided by de Löe (2002). Therefore, the given annual agricultural water demand estimates were assumed to be constant year-round.

Unpermitted Domestic Demand

Unpermitted domestic demand is primarily residences not serviced by municipal systems. Estimates of the population not serviced by municipal systems were based on 2006 population census data. This population is assumed to be consuming groundwater from individual wells or small communal supplies.

Unserviced domestic water use was calculated by combining population density estimates with typical per-capita water use rates. Demand was estimated using the rate 335 L/day/person (recommended in the provincial guidance module for water budgets (Ministry of the Environment and Climate Change, 2007). This was corrected for actual consumption because a significant portion of this water would be returned to the groundwater system through septic systems and drain fields.

The population not serviced by municipal systems was adjusted for the future scenario based on a growth rate of 20% over a 25-year period. No other demand estimates were adjusted for population growth. The total increase in the overall demand was approximately 12%.

3.4.3.4.3 Future Scenarios

Future scenarios (B, E, and H) were evaluated by scaling up the demands for municipal water supplies and unpermitted residential demands. Future demand was estimated from the Northumberland County Growth Plan: groundwater demand was increased by 12% over 25 years to account for increases in population.

The data restrictions for the future scenarios require adjustments to land cover that are reflective of future development in the watershed, which could in turn affect supply. Given the size of the subwatersheds in question, there would have to be significant changes to the landscape to result in large-scale changes in monthly streamflow. Such changes are not anticipated by the concerned municipalities, so model adjustments to reflect land use changes were not found to be necessary.

3.4.3.4.4 Drought Scenarios

Drought scenarios were evaluated using the MODFLOW model to simulate the 2-year drought conditions. The 2-year drought scenario was simulated by simulating zero groundwater recharge in the model. Results showed that because of the high available groundwater storage and the large amount of available drawdown in the wells, the simulated groundwater levels in the Brighton and Colborne wells did not fall below the well screens for the 2-year drought scenario. It was not required to calculate the 10-year drought scenarios (scenarios G and H), because an increase to a moderate water quantity stress level would require that simulated water levels under both the 2-year and 10-year drought scenarios fall below the well screens.

3.4.3.4.5 Water Quantity Stress Levels

Tier 2 water quantity stress levels were assigned in accordance with criteria that reflect the percent water demand calculated during the various scenarios and the water levels in the Colborne and Brighton wells. The criteria for assigning water quantity stress levels for groundwater are summarized in Table 3.4-20. The final water quantity stress levels assigned to the Colborne and Brighton subwatersheds are given in Table 3.4-21. The calculation of percent water demands for the Colborne and Brighton subwatersheds is summarized in Table 3.4-22 and Table 3.4-23, respectively.

Both the monthly and annual percent water demand calculations for Scenarios A and B were less than 8%, and a low stress was assigned to Scenario A and Scenario B for both the Colborne and Brighton subwatersheds. The drought scenario analysis showed the stress level was also low. Because of these two low stress levels, the final stress levels for the Colborne and Brighton subwatersheds were both low.

Table 3.4-20: Criteria for Assigning Water Quantity Stress Levels (Groundwater)

<table>
<tr><th>Stress Level</th><th colspan="9">Criteria for Assigning Stress Level (per Technical Rule 34)</th></tr>
<tr><td>Significant</td><td colspan="5">Annual percent water demand is greater than 25% during Scenario A or B</td><td>Or</td><td colspan="3">Monthly percent water demand is greater than 50% during Scenario A or B</td></tr>
<tr><td>Moderate</td><td>Annual percent water demand less than 25% but greater than 10% during Scenario A or B</td><td>Or</td><td>Monthly percent water demand less than 50% but greater than 25% during Scenario A or B</td><td>Or</td><td>At any time after January 1, 1990 or under Scenarios D, E, G, H:
i) The groundwater level in the vicinity of the well was not at a level sufficient for the normal operation of the well.
ii) The operation of a well pump was terminated because of an insufficient quantity of water being supplied to the well.</td><td>Or</td><td>All of the following are true:
i) The result of one or more annual percent water demand calculations is between 8-10%
ii) The uncertainty associated with the demand calculation is high
iii) A sensitivity analysis of the data used to prepare the Tier 2 water budget suggests that the stress level for the subwatershed could be moderate</td><td>Or</td><td>All of the following are true:
i) The result of one or more monthly maximum percent water demand calculations is between 18-20%
ii) The uncertainty associated with the percent demand calculation is high
iii) A sensitivity analysis of the data used to prepare the Tier 2 water budget suggests that the stress level for the subwatershed could be moderate</td></tr>
<tr><td>Low</td><td colspan="9">If none of the criteria for Significant or Moderate water quantity stress levels are met</td></tr>
</table>

Table 3.4-21: Scenario and Final Stress Levels for Colborne and Brighton Subwatersheds

Scenario[1]	Water Quantity Stress Level	
	Lake Ontario Subwatershed 1 (Colborne)	Lake Ontario Subwatershed 3 (Brighton)
A	Low	Low
B	Low	Low
D	Low	Low
E	Low	Low
G	*	*
H	*	*
Uncertainty	High	High
Final Level	Low	Low

*10-year drought scenarios were not calculated because the 2-year drought scenarios did not show water levels below well screens

[1] Scenarios C, F, and I are not listed because they refer to planned systems

Table 3.4-22: Calculated Annual and Monthly Percent Water Demand Colborne Subwatershed

Month	Supply (mm)	Reserve (mm)	Supply - Reserve (mm)	Demand (mm)		Percent Water Demand (%)	
				Current	Future	Current	Future
January	32.7	2.14	30.56	1.36	1.47	4%	5%
February	32.7	2.14	30.56	1.24	1.34	4%	4%
March	32.7	2.14	30.56	1.36	1.47	4%	5%
April	32.7	2.14	30.56	1.32	1.42	4%	5%
May	32.7	2.14	30.56	1.36	1.47	4%	5%
June	32.7	2.14	30.56	1.32	1.42	4%	5%
July	32.7	2.14	30.56	1.36	1.47	4%	5%
August	32.7	2.14	30.56	1.36	1.47	4%	5%
September	32.7	2.14	30.56	1.32	1.42	4%	5%
October	32.7	2.14	30.56	1.36	1.47	4%	5%
November	32.7	2.14	30.56	1.32	1.42	4%	5%
December	32.7	2.14	30.56	1.36	1.47	4%	5%
Annual	392.4	25.7	366.7	16.1	17.3	4%	5%

Table 3.4-23: Calculated Annual and Monthly Percent Water Demand Brighton Subwatershed

Month	Supply (mm)	Reserve (mm)	Supply - Reserve (mm)	Demand (mm)		Percent Water Demand	
				Current	Future	Current	Future
January	28.0	2.08	25.92	1.25	1.45	5%	6%
February	28.0	2.08	25.92	1.14	1.32	4%	5%
March	28.0	2.08	25.92	1.25	1.45	5%	6%
April	28.0	2.08	25.92	1.21	1.40	5%	5%
May	28.0	2.08	25.92	1.38	1.52	5%	6%
June	28.0	2.08	25.92	1.62	1.56	6%	6%
July	28.0	2.08	25.92	1.67	1.61	6%	6%
August	28.0	2.08	25.92	1.67	1.61	6%	6%
September	28.0	2.08	25.92	1.62	1.56	6%	6%
October	28.0	2.08	25.92	1.38	1.52	5%	6%
November	28.0	2.08	25.92	1.33	1.47	5%	6%
December	28.0	2.08	25.92	1.25	1.45	5%	6%
Annual	336.0	25.0	311.0	16.8	17.9	5%	6%

3.4.3.5 UNCERTAINTY

Overall, a low level of uncertainty was assigned to the Tier 2 water budget and percent demand calculations. The input data used for the MODFLOW model were estimates based on literature values, not based on direct measurement. The modelers felt that the hydrogeologic system was satisfactorily represented for the purposes of the Tier 2 study. Sources of uncertainty are listed in Table 3.4-24.

Table 3.4-24: Uncertainty ranking for the determination of the percent water demand

Uncertainty Element	Uncertainty Ratings	
	Lake Ontario Subwatershed 1 (Colborne)	Lake Ontario Subwatershed 3 (Brighton)
Distribution, variability, quality, and relevance of data	High	High
Ability of the methods and models used to accurately reflect the hydrologic system	Low	Low
Quality assurance and quality control procedures applied	Low	Low
Extent and level of calibration and validation achieved for models used or calculations or general assessments completed	Low	Low
Overall Uncertainty	Low	Low

Data Distribution: Borehole data and water levels were sparse in many critical locations in the study area. The number of wells and spatial coverage of higher-quality data is very limited compared to the Water Well Information System data. The intrinsic biases in the Ministry of the Environment and Climate Change Water Well log data are another source of uncertainty. In general, well owners only drill as deep as necessary, often completing the borehole in the top of the first aquifer encountered. This has resulted in a general tendency to record the extent of low permeability materials overlying the aquifers, but the wells provide limited information on the total thickness of the aquifer or on the properties of deeper aquifers and aquitards. However, it is reasonable to expect a low level of uncertainty in areas where data density is high. One of the most significant issues identified as part of the Tier 1 analysis was the level of uncertainty related to estimating actual water use from the information in the Permit to Take Water database. The current study benefited from having actual water use data for 2005 to 2008 from many of the permit holders. Consumptive use for unserviced demand and unpermitted agricultural use will always need to be estimated and will retain a high level of uncertainty. Overall, a high level of uncertainty was assigned to the data.

Groundwater Modeling: There are inherent limits in the level of confidence associated with all numerical modeling due to the quality of the input data as well as the simplifying assumptions made during model development. The parameters assigned to each of the model layers were based on literature values, and were not based on actual field tests. The estimated parameters included groundwater recharge, hydraulic conductivity, and storativity. The calibrated numerical model produced reasonable matches to the observed water levels and baseflows, and a low uncertainty was associated with the model.

3.4.3.6 CONCLUSIONS

The Tier 2 water budget and water quantity stress assessment assigned a low stress level to the Brighton and Colborne subwatersheds. The uncertainty of the Tier 2 analyses was assessed to be high. The Brighton and Colborne subwatersheds do not require a Tier 3 water budget and water quantity stress assessment based on the stress levels assigned for the required scenarios. Therefore, there are no water quantity threats in the Brighton or Colborne subwatersheds.

3.4.4 INFORMATION TO SUPPORT CONTINUAL IMPROVEMENT

Establish water level relationship between Lindsay dam and Caesarea staff gauge

Levels measured at the Caesarea staff gauge were pro-rated down to represent levels that would occur upstream of the Lindsay dam. Water levels at the Lindsay dam were not available. The resulting uncertainty could be reduced by the development of a relationship between levels at these two sites based on measurements taken at the same time over the complete range of water level and log setting.

3.4.5 REFERENCES

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CHAPTER 4: SURFACE WATER SYSTEMS: WATER QUALITY RISK ASSESSMENT

4.1 SUMMARY OF SURFACE WATER SYSTEMS

There are 16 municipal drinking water systems listed in the *Terms of Reference* for the four Trent source protection areas that draw water from surface water sources. Since the approval of the *Terms of Reference*, the Batawa system has been decommissioned and is not discussed in this report. General information regarding the remaining 15 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 sources are listed in Table 4.1-3.

Table 4.1-1: Summary of Municipal Residential Surface Water Systems in the Trent Source Protection Areas

System Name	Drinking Water System No.	Operating Authority	*Safe Drinking Water Act* Classification	Serviced Population (Approx.)[1]
Kawartha-Haliburton Source Protection Area				
Lindsay	220000175	City of Kawartha Lakes	Large Municipal Residential	20,000
Bobcaygeon	210000318	Ontario Clean Water Agency	Large Municipal Residential	3,000
Fenelon Falls	210000327	Ontario Clean Water Agency	Large Municipal Residential	2,000
Southview Estates	220012260	Ontario Clean Water Agency	Large Municipal Residential	360
Kinmount	260075231	Ontario Clean Water Agency	Small Municipal Residential	100
Norland	250001910	Ontario Clean Water Agency	Small Municipal Residential	225
Otonabee-Peterborough Source Protection Area				
Peterborough	220000497	Peterborough Utilities Services Inc.	Large Municipal Residential	79,320
Lakefield	220000488	PUG Services Corporation	Large Municipal Residential	3,100
Hastings	210000470	Municipality of Trent Hills	Large Municipal Residential	1,250
Crowe Valley Source Protection Area				
Marmora	220004803	Municipality of Marmora and Lake	Large Municipal Residential	1,300
Lower Trent Source Protection Area				
Bayside	220008079	City of Quinte West	Large Municipal Residential	3,500
Campbellford	220000834	Municipality of Trent Hills	Large Municipal Residential	3,300
Frankford-Batawa	210001889	City of Quinte West	Large Municipal Residential	2,200
Trenton	220001619	City of Quinte West	Large Municipal Residential	16,000
Warkworth	210000498	Municipality of Trent Hills	Large Municipal Residential	725

[1]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 in the Trent Source Protection Areas

System Name	Intake (s)					Water Treatment System			
	Location	No. Intakes	Size (mm)	Approx Depth (m)	Distance from Shore (m)	Coagulant / Coagulant Aid	Filtration	Disinfection	Other Available Treatment Details
Kawartha-Haliburton Source Protection Area									
Lindsay	Scugog River	2	350	2	20	• Aluminum sulphate • Polyaluminum chloride • Polymer	Dual media (GAC/sand)	• Sodium hypochlorite	
Bobcaygeon	Big Bob River (near Sturgeon Lake)	1	450	1	18	• Polyaluminum chloride • Aluminum sulphate	Dual media (sand/anthracite)	• Sodium hypochlorite • Ammonium sulphate	Pre-chlorination for zebra mussel control
Fenelon Falls	Cameron Lake	1	450	2	216	• Polyaluminum chloride	Microfiltration	• Sodium hypochlorite	Sodium hypochlorite for zebra mussel control
Southview Estates	Sturgeon Lake	1	200	2.1	439	• Polyaluminum chloride • Polymer	Dual media (anthracite & silica sand)	• Sodium hypochlorite	
Kinmount	Burnt River	1	300	2.8	20	• Polyaluminum chloride • Polymer	Dual media gravity filter (anthrcite, sand, gravel)	• Sodium hypochlorite	
Norland	Gull River	1	300	0.5	0	• Polyaluminum chloride	Dual media gravity filter (anthrcite, sand, gravel)	• Sodium hypochlorite	
Otonabee-Peterborough Source Protection Area									
Peterborough	Otonabee River	1[a]	2x760	2	22	• Alum • Sodium silicate (as required)	Dual media (sand/anthracite)	• Gas chlorination	3 filters include GAC for taste & odour control; Chlorination for zebra mussel control
Lakefield	Otonabee River (mouth of Katchewanooka Lk)	2	350	2	15	• Alum • Polymer	Dual media (sand/anthracite)	• Sodium hypochlorite	GAC contractor for taste & odour control (as required)
Hastings	Trent River	1	300	1.5	33	• Polyaluminum chloride	Dual media (GAC/sand)	• Gas chlorination	Pre-chlorination at intake for zebra mussel control
Crowe Valley Source Protection Area									
Marmora	Crowe River	1	250	2.9	6.1	• Alum • Polymer	Dual media (sand/anthracite)	• Sodium hypochlorite • UV irradiation	GAC contactor for taste & odour control
Lower Trent Source Protection Area									
Bayside	Bay of Quinte	1	900	6	399	• Aluminum sulphate	Dual media & GAC	• Sodium hypochlorite	Fluoridation
Campbellford	Trent River	1	600	2.75	0	• Polyaluminum chloride • Polymer	Dual media (GAC/sand)	• Chlorine • UV irradiation	Pre-chlorination at intake for zebra mussel control
Frankford-Batawa	Trent River	1	450	3	69	• Aluminum sulphate	Dual media & GAC	• Gas chlorination	
Trenton	Trent River	2	600/400	3	53	• Aluminum sulphate	GAC	• Gas chlorination	
Warkworth	Burnley (Mill) Creek	1	250	1	0	• Polyaluminum chloride • Polymer	Dual media (GAC/sand)	• Chlorine	

[a] Intake is connected to two adjacent cribs

Table 4.1-3: Pumping Rates for Municipal Residential Surface Water Systems in the Trent Source Protection Areas

System Name	Average Monthly Pumping Rates[1] (m^3/day)												Average Annual Pumping Rates[1] (m^3/day)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Kawartha-Haliburton Source Protection Area[3]													
Lindsay	7,105	7,739	7,523	8,045	10,044	9,619	9,852	9,139	9,892	8,707	7,749	7,468	8,573
Bobcaygeon	1,867	1,768	1,680	1,806	1,957	2,181	2,406	2,409	2,092	1,805	1,706	1,,850.5	1,961
Fenelon Falls	1,227	1,262	1,216	1,107	1,134	1,227	1,258	1,257	1,209	1,204	1,326	1,176	1,217
Southview Estates	87	55	55	57	68	76	76	69	75	67	66	67	68
Kinmount	26	30	27	26	31	60	47	48	34	31	27	37	35
Norland	94	99	99	78	118	100	95	99	91	71	84	68	91
Otonabee-Peterborough Source Protection Area[2]													
Peterborough	33,527	33,600	33,295	34,186	39,568	46,084	47,430	46,418	40,146	34,785	33,006	32,175	37,852
Lakefield	1,418	1,437	1,380	1,475	1,556	1,822	1,839	1,883	1,577	1,515	1,350	1,317	1,547
Hastings	741	752	811	727	796	863	800	745	694	742	640	711	752
Crowe Valley Source Protection Area[2,4]													
Marmora	755	796	832	724	754	722	739	854	862	786	704	741	772
Lower Trent Source Protection Area[2]													
Bayside	2,472	2,558	2,480	2,538	2,640	3,020	3,082	3,140	2,825	2,620	2,582	2,640	2,715
Campbellford	2,565	2,539	2,543	2,515	2,740	2,994	3,057	3,104	2,923	2,824	2,685	2,591	2,756
Frankford-Batawa	1,198	1,274	1,236	1,244	1,488	1,588	1,402	1,400	1,350	1,350	1,384	1,290	1,350
Trenton	10,756	11,150	11,380	11,118	11,484	13,270	12,596	13,258	12,066	11,068	10,416	10,080	11,554
Warkworth	248	236	238	234	244	270	273	245	244	228	210	227	242

[1]Expressed as a total of all intakes in the system using the last 5 years of available data (unless otherwise indicated)
[2]Data Source: Operating authorities (see Table 4.1-1)
[3]Data Source: City of Kawartha Lakes (2004-2008 data)
[4]Calculated using last 2 years of available data

4.2 INTAKE PROTECTION ZONES: DELINEATION & 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, and the land use, land cover, and slope of the area. This section is a description of the delineation of intake protection zones and the assignment of vulnerability scores for the surface water intakes identified in the *Terms of Reference* for the Trent source protection areas.

The surface water vulnerability assessment for the surface water intakes in the Trent source protection areas was completed under two separate studies completed by XCG Consultants Ltd. that are documented in the following reports and technical memoranda:

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

- *Vulnerability, Issues and Threats for Ten Surface Water Sourced Municipal Drinking Water Systems in the Trent Conservation Coalition Source Protection Region* (July 2010)
- *Vulnerability, Issues and Threats for Six Surface Water Sourced Municipal Drinking Water Systems in the City of Kawartha Lakes* (July 2010)
- *Technical Memorandum – Re-evaluated Vulnerability and Threats for the Trenton Drinking Water System after the De-commissioning of Batawa Drinking Water System (November 2010)*
- *Technical Memorandum – IPZ-2 Modifications Incorporating Time of Travel Analysis within Municipal Storm Sewers and Re-assess Threats (December 2010)*

This section is a summary of the relevant sections of the above documents.

4.2.1 INTAKE CLASSIFICATIONS

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:

- Type A: Intakes located in the Great Lakes
- Type B: Intakes located in connecting channels (these include the St. Lawrence, St. Mary's, St. Clair, Detroit, and Niagara rivers and the Welland Canal)
- Type C: Intakes located in rivers where neither the flow nor direction of water at the intake is affected by a water impoundment structure
- Type D: All other intakes (includes intakes located in inland lakes and rivers affected by water impoundment structures).

All of the surface water intakes in the Trent source protection areas (except the Warkworth intake) are classified as Type D intakes because they are affected by water impoundment structures associated with the Trent-Severn Waterway. The Warkworth intake is considered unaffected by these structures, so it is classified as a Type C intake. The classification of intakes is discussed for each intake below.

WARKWORTH

There is a dam controlled by a weir located directly downstream of the Warkworth intake that provides a pool for the intake to draw from (see Figure 4.2-1). The dam is essentially a concrete weir that has a single stop log bay that can hold a maximum of four six-inch stop logs.

The dam is not considered to significantly affect the flow and/or direction of the water in the vicinity of the Warkworth intake, so it was classified as a Type C intake (i.e., not affected by a water impoundment structure).

The dam is operated using two settings: from Victoria Day to Thanksgiving, all four logs are used to maximize the water level in the small pool that the water treatment plant draws water from. During the winter, two logs are kept in place to help with ice jamming that is prevalent on Burnley (Mill) Creek.

The following points are offered as justification for the Type C Classification:

- The regulation is conducted seasonally and due to the small available storage, so daily flows are not significantly impacted.
- The intake is located directly adjacent to the dam (the manhole shown in Figure 4.2-2 leads to the intake). When logs are added, the flooded area does not significantly increase because the upstream channel is steep and the stop logs become level with the top of the concrete weir; this holds water levels in a relatively stable manner.
- The channel downstream of the channel is quite steep, which makes it highly unlikely for contributing stream flows downstream of the dam to migrate upstream.

NORLAND, KINMOUNT & LINDSAY

The Norland, Kinmount, and Lindsay intakes are located within a defined river reach, but the operation of the waterway can affect the rate and direction of flow in the vicinity of the intakes. The dams are operated to maintain navigation water levels and head differentials for hydroelectric power generation (with the former carrying greater weight). These intakes are classified as Type D intakes.

BOBCAYGEON

The Bobcaygeon intake is described as being located in Sturgeon Lake. However, the outlet of the lake and the beginning of the Big Bob River are indistinguishable in this area, and this portion of Sturgeon Lake acts very much like a river (i.e., unidirectional flow). The wind has very little impact on flow patterns and the current is flow driven. Therefore this intake is classified as Type D intake.

LAKEFIELD, PETERBOROUGH, HASTINGS, MARMORA, CAMBELLFORD, FRANKFORD, & TRENTON

Each of the Lakefield, Peterborough, Hastings, Campbellford, Frankford, and Trenton intakes is located within a river reach, but the operation of the Trent-Severn Waterway affects the rate and direction of flow. The dams are operated to maintain navigation water levels, and to some extent, head differentials for hydroelectric power generation. There are also operational considerations for the hydroelectric dam on the Crowe River in Marmora (see Section 3.4.1.6). Because of these considerations, these intakes are classified as Type D intakes.

Figure 4.2-1: Photo of Warkworth WTP Looking Upstream

Figure 4.2-2: Photo of Warkworth WTP and Manhole

FENELON FALLS

The intake in Fenelon Falls is located near the outlet of Cameron Lake, and the flows in the vicinity of the intake begin to resemble the unidirectional flow of a river toward the Fenelon River. There are still some characteristics of lake current patterns in the vicinity of the intake, and the wind has some impact on flow and current. The intake is located a significant distance into the lake and is therefore classified as a Type D intake.

SOUTHVIEW ESTATES & BAYSIDE

Southview Estates and Bayside are also classified as Type D intakes because they are located a sufficient distance from the shorelines of Sturgeon Lake and the Bay of Quinte, respectively. The Bayside intake is located in the Bay of Quinte (an embayment of Lake Ontario) and is considered a Type A (Great Lakes) intake per the *Technical Rules*. However, since the hydrodynamics and water quality of the Bay of Quinte are distinctly different from Lake Ontario, Director's Approval was obtained to support the classification of the Bayside intake as a Type D (inland lake) intake (see Appendix A).

4.2.2 DELINEATION OF INTAKE PROTECTION ZONES

The *Technical Rules* sets out the 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: All upstream surface watercourses that may contribute water to an intake.

Intake Protection Zones 1, 2, and 3 were delineated for each municipal surface water system. Intake Protection Zones 1 and 2 for each system are shown on Maps 4-1a through 4-15a, and Intake Protection Zone 3 for each system is shown on Maps 4-1d through 4-15d. The delineation of each type of intake protection zone is described in the following sections.

4.2.2.1 Intake Protection Zone 1

The Intake Protection Zone 1 (IPZ-1) is the area immediately adjacent to the intake. This zone is considered the most vulnerable because, 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 the IPZ-1 for the intake types in the Trent source protection areas is discussed in the following sections.

4.2.2.1.1 Type C Intakes

For Type C intakes, the IPZ-1 is defined as the area within a semicircle with a radius of at least 200 m centered on the intake). Where an IPZ-1 extends onto or touches land, land within a 120 m setback of the high water mark of the related surface waterbody is included in the delineation (or, where greater, the Conservation Authority Regulation Limit). The zone also includes a fixed distance downstream of the intake (10 m minimum) to account for possible backflow. The IPZ-1 for rivers is oriented to be in line with streamflow.

4.2.2.1.2 Type D Intakes

For Type D intakes, the IPZ-1 is defined as the area contained by a circle with a 1,000 m radius (centered on the intake). As with Type C intakes, where an IPZ-1 extends onto or touches land, land within a 120 m setback of the high water mark of the related surface waterbody is included in the delineation (or, where greater, the Conservation Authority Regulation Limit).

Further, Technical Rule 64 allows the IPZ-1 to be modified to reflect local hydrodynamic conditions. Many of the Type D intakes in the Trent source protection areas are located within 1,000 m downstream of impoundment structures associated with the Trent-Severn Waterway. This condition would result in IPZ-1 delineations that extend downstream of impoundment structures. Physically this would represent a situation where water on the downstream side of a dam could travel back upstream due to the operation of a further downstream dam. Discussions with Bruce Kitchen (formerly of the Trent-Severn Waterway) were held regarding the operation of the dams in the vicinity of the intakes of interest along the waterway. It was decided that, due to the configuration of the dams, it would not be realistic to extend the IPZ-1 downstream of impoundment structures. In these cases, the IPZ-1 was cut off at the downstream dam.

4.2.2.2 Intake Protection Zone 2

The Intake Protection Zone 2 (IPZ-2) acts as a secondary protective zone that extends upstream of the IPZ-1. The 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. Discussions with plant personnel at each of the 16 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*. Where the IPZ-2 abuts land, land within a 120 m setback of the high water mark of the related surface waterbody is included in the delineation (or, where greater, the Conservation Authority Regulation Limit).

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

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 time of travel. The key task for delineating IPZ-2 was to accurately determine the 2-hour time of travel distance upstream of each intake.

4.2.2.2.1 Calculating Time of Travel Distance

Previous guidance from the Ministry of the Environment and Climate Change indicated that the 2-hour time of travel distance should be established at 2-year high flow. This distance was determined in the Trent source protection areas using a combination of dye and drogue studies and hydrodynamic modeling. These approaches are discussed below.

Dye Studies

In rivers, dye studies were conducted to determine flow velocities and directions. Fluorescent Rhodamine WT dye was injected across the width of the watercourse at a location estimated (based on available data) to be two hours upstream of the intake at the flow rate encountered on the day of the test. The time for the dye plume to reach the intake was measured using a calibrated portable fluorometer. Dye studies were completed for Norland, Kinmount, Lindsay, Lakefield, Peterborough, Hastings, Marmora, Campbellford, Warkworth, Frankford, and Trenton. Velocities determined from the dye studies, together with the corresponding flow rates (obtained from the Trent-Severn Waterway), were used to calibrate the hydrodynamic models.

Drogue Studies

In lakes, wind acts on the surface of the water and is the primary factor affecting the flow. For this reason, drogue studies were completed instead of dye studies. The drogues were constructed as sail-type devices, designed to be neutrally buoyant and unaffected by wind. They move with the surface current and provide an estimate of velocity. Drogue studies were completed for Fenelon Falls, Southview Estates, Bobcaygeon, and Bayside. Velocities determined from the drogue studies, together with the corresponding water levels and flow rates (obtained from the Trent-Severn Waterway), were used to calibrate the hydrodynamic models.

Orange Float Studies

Orange float studies were completed for Trenton, and Peterborough. An orange study is applied using the same principles as a particle velocity study (i.e., buoyant particles within a fluid are moving at the same speed as the fluid). These were used to estimate the average velocity in the vicinity of these intakes. (To find the average reach velocity, the reach length is simply divided by the time required for the oranges to travel from point A to point B.) Oranges are ideal for a velocity study because they are neutrally buoyant, bright in colour, and biodegradable.

Modeling Approach

Hydrodynamic modeling was used for all of the surface water intakes in the Trent source protection areas. The model for each intake was developed using the US Environmental Protection Agency's Environment Fluid Dynamics Code software (except the Peterborough intake, which used an existing HEC-RAS model). As inputs, the model required data detailing bathymetry, flow, and water level. Bathymetry data were collected from navigation charts or site-specific depth surveys. The model was run in steady state conditions and the effects of storage were not evaluated. To ensure that the model returned reasonable results, the model was calibrated to the field data obtained from the dye and drogue studies. In all cases, with appropriate parameter adjustment, the model was able to reasonably simulate the field data. With the field-truthed model developed, the 2-year flow and level were input into the model and the resultant 2-hour travel times were mapped as the IPZ-2.

For the Bayside intake (located in the Bay of Quinte), information on wind speed, wind duration, and fetch (the distance wind or waves can travel over open water without physical interference) was also taken into consideration. The results obtained from the hydrodynamic modeling for this intake were added to the wind drifts obtained from the James wind-drift forecasting curves (Hsu, 1988) to determine the distance of the 2-hour time of travel. The IPZ-2 for Bayside was extended further to incorporate a portion of a small stream, based on the findings of a dye study.

4.2.2.3 Intake Protection Zone 3

Intake Protection Zone 3 (IPZ-3) is a protective zone where early warning activities such as monitoring may be effective. The IPZ-3 for a Type C or Type D intake includes the area within each surface waterbody that may contribute water to the intake. Where the IPZ-3 abuts land, land within a 120 m setback of the high water mark of the related surface waterbody is included in the delineation (or, where greater, the Conservation Authority Regulation Limit). Mapping for the Conservation Authority Regulation Limit is not available for all of the IPZ-3s because some portions of the Trent source protection areas are outside of Conservation Authority jurisdiction (i.e., there are no established Regulation Limits). Where no mapping of Regulation Limits was available, the setback was set at 120 m.

The IPZ-3 may be further divided into subsections to allow for different vulnerability scores to be applied to different sections of the IPZ-3. For the purpose of calculating the area vulnerability factor, the IPZ-3 was separated into the following three subzones based on distance from the intake:

- IPZ-3a: portion of the IPZ-3 located less than 10 km from the intake
- IPZ-3b: portion of the IPZ-3 located between 10 and 25 km from the intake
- IPZ-3c: portion of the IPZ-3 located more than 25 km from the intake.

The 10 and 25 km ranges represent a rough approximation of the 10-hour and 24-hour time of travel distance using a flow velocity of 0.3 metres per second (m/s). This flow velocity was selected based on the average velocity of 0.3 m/s observed during the tributary dye studies conducted by the consultants in 2006. The selection of time of travel is based on the consultants' professional judgment resulting from their review of the various sizes of IPZ-3s in the TCC region and also a continuation of the rationale of a 2-hour travel time used for IPZ-2 delineation. The IPZ-3b or IPZ-3c were not delineated where the time of travel distance was less than the distance criteria used to divide the IPZ-3 into subzones. The subzones were assigned different area vulnerability factors (see Section 4.2.3.1.1) to account for their differences in proximity to the intake.

IPZ-3 delineations require identification of all contributing watercourses upstream of the intake of interest up to the boundary of the relevant source protection area. Since the Trent River watershed is so large and all of the intakes are located upstream or downstream of one or more of the other intakes, the IPZ-3 was truncated at the downstream boundary of the IPZ-1 that corresponds to the relevant upstream intake (i.e., a tessellation approach). With this approach, any threats in the contributing watershed upstream of the next intake will be better addressed with the assessment of vulnerability of the closest intake (i.e., the vulnerability score will be higher). Director's Approval was obtained for this approach (see Appendix A).

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 in an intake protection zone, the higher the vulnerability of that zone to contamination. The *Technical Rules* sets out a mechanism by which Intake Protection Zones 2 and 3 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).

Transport pathways in the Trent source protection areas were identified during the data collection phase of the vulnerability assessment, field reconnaissance trips, and during the dye studies. Storm drain outlets were identified using global positioning system (GPS) points of drainage outlets within the IPZ-1 and IPZ-2. Where available, polygon data representing storm sewersheds was used; in other cases, geospatial data of sewer pipes were used to delineate the extent of the storm sewershed. Storm sewershed information was available for the urban areas of Lindsay, Peterborough, Campbellford, Fenelon Falls and Trenton. Areas drained by tile drains were identified from a geographic dataset of tile-drained areas from the Ministry of Agriculture, Food and Rural Affairs. The transport pathways that were identified are listed in Table 4.2-1.

IPZ-2 and IPZ-3 delineations were expanded to incorporate areas drained by the identified storm sewers and tile drains. The *Technical Rules* require that where an IPZ-2 is expanded to include storm a sewershed as a transport pathway that the delineation must only include the portion of the storm sewershed where the time of travel to the intake is less than two hours (i.e. truncating any portion of the sewershed where the time of travel to the intake is greater than two hours). A time of travel analysis within municipal storm sewer lines was undertaken to identify the extent of the identified storm sewersheds that are within the two-hour time of travel to the corresponding intake. This analysis resulted in the truncation of storm sewersheds within the IPZ-2s for the Lindsay, Campbellford, Fenelon Falls, and Trenton intakes. Transport pathways were also considered during the assignment of vulnerability scores (see Section 4.2.3.1)."

Table 4.2-1: Transport Pathways

Intake	Description	Location	Coordinates[1]		Source of Information
			X	Y	
Norland	30” culvert	HWY 35 Roadside	671965	4956102	XCG Site Visit (October 10, 2007) GPS coordinates by XCG
	30” culvert	Near HWY 35 & Cameron Rd	672006	4955948	
	12” storm line	By Horticultural Gardens	673262	4955040	
	Suspected storm sewer outlet	By Horticultural Gardens	673211	4955066	
	Corrugated steel pipe estimated diameter 30”	Drainage for Main Norland Intersection HWY 35 and Monck Road.	673297	4955034	
	8” corrugated steel pipe	Located near Monck Street Bridge	673334	4955101	
	8” concrete	Bridge Drainage	673336	4955124	
Kinmount	6” PVC	Immediately DS of intake	685343	4961902	XCG Site Visit (August 15, 2007) GPS coordinates by XCG
	Approx. 20” corrugated steel pipe	Immediately DS of intake	685354	4961886	
	Approx. 20” corrugated steel pipe	Immediately DS of intake	685348	4961889	
	Approx. 24” corrugated steel pipe	Immediately DS of intake	685379	4961877	
Fenelon Falls	Drainage swale	Ditch Beside WTP	679385	4934233	XCG Site Visit (August 29, 2007) GPS coordinates by XCG
	Catch-basin Inlet	Backyard and Park Drainage	679444	4934129	
	16” corrugated metal pipe	Discharge into lake	679384	4934334	
	Catch-basin Inlet	Culvert passing under road, drains depression on opposite side of parking lots	679429	4934348	
Lindsay	12” pipe (concrete or iron)	West bank in front of WTP	681176	4913003	XCG Site Visit (October 12, 2007) GPS coordinates by XCG
	Supernatant discharge pipe, 20” steel	West bank, just DS of WTP	681199	4913051	
	10” steel with rate grate	West bank in front of WTP	681169	4912978	
	8” concrete pipe	West bank in front of WTP	681165	4912963	
	36” corrugated steel pipe	West bank upstream of HWY 35 bridge	680991	4912380	
	4” plastic pipe	West bank, downstream of WTP. Assumed to be house roof drain and/or sump	681184	4913024	
	Ditch	HWY 7 Drainage	680970	4910738	
	Drainage ditch	Farmers field drainage	681101	4911816	
Southview Estates	Culvert	Outlet near point leading towards intake	679955	4923984	XCG Site Visit (July 2007) GPS coordinates by XCG
Bobcaygeon	Storm outlet	North shore of Sturgeon Lake directly upstream of dam	694490	4934487	XCG Site Visit & Storm Sewer Mapping (May 2, 2008) GPS coordinates by XCG
Lakefield (cont’d next page)	Storm outfall	East bank of river	717340	4923460	Hardcopy storm outfall map provided by Municipality of Smith-Ennismore-Lakefield; locations measured from 1:10,000 mapping
	Storm outfall	East bank of river	717340	4923535	
	Storm outfall	East bank of river	717115	4923500	

[1]All coordinates are given for UTM Zone 17N except Campbellford, Warkworth, Frankford, Trenton, and Bayside, which are given for UTM

Table 4.2-1: Transport Pathways (cont.'d)

Intake	Description	Location	Coordinates[1]		Source of Information
			X	Y	
Lakefield (cont'd)	Tributary	SW corner of lake	716900	4923400	Measured from 1:10,000 mapping. Confirmed during XCG field reconnaissance, Oct/06.
	Tributary	West shore of lake	716630	4924140	
	Storm outfall	Opposite 14 Water St.	717231	4923040	GPS Coordinates provided by the Municipality of Smith-Ennismore-Lakefield
	Storm outfall	King St. and Water St.	717168	4922915	
	Storm outfall	Opposite 66 Water St.	717086	4922758	
	Storm outfall	Opposite 10 Reid St.	717021	4922694	
	Storm outfall	Private Marina	717410	4923634	
	Storm outfall	George St. and Hauge St.	716872	4922535	
	Storm outfall	D'Eyencourt St. and Hauge St.	716911	4922690	
	Storm outfall	South of Lakefield Beach	717074	4923097	
	Storm outfall	Burnham St. and Water St.	716960	4922538	
Peterborough	Storm outfall (12"corrugated steel)	East bank of river	714789	4913792	Located by XCG field crew
	Storm outfall (1m corrugated steel flowing into small stream)	West bank of river	714682	4913810	Located during XCG site visit, Dec/06
	Outlet from SWM pond	West bank of river	715095	4914245	1:10,000 mapping, confirmed by XCG field reconnaissance, Oct/06
	Drainage ditch	West bank just north of road bridge	715440	4914535	
Campbellford	Storm outfall (24" concrete)	East bank	276831	4910042	Located by XCG field crew
	Storm outfall (24" corrugated plastic)	West bank	276754	4910196	
	Storm outfall (15" corrugated plastic)	East bank	276940	4910319	
	Storm outfall (24" corrugated plastic)	East bank	277112	4910474	
Warkworth	Drainage ditch	South bank	268016	4897973	Located during June/06 XCG field reconnaissance
	Tile drain pipes (2 PVC)	North bank	267461	4897857	Located by XCG field crew during stream survey July/06
Frankford	Storm outfall	West bank, at Huffman Road	292360	4898650	Located during XCG site visit, Dec/06
	Drainage ditch	West bank, near Sill Island	292230	4899030	Located during Oct/06 XCG field reconnaissance
	Tile drain	Outlets to tributary near Glen Ross Rd.	291669	4899407	Lot/Concession tile drain locations provided by LTC
Trenton	Storm outfall	Tributary to Glen Miller Creek	293536	4889339	Storm sewer mapping layer (GIS) provided by LTC
	Outfall from storm pond	Tributary to Glen Miller Creek	293920	4889410	Storm sewer mapping layer (GIS) provided by LTC
	Tile drain	Outlets to tributary on west bank, north of Hwy 401	291836	4890178	Lot/Concession tile drain locations provided by LTC
Bayside	Drainage ditch or stream	South shore of Bay of Quinte	302510	4887305	1:10,000 mapping

[1]All coordinates are given for UTM Zone 17N except Campbellford, Warkworth, Frankford, Trenton, and Bayside, which are given for UTM Zone 18N

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 framework for assigning vulnerability scores to each of the three intake protection zones. There are two types of vulnerability factors associated with an intake protection zone: an area vulnerability factor and a source vulnerability factor – the product of these factors gives the final vulnerability score. Vulnerability factors and the final vulnerability scores assigned to intake protection zones are discussed in the following sections.

4.2.3.1 Vulnerability Factors

4.2.3.1.1 Area Vulnerability Factor

The area vulnerability factor reflects the physical characteristics of the intake protection zone. It differs for each of the three intake protection zones: the closer the zone to the intake, the higher the area vulnerability factor. The assignment of area vulnerability factors to intake protection zones is discussed below.

INTAKE PROTECTION ZONE 1

Due to its immediate proximity to the intake, the area vulnerability factor for the Intake Protection Zone 1 is fixed at 10 for all surface water intakes.

INTAKE PROTECTION ZONE 2

For the Intake Protection Zone 2, the area vulnerability factor can range between 7 and 9. Area vulnerability factors were assigned to IPZ-2 based on the following considerations:

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

A base area vulnerability factor of 8 was assigned to each IPZ-2, which was then adjusted to account for the above considerations per the methodology described below. The factors that were considered less important than others were adjusted by a value of 0.5, wheras the more important factors were adjusted by a value of 1.0.

Hydrologic and Hydrogeologic Factors: Hydrologic and hydrogeologic factors that contribute water to the area through transport pathways were a significant consideration for the IPZ-2. Increased numbers of transport pathways in the IPZ-2 would increase the vulnerability. Where numerous man-made pathways were present in the IPZ-2, the area vulnerability factor was increased by 1.

In the Trent River system the bulk of flow is conveyed by the major rivers (Otonabee and Trent) flowing from the Kawartha Lakes into the Bay of Quinte, most tributaries and transport pathways would provide comparatively small flow but a significant loading, especially for tributaries and transport pathways draining the urban areas.

Land Cover: Land cover is expected to have significant impact on the vulnerability of any area due to increased infiltration on forested areas versus increased runoff on highly impervious surfaces typical of urban areas. For intake protection zones located in urban areas, the area vulnerability factor was increased by 1, and where it was located in forested areas, it was decreased by 1. In the case of open fields, the factor was not adjusted.

Percent Land Coverage: The area vulnerability factor was increased by 0.5 where the intake protection zone had a higher percentage of land coverage near headwaters, left unchanged where there were larger rivers with some small lakes, and decreased by 0.5 where there were large lakes.

Based on the tessellated approach it can be said the land portion will always be greater than the water portion. The exception being a lake or reservoir based intake that has an upstream intake in close proximity (i.e. Bayside). For headwater areas where the streams are smaller, the portion of the area able to contribute to runoff is higher and thus the vulnerability would be higher.

Slope of Setbacks: The area vulnerability factor was modified to account for differences in the slope of setbacks. For steep slopes, the factor was increased by 0.5, for moderate slopes it was left unchanged, and for flat slopes it was decreased by 0.5.

Soil Type and Permeability: The area vulnerability factor was modified to account for soil type and permeability. For rock and clay, the factor was increased by 0.5, for silts it was left unchanged, and for sand and gravel it was decreased by 0.5.

INTAKE PROTECTION ZONE 3

For the Intake Protection Zone 3 (for Type C and D intakes), the area vulnerability factor can range between 1 and 9. Proximity to the intake was considered to have the most influence on the area vulnerability factor (physically, it makes sense that the farther away an area from an intake, the less impact it would have on that intake). The three subzones delineated for the IPZ-3 were assigned base area vulnerability factors of 6 (IPZ-3a), 3 (IPZ-3b), and 2 (IPZ-3c) (i.e., the base area vulnerability factor is reduced as you get further away from the intake). The base vulnerability scores were assigned based on the consultants’ professional judgment. This arrangement of base area vulnerability factors for IPZ-3 is also in agreement with the vulnerability scoring for IPZ-2: the highest base vulnerability score assigned to IPZ-3 (i.e., 6) is a step lower than the lowest vulnerability score that can be assigned to IPZ-2 (i.e., 7).

These base scores were adjusted to account for the presence of transport pathways and differences in land cover, soil type, slope of setbacks, and percent land coverage as described above for IPZ-2. Since area vulnerability factors must be integers, where a non-integer value was obtained, a review of the hydrologic and hydrogeologic contributions through transport pathways was used to determine whether to round up or down.

After proximity, transport pathways and land cover were considered to have the most significant impact on the assignment of the area vulnerability factor. The same adjustment factors used for the assignment of IPZ-2 area vulnerability factor were applied for IPZ-3.

4.2.3.1.2 Source Vulnerability Factor

The source vulnerability factor accounts for the location of the intake on a particular waterbody. Type C and Type D intakes are considered to be highly susceptible to contamination, so their range of possible source vulnerability factors is low; these can range from 0.9 to 1 for Type C and 0.8 to 1 for Type D.

Source vulnerability factors were assigned to each intake in consideration of the following factors:

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

Depth of the intake was the most important factor. The Bayside intake (the deepest intake) was assigned a source vulnerability factor of 0.8 (least vulnerable), and other intakes were assigned factors based on depth and the other considerations listed above.

4.2.3.2 Vulnerability Scores

The vulnerability score for each intake protection zone is calculated as the product of 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 can range from 0.8 to 10 (for Type C intakes) or 0.9 to 10 (for Type D intakes).

In some cases, the Intake Protection Zone 3 was subdivided into different areas for assignment of different vulnerability scores within the Intake Protection Zone 3. The vulnerability scores assigned to intake protection zones are summarized in Table 4.2-2 and Table 4.2-3. The assignment of vulnerability factors and vulnerability scores to each of the 16 intakes is described in the following subsections.

Table 4.2-2: Vulnerability Factors for Intake Protection Zones

Surface Water System	Source Vulnerability Factor	Area Vulnerability Factor				
		IPZ-1	IPZ-2	IPZ- 3		
				IPZ-3a	IPZ-3b	IPZ-3c
Norland	1	10	7	6	3	2
Kinmount	1	10	7	6	3	2
Fenelon Falls	0.9	10	8	5	3	2
Lindsay	1	10	9	6	2	2
Southview Estates	0.8	10	8	6	3	-
Bobcaygeon	1	10	8	5	3	-
Lakefield	1	10	8	5	2	2
Peterborough	1	10	9	6	3	-
Hastings	1	10	8	6	3	2
Marmora	1	10	7	5	4	3
Campbellford	1	10	9	6	4	-
Warkworth	1	10	9	6	2	-
Frankford	0.9	10	9	6	3	2
Trenton	1	10	9	6	-	-
Bayside	0.8	10	8	7	3	-

[1]Dashes indicate where the IPZ-3b or IPZ-3c was not delineated because the time-of-travel distance was less than the distance criteria established to subdivide the IPZ-3 into subzones (see Section 4.2.2.3)

Table 4.2-3: Vulnerability Scores for Intake Protection Zones

Surface Water System	IPZ-1	IPZ-2	IPZ-3		
			IPZ-3a	IPZ-3b	IPZ-3c
Norland	10	7	6	3	2
Kinmount	10	7	6	3	2
Fenelon Falls	9	7.2	4.5	2.7	1.8
Lindsay	10	9	6	2	2
Southview Estates	8	6.4	4.8	2.4	-
Bobcaygeon	10	8	5	3	-
Lakefield	10	8	5	2	2
Peterborough	10	9	6	3	-
Hastings	10	8	6	3	2
Marmora	10	7	5	4	3
Campbellford	10	9	6	4	-
Warkworth	10	9	6	2	-
Frankford	9	8.1	5.4	2.7	1.8
Trenton	10	9	6	-	-
Bayside	8	6.4	5.6	2.4	-

[1]Dashes indicate where the IPZ-3b or IPZ-3c was not delineated because the time-of-travel distance was less than the distance criteria established to subdivide the IPZ-3 into subzones (see Section 4.2.2.3)

4.2.3.2.1 Norland

A source vulnerability factor of 1 was selected for this intake, due to its proximity to the shore and its relatively shallow depth. Although the raw water quality is good, it was decided that the higher source vulnerability factor would be more appropriate based on the intake characteristics.

Although a number of transport pathways were identified, they appeared to service the immediate area (IPZ-1) and did not extend beyond into the IPZ-2. Given that the Gull River is quite narrow upstream of the intake, and the setbacks applied for the IPZ-2 are a minimum of 120 metres on both sides of the river, the percent land in the IPZ-2 is quite high.

The majority of the land in the IPZ-2 is forested, especially on the east side where there is very little development. Highway 35 roughly follows the west side of the Gull River within the IPZ-2, and there are a number of different land uses along the highway including forested land, cleared agricultural land, and some commercial land uses. The tributaries included in the eastern IPZ-2 delineation are located in pristine land with no development and therefore under forest or wetland.

The Gull River is noted for running along an ancient glacial spillway that was gouged into the bedrock. The majority of the IPZ-2 slopes gently “downstream” with no large elevation changes. There are some elevated areas in the eastern tributaries section of the IPZ-2 showing slightly sharper topography (a 20-metre elevation difference). As the IPZ-2 is located on the edge of the Georgian Bay Fringe, there is very little overburden, most of which is more recent deposits or glacial till.

Using the methodology described in Section 4.2.3.1.1., the area vulnerability factor for IPZ-2 was assigned the lowest possible number of 7.

The areas upstream of the Norland intake are mainly in the Georgian Bay Fringe and reach up into the Algonquin Highlands physiographic regions of the Canadian Shield. As noted above, the Gull River follows a glacial spillway. Again the soil is very shallow and consists of shallow recent deposits or glacial till. The land cover consists of largely forested areas except for the lakes and wetlands. Given the narrow waterbodies, the percent land area is high for the IPZ-3, although there are more lakes in the upper end of the IPZ-3.

The IPZ-3 extends approximately 80 kilometres north of Norland. The IPZ-3 was subdivided as described in Section 4.2.2.3., at the 10- and 25-kilometre radii from the intake. As all of these areas are similar in topography, soil, and land cover, the vulnerability of these areas is expected to be similar with the exception of distance to the intake. Therefore IPZ-3a was assigned the area vulnerability factor of 6, the IPZ-3b was assigned an area vulnerability factor of 3, and the area vulnerability factor for IPZ-3c was 2.

4.2.3.2.2 Kinmount

A source vulnerability factor of 1 was selected for the Kinmount intake, due to its relatively shallow depth and proximity to the shoreline, although the water quality was good.

There are no identified anthropogenic transport pathways for pollutants in the IPZ-2 for Kinmount. The land use upstream of the intake includes very little developed land with the remainder of the IPZ-2 under natural forested cover and wetlands. Kinmount, like Norland, is located in the Georgian Bay Fringe of the Canadian Shield and soil cover is very shallow to none with bare outcrops. The Burnt River, like the Gull River, is located in a glacial spillway and, also like the Gull River, the majority of the IPZ-2 consists of land rather than water. The topography in the IPZ-2 is a little more rugged than the Norland area, with steeper slopes directing overland flow to tributaries and the Burnt River. The area vulnerability factor for the IPZ-2 was assigned the lowest possible number of 7.

Again, similar to Norland, the areas upstream of the Kinmount intake that are included in the IPZ-3 delineation are mainly in the Canadian Shield area with little land use other than cottages around the lakes and rivers. Although the town of Haliburton is upstream on one of the lakes on the upper Burnt River system, this development is well beyond the intake (approximately 45 km north). The majority of the land cover is forested, the soils in the IPZ-3 are shallow or there is bare rock, and the topography is rugged. Similar to Norland, as all of these areas are similar in topography, soil, and land cover, the vulnerability of these areas is expected to be similar with the exception of distance to the intake. Therefore, IPZ-3a was assigned the area vulnerability factor of 6, the IPZ-3b was assigned an area vulnerability factor of 3, and the IPZ-3c was assigned an area vulnerability factor of 2.

4.2.3.2.3 Fenelon Falls

A source vulnerability factor of 0.9, the middle value allowed for Type D intakes, was selected for the Fenelon Falls intake, due to its location away from the shoreline and the fact that the intake is in fairly deep water, although there are a number of transport pathways. There is also fairly intensive recreational use of the lake and river within this area.

Although there are no tributaries contributing runoff to the IPZ-1 and IPZ-2, there is potential for runoff generation from the storm drains system. The IPZ-2 consists of small areas in the town that drain to the IPZ-1. Fenelon Falls is located on the very western edge of the Dummer Moraine. This stony till plain is quite flat in the area of the IPZ-2. All of the IPZ-2 is developed so the land cover consists of buildings, lawns, and roadway. There is no water in the IPZ-2, therefore it is 100% land. Given these considerations, the IPZ-2 for Fenelon Falls was given a moderate area vulnerability factor of 8.

The IPZ-3 for Fenelon Falls is located within four separate physiographic regions: the Dummer Moraine along the mideastern section; the Peterborough Drumlin Field in the area to the south of Cameron and Balsam Lakes; the Carden Plain north of the two large lakes; and the Georgian Bay Fringe at the most northern end of the IPZ-3 where the delineation is terminated at the Kinmount and Norland intakes. Each of these physiographic regions has specific soil types and topography associated with it. As mentioned earlier, the Georgian Bay Fringe has a high land percentage due to the headwaters of the rivers and streams, whereas the two large lakes, along with smaller lakes in the Carden Plain area, indicate lower percentage land. The southern Peterborough Drumlin area also demonstrates lower percent land numbers due to the wetland areas between the drumlins.

The Carden Plain consists of a shallow-depth clay plain over limestone bedrock with very little topographic relief. The hummocky terrain of the drumlin field consists of silty sand and sandy silt deposits while the Georgian Bay Fringe exhibits very little soil and more rugged topography. IPZ-3a contains all of Cameron Lake and part of Balsam Lake, IPZ-3b contains the remainder of contributing watersheds including Gull and Burnt Rivers up to Norland and Kinmount. The area vulnerability factors assigned to these areas were 5, 3, and 2, respectively.

4.2.3.2.4 Lindsay

A source vulnerability factor of 1 was selected for the Lindsay intake, due to its relatively shallow depth and proximity to shore.

The majority of the IPZ-2 and IPZ-3 for Lindsay are located on the Schomberg Clay Plain with underlying sediments of varved clays. The soils are noted to be silty clay loam. The northwestern portion of the watershed is located within the Peterborough Drumlin Field while the southern edge of the IPZ-3 is located within the north slope of the Oak Ridges Moraine.

The highest possible area vulnerability factor of 9 was selected for the IPZ-2, due to the presence of a number of transport pathways that service industrial, commercial, and agricultural areas of the nearby watershed.

Although the Scugog River is not as heavily used as the Trent-Severn Waterway, there is still some recreational usage of the Scugog River and Lake area. There is intensive agricultural use of the land in the IPZ-3 indicating significant field cover and little urban area. The flatter slope of the area around Scugog Lake and other large bodies of water lowered the vulnerability factor in the IPZ-3b and IPZ-3c. Overall, the area vulnerability scores assigned to the IPZ-3 were 6, 2, and 2 for IPZ-3a, IPZ-3b, and IPZ-3c, respectively.

4.2.3.2.5 Southview Estates

A source vulnerability factor of 0.8, the lowest possible value for a Type D intake, was selected for the Southview Estates intake, due to its significant distance away from shore and moderate raw water quality.

The entire IPZ for Southview Estates is located within the physiographic region of the Peterborough Drumlin Fields. The area vulnerability factor for IPZ-2 was assigned the mid-range number of 8, due to the presence of one transport pathway for pollutants and other factors. The land in the IPZ-2 is mostly grassed fields beyond the single family dwellings of the subdivision with a gentle slope toward the water. There is no water portion to the IPZ-2 delineation and therefore the percent land is high.

The IPZ-3 for Southview Estates was subdivided into two areas for area vulnerability factor assignment. The nearest 10-kilometre circle (IPZ-3a) includes a significant portion of Sturgeon Lake and the Scugog River. Again the entire area, being part of the drumlin fields, shows a hummocky terrain, and the soils are typically glacial till of massive silty-sand to sandy-silt. Along the western shore of Sturgeon Lake there are some sandy deposits but the southern end of the lake and down the Scugog River indicate peat and muck deposits. The land is typically open fields with little forested area. The IPZ-3a was assigned an area vulnerability factor of 6, and the IPZ-3b was assigned an area vulnerability factor of 3.

4.2.3.2.6 Bobcaygeon

The highest possible source vulnerability factor was selected for the Bobcaygeon intake, due to its short distance from shore, shallow depth, and moderate raw water quality.

A mid-range value of the area vulnerability factor for the IPZ-2 was selected, due to the presence of a tributary in close proximity to the intake, the moderate runoff generation potential with the moderate slope in the IPZ-2, and the exposed bedrock along the waters' edges but with silty sand in the northern portion of the IPZ-2. The presence of the very eastern end of Sturgeon Lake decreased the percent land factor and therefore an area vulnerability factor of 8 was assigned to IPZ-2.

Like Southview Estates, Bobcaygeon was divided into two IPZ-3 zones based on proximity to the intake. The portion of the IPZ-3s that falls north of Sturgeon Lake is located within the Dummer Moraine with gentle slopes and stony silty sandy soils. To the south of Sturgeon Lake is the physiographic region of the Peterborough Drumlin Fields with hummocky terrain and massive sandy silt tills. Both areas indicate significant agricultural usage with open fields for land cover, and the presence of Sturgeon Lake keeps the percent land numbers lower. The resulting area vulnerability factors are 5 and 3 for IPZ-3a and IPZ-3b, respectively.

4.2.3.2.7 Lakefield

A source vulnerability factor of 1 was selected for this intake, due to its proximity to the shore and its relatively shallow depth. Although the raw water quality is good with issues identified for naturally occurring parameters only, it was decided that the higher source vulnerability factor would be more appropriate based on intake location.

The IPZ-2 was assigned an area vulnerability factor of 8, the median value, as there are some transport pathways for pollutants in close proximity to the intake, but the majority of the soils in the IPZ-2 consist of well drained soils that would reduce the factor. Also, there is urbanized land use upstream of the intake in Lakefield, thus runoff generation potential is moderate. Land cover in this case would consist of many impermeable surfaces but the large percentage of water in the IPZ-2 would also reduce the factor.

The IPZ-3 for Lakefield was subdivided into three subzones: IPZ-3a – the northern portion of Katewanooka Lake and associated tributaries to this lake; IPZ-3b – the eastern Kawartha Lakes including Stoney, Chemong, Clear, Lower Buckhorn, Buckhorn, and Pigeon Lakes; and IPZ-3c – the tributaries south of Pigeon Lake and tributaries to the north of the eastern Kawartha Lakes.

The IPZ-3a closest to the intake was assigned an area vulnerability factor of 5 due to the proximity to the intake and the land cover of mostly open fields. This area is defined physiographically by both the Peterborough Drumlin Fields and the Dummer Moraine, with till soils exhibiting moderate permeability on average as well as a fairly flat slope to the area.

The IPZ-3b was assigned a lower area vulnerability factor of 2, with percent land being low with the presence of the large bodies of water in this zone. Other factors that reduced the score included the fairly flat slope in the IPZ-3 around the lakes.

The final IPZ-3c area has a majority of the area within the Canadian Shield, with very little soil cover (increase vulnerability) and forested lands (decrease vulnerability). This headwater area would also have a high percent land ratio as well, increasing the vulnerability. Overall the area vulnerability factor of 2 was assigned to this subzone.

4.2.3.2.8 Peterborough

A source vulnerability factor of 1 was selected for the Peterborough intake, due to its relatively shallow depth, close proximity to the shore, and moderate raw water quality.

The area vulnerability factor for the IPZ-2 was assigned as the highest possible number, due to the presence of several transport pathways for pollutants in close proximity to the intake. Also, there is urbanized land use upstream of the intake in Peterborough, indicating significant impermeable surfaces for land cover.

The IPZ-3 for Peterborough was subdivided into two sections for vulnerability assessment. The IPZ-3a consists of the Otonabee River up to the Lakefield IPZ. The IPZ-3b extends beyond the IPZ-3a to include the upper reaches of tributaries to the Otonabee River reach between Lakefield and Peterborough, including Sawyer Creek. Upper Sawyer Creek includes a large wetland area and Buckley and Long Lakes as contributing waterbodies.

The IPZ-3a was assigned an area vulnerability factor of 6, which took into account the ancient glacial spillway that follows the Otonabee River between Lakefield and Peterborough. The majority of the soils along the river are listed as different types of loams (Otonabee, Dummer, and Farmington) that are well drained to excessively well drained (Peterborough County Soils Map), thus reducing the vulnerability factor, while other considerations such as land cover and slope provided a neutral effect to the vulnerability factor.

The majority of the IPZ-3b subzone is located on a very flat area (decreased vulnerability) and the land cover is undeveloped wetland. The presence of the wetlands has a neutral effect on the vulnerability factor in terms of percent land considerations. Overall this subzone was assigned an area vulnerability factor of 3.

4.2.3.2.9 Hastings

A source vulnerability factor of 1 was selected for the Hastings intake, due to its relatively shallow depth and moderate raw water quality.

The area vulnerability factor for the IPZ-2 was assigned to the middle of the range – 8. There are some tributaries contributing runoff to the river upstream of the intake, but no identified transport pathways such as storm outfalls. The majority of the land cover in the IPZ-2 consists of residential development with some impermeable surfaces and lawns. Open fields are also present in the IPZ-2.

The IPZ-3 for Hastings encompasses a large area from Hastings to Peterborough including Rice Lake. For the assignment of vulnerability scores, the IPZ-3 was subdivided into three areas: IPZ-3a – the Trent River, the very eastern portion of Rice Lake, and the lower part of the Ouse River; IPZ-3b – the central portion of Rice Lake and the Indian River system and various tributaries; and IPZ-3c – the western portion of Rice Lake, the Otonabee River, and the City of Peterborough storm sewer system. The area vulnerability factors assigned to these areas were 6, 3, and 2, respectively.

The majority of the IPZ-3 is located within the Peterborough Drumlin Field, which exhibits rolling landscape with numerous drumlins (neutral effect). Typical soils are well drained loams, with sandy loams found along the northern shoreline of Rice Lake (decreasing vulnerability). Ancient glacial spillways are present along the Indian River and Ouse River with poorly drained loams present, increasing the vulnerability along these rivers. As each subzone was assessed on the entire area, these factors had to be averaged over the area. Overall, the vulnerability scores reflected the starting scores based on proximity to the intake for each subzone.

4.2.3.2.10 Marmora

A source vulnerability factor of 1 was selected for the Marmora intake, due to its relatively shallow depth and proximity to shore.

The lowest possible area vulnerability factor of 7 was selected for the IPZ-2, due to few preferential pathways present in this area. There is significant recreational property on the Crowe River, and upstream on Crowe Lake, however, the river water quality does not appear to be affected by this use to any great extent.

The IPZ-3 for Marmora was subdivided into three subzones based on proximity to the intake. The IPZ-3a includes Crowe Lake and some nearby tributaries. The IPZ-3b extends up the watershed along the Crowe River and North River, just beyond Oak Lake and Bog Lake. The IPZ-3c extends further beyond to the headwaters of the Crowe River system.

The majority of this IPZ-3 is located in the physiographic regions of the Georgian Bay Fringe and the Algonquin Highlands, exhibiting very little soil cover and increasing vulnerability in these areas. In all areas, the land cover is typically forested, which is the only consideration that decreases the vulnerability in all subzones. The percent land in the IPZ-3b and the IPZ-3c is high, increasing the vulnerability. Overall the area vulnerability factors assigned to each subzone are 5, 4, and 3, respectively.

4.2.3.2.11 Campbellford

A source vulnerability factor of 1 was selected for the Campbellford intake, due to its location right at the shore and moderate raw water quality.

The area vulnerability factor for the IPZ-2 was assigned the highest possible number (9) due to the presence of several transport pathways for pollutants in close proximity to the intake. Also, there is significant urbanized land use upstream of the intake in Campbellford, and land cover is very impermeable indicating that runoff generation potential is high.

The IPZ-3 for Campbellford was subdivided into two areas. The IPZ-3a consists of the Trent River and tributaries such as Trout Creek, upstream of the intake to Seymour Lake and Burnt Point Bay. The IPZ-3b includes the

Crowe River and tributaries up to the Marmora IPZ, and the Trent River and tributaries from Burnt Point Bay to the Hastings IPZ.

The IPZ-3a is located within the Peterborough Drumlin Field physiographic region. The IPZ-3a was assigned an area vulnerability factor of 6, as all other factors such as land cover (fields), slope (moderate), soils (average permeability), and percent land (large river) are considered to be neutral to the proximity to intake factor. The section of the IPZ-3b that follows the Crowe River is located within the Dummer Moraine, indicating stony till soils along the river. There is a large sand plain along the north shore of the Trent River near Seymour Lake that would decrease the vulnerability factor in this area. The section of the Trent River that approaches Hastings exhibits the rolling landscape of the Peterborough Drumlin Field. Overall this subzone was assigned the area vulnerability factor of 4.

4.2.3.2.12 Warkworth

The Warkworth intake was assigned the highest source vulnerability factor of 1 due to its location right at shore, shallow depth, and poor raw water quality.

The area vulnerability factor for the IPZ-2 was also assigned the highest possible number (9) due to the presence of transport pathways in close proximity to the intake.

The IPZ-3 was subdivided into two subzones based on proximity to the intake. Both subzones follow Burnley Creek, located within the Peterborough Drumlin Field. The extreme western end of the creek has its headwaters in the Oak Ridges Moraine. There is an identified sand plain along the northern shore of the IPZ-3a. The fact that the percent land is high for both of these areas increases the vulnerability but the highly permeable soils decrease the vulnerability. Land cover in the very upper section of the watershed is undeveloped with forested areas indicating reduced vulnerability. Therefore, the area vulnerability factors assigned to IPZ-3a and IPZ-3b are 6 and 2, respectively.

4.2.3.2.13 Frankford

A source vulnerability factor of 0.9 was selected for the Frankford intake, due to its location further in the middle of the river, moderate depth, and its good raw water quality.

A value of 9 was calculated for the area vulnerability factor for the IPZ-2 for Frankford due to the presence of a few transport pathways and average permeability soils (Percy, Bondhead, and Tioga soils). The land cover in the IPZ-2 consists of some forested areas and some fields. There are residential developments along the Trent River as well as steep slopes along the IPZ-2.

For the IPZ-3 vulnerability scores for Frankford, the IPZ-3 was subdivided into three subzones based on proximity to the intake, similar to other intakes. IPZ-3a follows the Trent River to Percy Reach. IPZ-3b continues along the Trent River to the Campbellford IPZ. Tributaries of the Trent River are also included in the IPZ-3b, including Rawdon Creek, Hoards Creek, Salt Creek, Percy Creek, and Murray Marsh. IPZ-3c consists of the further headwaters of some of these tributaries.

In all of these areas, the land cover is typically agricultural with some small forested areas, providing neutral consideration from the initial intake proximity-based assessment of area vulnerability factor. The majority of the IPZ-3a is located upon either clay plain or limestone plain. The soils in this area are less permeable (increase in vulnerability) but the slope of the area is quite flat (decrease in vulnerability). Therefore, the area vulnerability factor assigned to this area is 6. For the IPZ-3b, the majority of the land is located within a drumlinized till plain, with the exception of the Murray Marsh area. The rolling landscape and the moderate percent land as a result of the Trent River and the marsh are also neutral to the applied vulnerability, resulting in an area vulnerability factor of 3. The high percent land factor for the IPZ-3c is not enough to change the area vulnerability factor assigned from the original factor of 2.

4.2.3.2.14 Trenton

A source vulnerability factor of 1 was assigned for the Trenton intake, due to its proximity to shore and moderate raw water quality.

The area vulnerability factor for IPZ-2 was assigned the highest possible number (9) due to the presence of several transport pathways for pollutants. Also there is significant urbanized land use upstream of the intake in Glen Miller, including industrial land use, and thus runoff generation potential is high due to the impermeable surface land cover. There are also two major corridors upstream of the intake (a rail crossing and Highway 401) that could be considered transport pathways.

The IPZ-3 extends upstream to Frankford to include a portion of Glen Miller Creek on the east side of the Trent River, a portion of Big Boulder Creek on the west side of the River, the entire Cold Creek, and smaller creek contributions. The Trenton IPZ-3 *w*as subdivided into three subzones.

Within the IPZ-3a, the slope of is generally flat, which decrease vulnerability, and the soils are typically not very permeable (Elmbrook, Farmington, and Sidney soils), which increase vulnerability. Land cover is typically fields and the percent land is moderate due to the presence of the Trent River; both of these factors are neutral to the area vulnerability factor. The area vulnerability factor of 6 was assigned to the Trenton IPZ-3a.

The IPZ-3b is located in a sand plain area with varying types of soil but most with higher permeability, which decreases its vulnerability. The IPZ-3c is located within highly permeable soils in the Oak Ridges Moraine, which reduces its vulnerability as well. IPZ-3b and IPZ-3c exhibit gentle sloping land (neutral to vulnerability) and have a low percent land (increase in vulnerability) as these areas contain more small streams and headwaters. The area vulnerability factors assigned to IPZ-3b and IPZ-3c are 3 and 2, respectively.

4.2.3.2.15 Bayside

The lowest possible source vulnerability factor was selected for the Bayside intake (0.8 for a Type D intake) due to its longer distance from shore, greater depth, and moderate raw water quality.

A mid-range value of the area vulnerability factor for the IPZ-2 was selected (8) due to the presence of a tributary in close proximity to the intake and the moderate runoff generation potential from the gently sloping lands and clay type soils.

For the IPZ-3, the zone was subdivided into two areas. The IPZ-3a includes the Bay of Quinte, the Trent River up to the Trenton IPZ, and the tributaries along the northern shoreline of the Bay of Quinte. The IPZ-3b consists of the Murray Canal and associated tributaries of the canal including Dead Creek and the majority of Mayhew Creek that discharges into the west side of the Trent River in Trenton.

As there is significant urban land use and therefore a large amount of impermeable surfaces in the IPZ-3a, this would increase the vulnerability factor for the area. The presence of numerous transport pathways and the clay type soils in the area would increase the vulnerability, and the flat topography and low percent land would decrease the vulnerability, resulting in an area vulnerability factor of 7 for the IPZ-3a. The IPZ-3b consists of headwater areas (high percent land), but the majority of soils appear to be well draining and they would reduce vulnerability. Overall, the area vulnerability factor assigned to the IPZ-3b for Bayside is 3.

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 confidence that include 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 examining the following:

- Evaluation of the uncertainty of the IPZ-1, IPZ-2, and IPZ-3 delineation for each intake
- Evaluation of the uncertainty of the vulnerability score assigned to each intake protection zone
- Assignment of an overall uncertainty rating (high or low) to each intake protection zone (based on the highest uncertainty rating assigned to the intake protection zone).

The following factors were considered in the evaluation of uncertainty:

- Distribution, variability, quality, and relevance of data used in the analysis
- Ability of the methods and models used to accurately reflect the flow processes in the hydrological system
- The quality assurance and quality control procedures applied
- The extent and level of calibration and validation achieved for models or assessment methods used.

4.2.4.1 Intake Protection Zone Delineation

Intake Protection Zone 1: There was a high degree of confidence associated with the delineation of the Intake Protection Zone 1 areas because the delineation is prescribed by the *Technical Rules*. Thus, a low uncertainty rating was assigned to the delineation of the IPZ-1.

Intake Protection Zone 2: The uncertainty ratings associated with each of the factors listed above for the delineation of the IPZ-2 are listed in Table 4.2-4. All of the IPZ-2 delineations except Kinmount were assigned a low uncertainty in consideration of the four factors listed above. The model was calibrated to match the results from the dye and drogue studies and verified with independent dye and drogue studies as best as possible.

Based on the consultants' professional judgment derived from the level of effort and the quality of data utilized, the uncertainty level was assigned to be low, except in the case of Kinmount. For the Kinmount system, the IPZ-2 delineated from the mathematical model was assigned a high uncertainty due to the limitation of the bathymetry information that was required to build the model.

Table 4.2-4: Summary of Uncertainty for Intake Protection Zone 2

Consideration	Uncertainty for IPZ-2	
	IPZ-2 for Kinmount	All other IPZ-2
Distribution, variability, quality, and relevance of data	High	Low
Ability of methods and models used to accurately reflect the flow processes in the hydrological system	Low	Low
QA/QC procedures applied	Low	Low
Extent and level of calibration and validation achieved for models or assessment methods used	Low	Low

Intake Protection Zone 3: A low uncertainty rating was assigned to the delineation of the IPZ-3 for all 15 intakes because these zones were delineated using provincial watercourse/waterbody digital data (from the Water Resources Information Project) and Conservation Authority Regulation Limit mapping. The uncertainty ratings assigned to the delineation of each intake protection zone are listed in Table 4.2-5.

4.2.4.2 Vulnerability Scoring

Source Vulnerability Factor: The source vulnerability factors for Type C intakes have one of two options (1.0 or 0.9), and the Type D intakes have three options (0.8, 0.9, or 1.0). The uncertainty associated with the selection of the appropriate source vulnerability factor is low for all of the intakes.

Area Vulnerability Factor: The area factors for Intake Protection Zone 1 are set with no variation (i.e., they must all be 10), so there is no uncertainty in these numbers. For the Intake Protection Zone 2, the range of area factors is from 7 to 9. The regional approach used for the assignment of these factors and the limited range of options have led to a low uncertainty for these factors as well. Each Intake Protection Zone 3 may have up to three different area vulnerability factors assigned to different areas of the Intake Protection Zone 3. Again, a regional approach was used that applied information regarding land use, soil permeability, slope, percent land, and distance from the intake to arrive at vulnerability factors that were assigned with a high degree of certainty.

The uncertainty ratings assigned to the delineation of intake protection zones, the assignment of vulnerability scores, and the final uncertainty for intake protection zones are listed in Table 4.2-5.

Table 4.2-5: 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
Norland	Low	Low	Low	Low	Low	Low	Low	Low	Low
Kinmount	Low	**High**	Low	Low	Low	Low	Low	**High**	Low
Fenelon Falls	Low	Low	Low	Low	Low	Low	Low	Low	Low
Lindsay	Low	Low	Low	Low	Low	Low	Low	Low	Low
Southview Estates	Low	Low	Low	Low	Low	Low	Low	Low	Low
Bobcaygeon	Low	Low	Low	Low	Low	Low	Low	Low	Low
Lakefield	Low	Low	Low	Low	Low	Low	Low	Low	Low
Peterborough	Low	Low	Low	Low	Low	Low	Low	Low	Low
Hastings	Low	Low	Low	Low	Low	Low	Low	Low	Low
Marmora	Low	Low	Low	Low	Low	Low	Low	Low	Low
Campbellford	Low	Low	Low	Low	Low	Low	Low	Low	Low
Warkworth	Low	Low	Low	Low	Low	Low	Low	Low	Low
Frankford	Low	Low	Low	Low	Low	Low	Low	Low	Low
Trenton	Low	Low	Low	Low	Low	Low	Low	Low	Low
Bayside	Low	Low	Low	Low	Low	Low	Low	Low	Low

4.2.5 INFORMATION TO SUPPORT CONTINUAL IMPROVEMENT

The analysis presented in this section could be enhanced with the collection of additional data. This includes the following:

IMPROVEMENTS TO INTAKE PROTECTION ZONE 2 DELINEATION FOR KINMOUNT INTAKE

The IPZ-2 for the Kinmount surface water intake was delineated from a mathematical model. The uncertainty for the delineation is high due to the limitation of bathymetry information required to build the model. The velocity of flow derived from actual field measurements (e.g., velocity tracking studies using orange floats or dye) corresponding to a flow that is very close to a 2-year flow (approximately 100 cubic metres per second) is needed to delineate a more reasonable IPZ-2 for the Kinmount intake and lower the associated uncertainty.

Addition of Intake Protection Zone 3 for Lake Ontario

Should an IPZ-3 be identified for a source protection area on Lake Ontario, which extends into the Trent source protection areas, the information will need to be included in an updated Assessment Report.

4.2.6 REFERENCES

XCG Consultants. (2009a). City of Kawartha Lakes: Vulnerability Assessment for Six Municipal Surface Water Sourced Drinking Water Systems.

XCG Consultants. (2009b). Trent Conservation Coalition Source Protection Region: Vulnerability Assessment for Ten Surface Water Sourced Drinking Water Systems

Hsu, S.A. (1988). Coastal Meteorology. Academic Press Inc., 224.

Leopold, L.B., & T. Maddox. (1953). The Hydraulic Geometry of Stream Channels and Some Physiographic Implications. Professional Paper 252. Washington (DC): U.S. Geological Survey.

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 surface water intakes in the Trent source protection areas was completed under two separate studies by XCG Consultants Ltd, which are documented in the following reports and technical memorandum:

- *Vulnerability, Issues and Threats for Ten Surface Water Sourced Municipal Drinking Water Systems in the Trent Conservation Coalition Source Protection Region* (July 2010)
- *Vulnerability, Issues and Threats for Six Surface Water Sourced Municipal Drinking Water Systems in the City of Kawartha Lakes* (July 2010)
- *Technical Memorandum on Issues Update for Norland Drinking Water System* (March 2011)

This section is a summary of the relevant sections of these documents.

4.3.1 METHODOLOGY

The *Technical Rules* defines a drinking water issue as the presence of a parameter listed in Schedule 1, 2, or 3 of the Ontario Drinking Water Quality Standards or Table 4 of the *Technical Support Document for Ontario Drinking Water Standards, Objectives and Guidelines*, at a concentration that may result in the deterioration of the quality of the water for use as a source of drinking water. Upward trends in concentration that may result in a similar deterioration are also considered drinking water issues.

Exceedances of the standards and trends were identified through a review of the available water quality data. The determination as to whether an exceedance or trend would result in the deterioration of the quality of the water for use as a source of drinking water was made on a parameter-by-parameter basis. The Ontario Drinking Water Quality Standards, available sources of data, and review of water quality data are discussed in more detail below.

4.3.1.1 ONTARIO DRINKING WATER QUALITY STANDARDS

The Ontario Drinking Water Quality Standards indicates the maximum acceptable concentrations of a variety of water quality parameters in treated drinking water. The *Technical Rules* requires that the drinking water issues assessment consider the parameters listed in Schedules 1 to 3 of these standards, which include microbiological, chemical, and radiological parameters, and also 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. No data for radiological parameters were available, so Schedule 3 parameters were not considered in the issues assessment. Additional notes about selected parameters are included below.

Parameters with Multiple Benchmarks

Eight organic parameters are listed in both Schedule 2 of the standards and Table 4 of the support document; in these cases, the aesthetic objectives and operational guidelines in Table 4 are always lower, so they were used for the issues assessment.

Standards Expressed as Ranges

The operational guidelines for pH and alkalinity are listed as ranges rather than single maximum limits. When reviewing these parameters as a drinking water issue, any data outside of the ranges were considered issues.

Escherichia coli

The standard for E. coli in treated water is “not detectable” (i.e., 0 cfu/100 mL or 0 colony forming units per 100 millilitres). It is unrealistic to expect no detectable E. coli in raw surface water because it is a naturally occurring parameter. In most cases, the level of treatment required for surface water systems under the *Safe Drinking Water Act* (i.e., primary disinfection and chemically assisted filtration, or the equivalent) is sufficient to treat the concentrations of E. coli found in surface water.

Turbidity

The standard for turbidity is 5 Nephelometric Turbidity Units (NTU). However, under the *Drinking Water Systems Regulation* of the *Safe Drinking Water Act* (O. Reg. 170/03), turbidity levels above 1 NTU in treated water trigger an adverse water quality report to the Ministry of the Environment and Climate Change Spills Action Centre and the Public Health Unit. The aesthetic objective of 5 NTU was used as the benchmark for turbidity in this assessment of drinking water.

Temperature

The aesthetic objective for temperature is 15 ^{o}C. It is well known that in Ontario the source water temperature varies significantly over the course of the seasons. It is acknowledged that in the summer months, the aesthetic objective will be exceeded in many cases for surface water systems. Temperatures exceeding the aesthetic objective will be listed as an issue but will be deemed naturally occurring.

4.3.1.2 REVIEW OF AVAILABLE WATER QUALITY DATA

The available water quality data were reviewed to identify exceedances of the Ontario Drinking Water Quality Standards or upward trends that might result in an exceedance. The available data for each surface water system were identified through a review of the following data sources:

- Watershed characterization reports
- Certificates of Approval
- Permits to Take Water
- Municipal water supply water quality data
- Weekly certificates of analysis
- Annual water supply water quality monitoring reports
- Provincial water quality databases (e.g., drinking water information system, drinking water surveillance program, and drinking water inspection program)
- Provincial Water Quality Monitoring Network
- Various background reports.

The sources of data used to identify drinking water issues at each surface water intake are listed in Table 4.3-1. The amount of data available on raw (untreated) water quality was found to be very limited for some systems. Since testing of raw water is generally not required, most of the available data are for treated water. Data for water in distribution systems were only considered where there were no measured values for raw or treated water. When considering distribution system data, it was acknowledged that the presence of contaminants may not be related to the source water, but rather to the treatment and distribution systems (i.e., disinfection by-products, pipe corrosion, old plumbing fixtures, etc.).

Two benchmarks were established for the review of water quality data: a primary benchmark where a parameter exceeded the water quality standards, and a secondary benchmark where a parameter did not exceed the benchmark but reached at least 25% of it. Parameters that exceeded the primary benchmark were considered in the issues assessment. Parameters that exceeded the secondary benchmark were evaluated for trends. Parameters that showed a statistically significant upward trend that would result in an exceedance of the water quality standards within 50 years were considered in the issues assessment. (Since the *Technical Rules* is silent on this issue, the consultants used a 50 year period for trend analysis for precautionary purposes.)

The determination as to whether or not an exceedance or upward trend of a given water quality parameter would result in the deterioration of the quality of the water for use as a source of drinking water was made in consideration of the following factors:

- Number of exceedances of the parameter on record
- Comprehensiveness of data for the parameter (excluding anomalous data points)
- Level of treatment for the given parameter at the water treatment plant
- Other information provided by water treatment plant operators.

4.3.1.3 WATER TREATMENT PLANT OPERATOR INTERVIEWS

Once a preliminary list of issues was identified, interviews were held with the water treatment plant operators of each surface water system to gather additional information. Prior to the interviews, the Certificate of Approval and the most recent Ministry of the Environment and Climate Change Drinking Water System Inspection Report were reviewed to collect information on the treatment processes used in each system. The operators were provided with a questionnaire prior to the interview so that they could familiarize themselves with the questions that would be asked. The interviews focused on the preliminary list of issues for the system, the treatment technology used at the system, and the threshold concentrations of the parameters listed as preliminary issues that could be handled by the existing treatment system. Follow-up interviews were conducted where required.

4.3.1.4 IDENTIFICATION OF ISSUE SOURCE (NATURAL OR ANTHROPOGENIC)

The deterioration of surface water quality as a source of drinking water can result from natural conditions and/or anthropogenic activities. The *Technical Rules* requires that only drinking water issues that are at least partially a result of anthropogenic activities are to be considered in the identification of drinking water threats.

Table 4.3-1: Data Sources Used for Assessment of Drinking Water Issues

Data Source	Water Type	Years on Record														
		Norland	Kinmount	Fenelon Falls	Lindsay	Southview Estates	Bobcaygeon	Lakefield	Peterborough	Hastings	Marmora	Campbellford	Warkworth	Frankford	Trenton	Bayside
Annual Reports	Raw & Treated	03-04; 06-08	03-08	03-08	03-08	03-04;06-08	03-08		05-07	04-08	06-08	04-08	04-08	01; 06-08	06-08	06-08
Ministry of the Environment and Climate Change Drinking Water System Inspection Reports	Raw & Treated	84; 87; 89; 01; 02; 04-07; 09	01; 03-05; 07-08	96; 99; 01-08	03-08	89; 00; 01; 03; 04; 06-08	04; 06-08	00; 02-08	04-08	00-05; 07-09	00-06; 08	00-02; 04-08	95; 96; 01; 02; 04; 05; 07	00-03; 05-08	00; 03; 04; 05; 06; 08	01-03; 06; 08
Certificates of Analysis	Raw & Treated	06-11	06-09	03-09	03-09	03-09	03-09	03		96-00			00			
Drinking Water Information System	Raw & Treated	05-08	06-08	05-08	05-08	05-08	05-08	05-08	05-08	05-08	05-08	05-08	05-08	05-08	05-08	05-08
SWIP Data (MOECC's Drinking Water Inspection/Compliance Program)	Raw & Treated	98-07	01-05	00-07	01-07	00-07	00-07	00-07	01-07	00-07	01-06	00-07	98-07	00-07	01-07	00-07
Water Treatment Plant Water Quality	Raw		06-07[a]	03-07[b]	03-07	06-07	03-07	03-06	03-06	03-06	03-06					
Drinking Water Surveillance Program	Raw				90–05				90–05							90–05
Drinking Water Surveillance Program (Routine)	Raw & Treated				98-07				98-07		00-04[d]					01-07
Drinking Water Surveillance Program (Microcystin survey)	Raw & Treated															02-08
Ministry of the Environment and Climate Change Laboratory Analysis	Raw & Treated							03	02-08	92; 94-96; 02; 03; 07		00; 03	00; 03; 07			
Great Lakes Index Station Network (GLISN) – Station 462	Raw															97; 00; 03[c]
Ontario Clean Water Agency	Raw & Treated															00

[a]Schedule 1 parameters only
[b]Schedule 1 & 4 parameters only
[c]Schedule 2 & 4 parameters only
[d]Treated water only

4.3.2 RESULTS

A total of 79 drinking water issues were identified at the surface water intakes in the Trent source protection areas. These are all related to natural sources. One additional parameter (Microcystin-LR at the Bayside intake) exceeded the primary or secondary benchmarks, but more information is required to determine if it is an issue and to identify its source.

The drinking water issues identified as per Technical Rule 114 in the Trent source protection areas and their sources are listed in Table 4.3-2. The issues evaluation for each surface water system in the Trent source protection areas is summarized in the following subsections (4.3.2.1.1 to 4.3.2.1.16). Each subsection includes a table that summarizes the data used to identify exceedances of the standards and indicates the quantity of exceedances on record. For systems that had parameters that exceeded the secondary benchmark (25% of the standard), a second table is included that summarizes the trend analysis (including the direction and statistical significance (p-value) of the trend and the expected concentration of the parameter 25 and 50 years in the future). Both tables indicate whether or not the parameter was considered a drinking water issue as per Technical Rule 114 and the rationale for the conclusion.

Table 4.3-2: Summary of Drinking Water Issues in the Trent Source Protection Areas

Drinking Water System	Alkalinity	Aluminum	Colour	DOC	Hardness	Iron	Manganese	Microcystin	pH	Temperature	Turbidity
Norland	N	N	N		N					N	
Kinmount	N				N	N				N	N
Fenelon Falls				N	N					N	N
Lindsay		N	N	N	N		N		N	N	N
Southview Estates		N	N	N	N		N		N	N	N
Bobcaygeon			N	N	N				N	N	N
Lakefield				N	N					N	N
Peterborough			N	N	N					N	N
Hastings			N		N		N			N	N
Marmora			N	N	N					N	N
Campbellford		N			N	N	N			N	N
Warkworth									N		
Frankford			N		N					N	N
Trenton		N	N	N	N					N	N
Bayside			N	N	N		N	U	N	N	N

U = Unknown/unconfirmed source
N = Natural source

4.3.2.1.1 Norland

Five drinking water issues were identified at the Norland intake. These were all identified due to exceedances of the standards that result in the deterioration of the potable water quality. These issues are all related to natural sources, so the identification of contributing sources and the delineation of issue contributing areas were not required for these four issues. The drinking water issues evaluation for Norland is summarized in Table 4.3-3, which lists the water quality parameters that exceeded the water quality standards and indicates whether or not they were considered issues and the rationale for the conclusion.

Table 4.3-3: Norland Water Quality Standards Exceedances

Parameter	Water Type[1]	Years on Record	Exceedances		Standard		Source	Drinking Water Issue?	Rationale
			%	#	Value	Type[2]			
Schedule 1									
Total Coliforms	Raw	72-09	100	421	0 cfu/100 mL	MAC		NO	• Typical results for a surface water system • Adequate level of treatment in place
E. coli	Raw	72-09	91	428	0 cfu/100 mL	MAC		NO	• Typical results for a surface water system • Adequate level of treatment in place
Schedule 2									
Lead	Raw	81-05	1	1	0.01 mg/L	MAC		NO	• Single exceedance considered anomalous
Trihalomethanes	Treated	03-08	18	2	0.100 mg/L	MAC		NO	• Two exceedances only • No recent exceedances
Table 4									
Alkalinity	Raw	78-04	99	119	30-500 mg/L	OG	Natural	YES	• Outside acceptable aesthetic or operation guidelines
Aluminum	Raw	10-11	14	1	0.1 mg/L	OG	Natural	YES	• Outside acceptable aesthetic or operation guidelines
Colour	Raw	04-05	100	6	5 TCU	AO	Natural	YES	• Typical results for a surface water system • Outside acceptable aesthetic or operation guidelines
DOC	Raw	72-85	50	1	5 mg/L	AO		NO	• Limited data (2 samples)
Hardness	Raw	04	100	1	80-100 mg/L	OG	Natural	YES	• Typical results for a surface water system • Outside acceptable aesthetic or operation guidelines
Iron	Treated	84-07	9	1	0.3 mg/L	AO		NO	• Single exceedance considered anomalous
Manganese	Raw	04	100	1	0.05 mg/L	AO		NO	• Single exceedance considered anomalous (possible reporting error)
Organic Nitrogen	Raw	04	100	1	0.15 mg/L	OG		NO	• Single exceedance • Limited data
pH	Raw	79-05	3	4	6.5-8.5	OG		NO	• Generally within acceptable range
Temperature	Raw	72-90	37	195	15°C	AO	Natural	YES	• Typical results for a surface water system • Outside acceptable aesthetic or operation guidelines
Turbidity	Raw	72-05	2%	4	5 NTU	AO		NO	• Four exceedances before 1980 • No recent exceedances

[1]Indicates if the data on record is for raw (untreated) or treated water
[2]Standard types: MAC=Maximum Acceptable Concentration; AO=Aesthetic Objective; OG=Operational Guideline
[3]Indicates the statistical significance of the proposed hypothesis that the trend is occurring as reported (trends are generally considered statistically significant where $p<0.05$)
[4]Indicates the concentration that the parameter would reach in 25 and 50 years if the trend remains constant

4.3.2.1.2 Kinmount

Five drinking water issues were identified at the Kinmount intake. They are all related to natural sources, so the identification of contributing sources and the delineation of issue contributing areas were not required for these issues. The drinking water issues evaluation for Kinmount is summarized in Table 4.3-4, which lists the water quality parameters that exceeded the water quality standards and indicates whether or not they were considered issues and the rationale for the conclusion. No parameters that exceeded a secondary benchmark (25% of its water quality standard) showed statistically significant trends.

Table 4.3-4: Kinmount Water Quality Standards Exceedances

Parameter	Water Type[1]	Years on Record	Exceedances		Standard		Source	Drinking Water Issue?	Rationale
			%	#	Value	Type[2]			
Schedule 1									
Total Coliforms	Raw	72-09	89	167	0 cfu/100mL	MAC		NO	• Typical results for a surface water system • Adequate level of treatment in place
E. coli	Raw	72-09	90	227	0 cfu/100mL	MAC		NO	• Typical results for a surface water system • Adequate level of treatment in place
Schedule 2									
Lead	Raw	81-04	2	3	0.01 mg/L	MAC		NO	• 3 exceedances only (1 considered an outlier)
THMs	Treated	03-08	63	12	0.100 mg/L	MAC		NO	• No recent exceedances (after new treatment plan in 2005)
Table 4									
Alkalinity	Raw	78-07	15	33	30-500 mg/L	OG	Natural	YES	• Outside acceptable aesthetic or operation guidelines
Aluminum	Raw	96-07	2	2	0.1 mg/L	OG		NO	• 2 exceedances only (1 considered an outlier)
DOC	Raw	72-85	67	2	5 mg/L	AO		NO	• Insufficient data (3 data points)
Hardness	Raw	96-07	100	94	80-100 mg/L	OG	Natural	YES	• Typical results for a surface water system • Outside acceptable aesthetic or operation guidelines
Iron	Raw	72-07	37	77	0.3 mg/L	AO	Natural	YES	• Exceeded standards
Manganese	Raw	96-07	2	2	0.05 mg/L	AO		NO	• 2 exceedances only (1 considered an outlier)
Temperature	Raw	72-07	45	130	15°C	AO	Natural	YES	• Typical results for a surface water system • Outside acceptable aesthetic or operation guidelines
Turbidity	Raw	72-06	3	10	5 NTU	AO	Natural	YES	• Typical results for a surface water system • Outside acceptable aesthetic or operation guidelines

[1]Indicates if the data on record is for raw (untreated) or treated water
[2]Standard types: MAC=Maximum Acceptable Concentration; AO=Aesthetic Objective; OG=Operational Guideline

4.3.2.1.3 Fenelon Falls

Four drinking water issues were identified at the Fenelon Falls intake. They are all related to natural sources, so the identification of contributing sources and the delineation of issue contributing areas were not required for these issues. The drinking water issues evaluation for Fenelon Falls is summarized in Table 4.3-5, which lists the water quality parameters that exceeded the water quality standards and indicates whether or not they were considered issues and the rationale for the conclusion. Three parameters exceeded the secondary benchmark (25% of its water quality standard) and showed a statistically significant upward trend: Benzene, Dichloromethane, and Vinyl Chloride. The trend analysis for these parameters is summarized in Table 4.3-6.

Table 4.3-5: Fenelon Falls Water Quality Standards Exceedances

Parameter	Water Type[1]	Years on Record	Exceedances		Standard		Source	Drinking Water Issue?	Rationale
			%	#	Value	Type[2]			
Schedule 1									
Total Coliforms	Raw	66-07	99	556	0 cfu/100mL	MAC		NO	• Typical results for a surface water system • Adequate level of treatment in place
E. coli	Raw	72-07	83	520	0 cfu/100mL	MAC		NO	• Typical results for a surface water system • Adequate level of treatment in place
Schedule 2									
Benzo(a)pyrene	Treated	03-09	4	3	0.00001 mg/L	MAC		NO	• Results below method detection limit
Dichloromethane	Raw	06	50	1	0.05 mg/L	MAC		NO	• Single exceedance considered anomalous
Lead	Raw	81-07	0.4	1	0.01 mg/L	MAC		NO	• Single exceedance (in 245 samples)
THMs	Treated	04-06	14	1	0.1 mg/L	MAC		NO	• Single exceedance
Table 4									
Aluminum	Treated	00-07	78	7	0.1 mg/L	OG		NO	• No exceedances in the raw water therefore it is likely a by-product of the treatment process
Colour	Raw	66	100	1	5 TCU	AO		NO	• Insufficient data
DOC	Raw	71-05	75	24	5 mg/L	AO	Natural	YES	• Exceeded standards
Hardness	Raw	66-07	100	126	80-100 mg/L	OG	Natural	YES	• Typical results for a surface water system • Outside acceptable aesthetic or operation guidelines
Iron	Raw	66-07	0.4	1	0.3 mg/L	AO		NO	• Single exceedance considered anomalous
Manganese	Raw	96-07	1	1	0.05 mg/L	AO		NO	• Single exceedance considered anomalous
pH	Raw	79-07	4	7	6.5-8.5	OG		NO	• Small percentage outside of acceptable range
Temperature	Raw	66-07	45	173	15°C	AO	Natural	YES	• Typical results for a surface water system • Outside acceptable aesthetic or operation guidelines
Turbidity	Raw	66-06	2	8	5 NTU	AO	Natural	YES	• Typical results for a surface water system • Outside acceptable aesthetic or operation guidelines

Table 4.3-6: Fenelon Falls Water Quality Trend Analysis

Parameter	Water Type[1]	Samples on Record	Trend		Extrapolation[4]		Standard		Drinking Water Issue?	Rationale
			Direction	p[3]	25 Years	50 Years	Value	Type		
Benzene	Treated	73	↑	2.88E-2	0.001 mg/L	0.002 mg/L	0.005 mg/L	MAC	NO	• Trend does not exceed standards within 50 years
Dichloromethane	Treated	74	↑	6.67E-7	0.02 mg/L	0.04 mg/L	0.05 mg/L	MAC	NO	• Trend does not exceed standards within 50 years
Vinyl Chloride	Treated	57	↑	1.91E-8	0.0004 mg/L	0.0007 mg/L	0.002 mg/L	MAC	NO	• Trend does not exceed standards within 50 years

[1]Indicates if the data on record is for raw (untreated) or treated water
[2]Standard types: MAC=Maximum Acceptable Concentration; AO=Aesthetic Objective; OG=Operational Guideline
[3]Indicates the statistical significance of the proposed hypothesis that the trend is occurring as reported (trends are generally considered statistically significant where $p<0.05$)
[4]Indicates the concentration that the parameter would reach in 25 and 50 years if the trend remains constant

4.3.2.1.4 Lindsay

Eight drinking water issues were identified at the Lindsay intake. They are all related to natural sources, so the identification of contributing sources and the delineation of issue contributing areas were not required for these issues. The drinking water issues evaluation for Lindsay is summarized in Table 4.3-7, which lists the water quality parameters that exceeded the water quality standards and indicates whether or not they were considered issues and the rationale for the conclusion. No parameters that exceeded a secondary benchmark (25% of its water quality standard) showed statistically significant trends.

Table 4.3-7: Lindsay Water Quality Standards Exceedances

Parameter	Water Type[1]	Years on Record	Exceedances		Standard		Source	Drinking Water Issue?	Rationale
			%	#	Value	Type[2]			
Schedule 1									
Total Coliforms	Raw	70-07	99	485	0 cfu/100mL	MAC		NO	• Typical results for a surface water system • Adequate level of treatment in place
E. coli	Raw	72-07	99	562	0 cfu/100mL	MAC		NO	• Typical results for a surface water system • Adequate level of treatment in place
Schedule 2									
Lead	Raw	81-07	0.4	1	0.01 mg/L	MAC		NO	• Single exceedance considered anomalous
NDMA	Treated	98-07	7	1	0.009 ug/L	MAC		NO	• Single exceedance considered anomalous
THMs	Treated	98-08	24	19	0.100 mg/L	MAC		NO	• By-product of treatment • Results for THMs in raw were below detection limits
Table 4									
Aluminum	Raw	90-07	6	8	0.1 mg/L	OG	Natural	YES	• Exceeded standards
Colour	Raw	90-07	100	43	5 TCU	AO	Natural	YES	• Typical results for a surface water system • Outside acceptable aesthetic or operation guidelines
DOC	Raw	71-07	100	59	5 mg/L	AO	Natural	YES	• Exceeded standards
Hardness	Raw	70-07	100	158	80-100 mg/L	OG	Natural	YES	• Typical results for a surface water system • Outside acceptable aesthetic or operation guidelines
Iron	Raw	70-07	4	6	0.3 mg/L	AO		NO	• Single exceedance (in recent data) considered anomalous
Manganese	Raw	90-07	6	8	0.05 mg/L	AO	Natural	YES	• Exceeded standards
pH	Raw	79-07	2	4	6.5-8.5	OG	Natural	YES	• Typical results for a surface water system • Outside acceptable aesthetic or operation guidelines
Temperature	Raw	70-07	45	151	15°C	AO	Natural	YES	• Typical results for a surface water system • Outside acceptable aesthetic or operation guidelines
Turbidity	Raw	70-06	36	128	5 NTU	AO	Natural	YES	• Typical results for a surface water system • Outside acceptable aesthetic or operation guidelines

[1]Indicates if the data on record is for raw (untreated) or treated water
[2]Standard types: MAC=Maximum Acceptable Concentration; AO=Aesthetic Objective; OG=Operational Guideline

4.3.2.1.5 Southview Estates

Eight drinking water issues were identified at the Southview Estates intake. They are all related to natural sources, so the identification of contributing sources and the delineation of issue contributing areas were not required for these issues. The drinking water issues evaluation for Southview Estates is summarized in Table 4.3-8, which lists the water quality parameters that exceeded the water quality standards and indicates whether or not they were considered issues and the rationale for the conclusion. The only parameter that exceeded the secondary benchmark (25% of its water quality standard) and showed a statistically significant upward trend was chloride. The trend analysis for aluminum is summarized in Table 4.3-9.

Table 4.3-8: Southview Estates Water Quality Standards Exceedances

Parameter	Water Type[1]	Years on Record	Exceedances		Standard		Source	Drinking Water Issue?	Rationale
			%	#	Value	Type[2]			
Schedule 1									
Total Coliforms	Raw	70-07	94	378	0 cfu/100mL	MAC		NO	• Typical results for a surface water system • Adequate level of treatment in place
E. coli	Raw	72-07	71	333	0 cfu/100mL	MAC		NO	• Typical results for a surface water system • Adequate level of treatment in place
Schedule 2									
Lead	Raw	81-07	1	1	0.01 mg/L	MAC		NO	• Single exceedance considered anomalous
THMs	Treated	03-08	100	10	0.100 mg/L	MAC		NO	• By-product of treatment
Table 4									
Aluminum	Raw	96-07	27	23	0.1 mg/L	OG	Natural	YES	• Exceeded standards
Colour	Raw	70-05	100	8	5 TCU	AO	Natural	YES	• Typical results for a surface water system • Outside acceptable aesthetic or operation guidelines
DOC	Raw	71-85	100	8	5 mg/L	AO	Natural	YES	• Typical results for a surface water system • Outside acceptable aesthetic or operation guidelines
Hardness	Raw	70-07	100	89	80-100 mg/L	OG	Natural	YES	• Typical results for a surface water system • Outside acceptable aesthetic or operation guidelines
Iron	Raw	70-07	2	2	0.3 mg/L	AO		NO	• Exceedances prior to 1973 • No exceedances in recent data (since 1994)
Manganese	Raw	96-07	11	9	0.05 mg/L	AO	Natural	YES	• Exceeded standards
pH	Raw	80-07	9	13	6.5-8.5 OG	OG	Natural	YES	• Outside acceptable range
Temperature	Raw	70-07	53	144	15°C	AO	Natural	YES	• Typical results for a surface water system • Outside acceptable aesthetic or operation guidelines
Turbidity	Raw	70-06	53	151	5 NTU	AO	Natural	YES	• Typical results for a surface water system • Outside acceptable aesthetic or operation guidelines

Table 4.3-9: Southview Estates Water Quality Trend Analysis

Parameter	Water Type[1]	Samples on Record	Trend		Extrapolation[4]		Standard		Drinking Water Issue?	Rationale
			Direction	p[3]	25 Years	50 Years	Value	Type[2]		
Chloride	Raw	297	↑	3.44E-12	45.1 mg/L	56.8 mg/L	250 mg/L	AO	NO	• Trend does not exceed standards within 50 years

[1]Indicates if the data on record is for raw (untreated) or treated water
[2]Standard types: MAC=Maximum Acceptable Concentration; AO=Aesthetic Objective; OG=Operational Guideline
[3]Indicates the statistical significance of the proposed hypothesis that the trend is occurring as reported (trends are generally considered statistically significant where $p<0.05$)
[4]Indicates the concentration that the parameter would reach in 25 and 50 years if the trend remains constant

4.3.2.1.6 Bobcaygeon

Six drinking water issues were identified at the Bobcaygeon intake. They are all related to natural sources, so the identification of contributing sources and the delineation of issue contributing areas were not required for these issues. The drinking water issues evaluation for Bobcaygeon is summarized in Table 4.3-10, which lists the water quality parameters that exceeded the water quality standards and indicates whether or not they were considered issues and the rationale for the conclusion. No parameters that exceeded a secondary benchmark (25% of its water quality standard) showed statistically significant trends.

Table 4.3-10: Bobcaygeon Water Quality Standards Exceedances

Parameter	Water Type[1]	Years on Record	Exceedances		Standard		Source	Drinking Water Issue?	Rationale
			%	#	Value	Type[2]			
Schedule 1									
Total Coliforms	Raw	66-07	97	532	0 cfu/100 mL	MAC		NO	• Typical results for a surface water system • Adequate level of treatment in place
E. coli	Raw	72-07	67	417	0 cfu/100 mL	MAC		NO	• Typical results for a surface water system • Adequate level of treatment in place
Schedule 2									
Lead	Raw	81-07	1	3	0.01 mg/L	MAC		NO	• 3 exceedances in significant amount of data (prior to 2003)
THMs	Treated	03-09	5	2	0.1 mg/L	MAC		NO	• No recent exceedances (after new treatment system)
Table 4									
Alkalinity	Raw	66-07	0.3	1	30-500 mg/L	OG		NO	• Single outlier considered anomalous
Aluminum	Raw	96-07	1	1	0.1 mg/L	OG		NO	• Single exceedance
Colour	Raw	66-04	100	6	5 TCU	AO	Natural	YES	• Typical results for a surface water system • Outside acceptable aesthetic or operation guidelines
DOC	Raw	71-85	100	29	5 mg/L	AO	Natural	YES	• Exceeded standards
Hardness	Raw	66-07	50	65	80-100 mg/L	OG	Natural	YES	• Typical results for a surface water system • Outside acceptable aesthetic or operation guidelines
Iron	Raw	66-07	1	4	0.3 mg/L	AO		NO	• No exceedances since 1987 • Decreasing trend
Manganese	Raw	96-07	2	2	0.05 mg/L	AO		NO	• 2 exceedances • Decreasing trend
pH	Raw	79-07	8	16	6.5-8.5	OG	Natural	YES	• Exceeded standards
Temperature	Raw	66-07	43	175	15°C	AO	Natural	YES	• Typical results for a surface water system • Outside acceptable aesthetic or operation guidelines
Turbidity	Raw	66-06	7	29	5 NTU	AO	Natural	YES	• Typical results for a surface water system • Outside acceptable aesthetic or operation guidelines

[1]Indicates if the data on record is for raw (untreated) or treated water
[2]Standard types: MAC=Maximum Acceptable Concentration; AO=Aesthetic Objective; OG=Operational Guideline

4.3.2.1.7 Lakefield

Four drinking water issues were identified at the Lakefield intake. They are all related to natural sources, so the identification of contributing sources and the delineation of issue contributing areas were not required for these issues. The drinking water issues evaluation for Lakefield is summarized in Table 4.3-11, which lists the water quality parameters that exceeded the water quality standards and indicates whether or not they were considered issues and the rationale for the conclusion. The only parameter that exceeded the secondary benchmark (25% of its water quality standard) and showed a statistically significant upward trend was sodium. The trend analysis for sodium is summarized in Table 4.3-12.

Table 4.3-11: Lakefield Water Quality Standards Exceedances

Parameter	Water Type[1]	Years on Record	Exceedances		Standard		Source	Drinking Water Issue?	Rationale (Notes)
			%	#	Value	Type[2]			
Schedule 1									
Total Coliforms	Raw	66-08	99	643	0 cfu/100 mL	MAC		NO	• Typical results for a surface water system • Adequate level of treatment in place
E. coli	Raw	72-08	84	655	0 cfu/100 mL	MAC		NO	• Typical results for a surface water system • Adequate level of treatment in place
Schedule 2									
Lead	Raw	81-07	0.5	2	0.01 mg/L	MAC		NO	• Single exceedance considered anomalous
NDMA	Treated	03	50	2	0.009 ug/L	MAC		NO	• Exceedances due to laboratory error
Table 4									
DOC	Raw	71-07	91	32	5 mg/L	AO	Natural	YES	• Exceeded standards
Hardness	Raw	66-07	12	19	80-100 mg/L	OG	Natural	YES	• Typical results for a surface water system • Outside acceptable aesthetic or operation guidelines
Manganese	Raw	95-01	2	2	0.05 mg/L	AO		NO	• Exceedances considered anomalous • No recent exceedances
Temperature	Raw	66-07	45	291	15°C	AO	Natural	YES	• Typical results for a surface water system • Outside acceptable aesthetic or operation guidelines
Turbidity	Raw	66-06	5	29	5 NTU	AO	Natural	YES	• Typical results for a surface water system • Outside acceptable aesthetic or operation guidelines

Table 4.3-12: Lakefield Water Quality Trend Analysis

Parameter	Water Type[1]	Samples on Record	Trend		Extrapolation[4]		Standard		Drinking Water Issue?	Rationale
			Direction	p[3]	25 Years	50 Years	Value	Type[2]		
Sodium	Treated	130	↑	1.32E-39	12.0 mg/L	17.2 mg/L	200mg/L	AO	NO	• No exceedances on record • Trend does not exceed standards within 50 years

[1]Indicates if the data on record is for raw (untreated) or treated water
[2]Standard types: MAC=Maximum Acceptable Concentration; AO=Aesthetic Objective; OG=Operational Guideline
[3]Indicates the statistical significance of the proposed hypothesis that the trend is occurring as reported (trends are generally considered statistically significant where $p<0.05$)
[4]Indicates the concentration that the parameter would reach in 25 and 50 years if the trend remains constant

4.3.2.1.8 Peterborough

Five drinking water issues were identified at the Peterborough intake. They are all related to natural sources, so the identification of contributing sources and the delineation of issue contributing areas were not required for these issues. The drinking water issues evaluation for Peterborough is summarized in Table 4.3-13, which lists the water quality parameters that exceeded the water quality standards and indicates whether or not they were considered issues and the rationale for the conclusion. Four parameters exceeded the secondary benchmark (25% of its water quality standard) and showed a statistically significant upward trend: nitrite, THMs, sodium, and chloride. The trend analysis for these parameters is summarized in Table 4.3-14.

Table 4.3-13: Peterborough Water Quality Standards Exceedances

Parameter	Water Type[1]	Years on Record	Exceedances		Standard		Source	Drinking Water Issue?	Rationale
			%	#	Value	Type[2]			
Schedule 1									
Total Coliforms	Raw	65-08	98	1809	0 cfu/100mL	MAC		NO	• Typical results for a surface water system • Adequate level of treatment in place
	Treated	06	0-1[a]						
E. coli	Raw	72-08	81	1511	0 cfu/100mL	MAC		NO	• Typical results for a surface water system • Adequate level of treatment in place
Schedule 2									
Cadmium	Raw	90-07	1	1	0.005 mg/L	MAC		NO	• Single exceedance considered anomalous
Chromium	Raw	90-07	1	1	0.05 mg/L	MAC		NO	• Single exceedance considered anomalous
Lead	Raw	81-07	1	2	0.01 mg/L	MAC		NO	• Single exceedance considered anomalous
NDMA	Treated	99-06	18	3	0.009 ug/L	MAC		NO	• Exceedances due to laboratory error
Table 4									
Aluminum	Raw	90-07	1	1	0.1 mg/L	OG		NO	• Single exceedance considered anomalous
Colour	Raw	90-07	100	46	5 TCU	AO	Natural	YES	• Typical results for a surface water system • Outside acceptable aesthetic or operation guidelines
DOC	Raw	71-07	77	27	5 mg/L	AO	Natural	YES	• Typical results for a surface water system • Outside acceptable aesthetic or operation guidelines
Hardness	Raw	67-07	2	2	80-100 mg/L	OG	Natural	YES	• Typical results for a surface water system • Outside acceptable aesthetic or operation guidelines
Iron	Raw	67-07	1	2	0.3 mg/L	AO		NO	• 2 exceedances considered anomalous
Manganese	Raw	90-07	1	1	0.05 mg/L	AO		NO	• Single exceedance considered anomalous
Temperature	Raw	65-07	45	17	15°C	AO	Natural	YES	• Typical results for a surface water system • Outside acceptable aesthetic or operation guidelines
Turbidity	Raw	65-07	4	16	5 NTU	AO	Natural	YES	• Typical results for a surface water system • Outside acceptable aesthetic or operation guidelines

[a]Parameter reported as a range of results in cfu/100 mL

[1]Indicates if the data on record is for raw (untreated) or treated water
[2]Standard types: MAC=Maximum Acceptable Concentration; AO=Aesthetic Objective; OG=Operational Guideline

Table 4.3-14: Peterborough Water Quality Trend Analysis

Parameter	Water Type[1]	Samples on Record	Trend		Extrapolation[4]		Standard		Drinking Water Issue?	Rationale
			Direction	p[3]	25 Years	50 Years	Value	Type[2]		
Nitrite	Treated	38	↑	0.013	0.007 mg/L	0.012 mg/L	1.0 mg/L	MAC	NO	• Trend does not exceed standards within 50 years
THMs	Treated	6	↑	0.020	0.6 mg/L	1.0 mg/L	0.1 mg/L	MAC	NO	• Trend exceeds standards within 50 years • By-product of treatment
Sodium	Raw	107	↑	9.10E-06	11.9 mg/L	16.6 mg/L	200 mg/L	AO	NO	• Trend does not exceed standards within 50 years
Chloride	Raw	337	↑	2.74E-21	17.0 mg/L	22.4 mg/L	250 mg/L	AO	NO	• Trend does not exceed standards within 50 years

[1]Indicates if the data on record is for raw (untreated) or treated water
[2]Standard types: MAC=Maximum Acceptable Concentration; AO=Aesthetic Objective; OG=Operational Guideline
[3]Indicates the statistical significance of the proposed hypothesis that the trend is occurring as reported (trends are generally considered statistically significant where $p<0.05$)
[4]Indicates the concentration that the parameter would reach in 25 and 50 years if the trend remains constant

4.3.2.1.9 Hastings

Five drinking water issues were identified at the Hastings intake. They are all related to natural sources, so the identification of contributing sources and the delineation of issue contributing areas were not required for these issues. The drinking water issues evaluation for Hastings is summarized in Table 4.3-15, which lists the water quality parameters that exceeded the water quality standards and indicates whether or not they were considered issues and the rationale for the conclusion. The only parameter that exceeded the secondary benchmark (25% of its water quality standard) and showed a statistically significant upward trend was sodium. The trend analysis for sodium is summarized in Table 4.3-16.

Table 4.3-15: Hastings Water Quality Standards Exceedances

Parameter	Water Type[1]	Years on Record	Exceedances		Standard		Source	Drinking Water Issue?	Rationale
			%	#	Value	Type[2]			
Schedule 1									
Total Coliforms	Raw	72-08	99	462	0 cfu/100 mL	MAC		NO	• Typical results for a surface water system • Adequate level of treatment in place
	Treated	06	0-18[a]						
E. coli	Raw	72-08	94	513	0 cfu/100 mL	MAC		NO	• Typical results for a surface water system • Adequate level of treatment in place
	Treated	06	0-52[a]						
Table 4									
Colour	Raw	92	100	12	5 TCU	AO	Natural	YES	• Typical results for a surface water system • Outside acceptable aesthetic or operation guidelines
DOC	Treated	72-99	71	5	5 mg/L	AO		NO	• No exceedances in more recent data • Limited data • THMs below standards
Hardness	Raw	92-07	83	70	80-100 mg/L	OG	Natural	YES	• Typical results for a surface water system • Outside acceptable aesthetic or operation guidelines
Manganese	Raw	95-04	9	6	0.05 mg/L	AO	Natural	YES	• Exceeded standards
Temperature	Raw	72-07	46	133	15°C	AO	Natural	YES	• Typical results for a surface water system • Outside acceptable aesthetic or operation guidelines
Turbidity	Raw	72-06	18	58	5 NTU	AO	Natural	YES	• Typical results for a surface water system • Outside acceptable aesthetic or operation guidelines

[a]Parameter reported as a range of results in cfu/100 mL

Table 4.3-16: Hastings Water Quality Trend Analysis

Parameter	Water Type	Samples on Record	Trend		Extrapolation[4]		Standard		Drinking Water Issue?	Rationale
			Direction	p[3]	25 Years	50 Years	Value	Type[2]		
Sodium	Raw	66	↑	2.41E-12	15.0 mg/L	21.2 mg/L	200 mg/L	AO	NO	• Trend does not exceed standards within 50 years

[1]Indicates if the data on record is for raw (untreated) or treated water
[2]Standard types: MAC=Maximum Acceptable Concentration; AO=Aesthetic Objective; OG=Operational Guideline
[3]Indicates the statistical significance of the proposed hypothesis that the trend is occurring as reported (trends are generally considered statistically significant where $p<0.05$)
[4]Indicates the concentration that the parameter would reach in 25 and 50 years if the trend remains constant

4.3.2.1.10 Marmora

Five drinking water issues were identified at the Marmora intake. They are all related to natural sources, so the identification of contributing sources and the delineation of issue contributing areas were not required for these issues. The drinking water issues evaluation for Marmora is summarized in Table 4.3-17, which lists the water quality parameters that exceeded the water quality standards and indicates whether or not they were considered issues and the rationale for the conclusion. Four parameters exceeded the secondary benchmark (25% of its water quality standard) and showed a statistically significant upward trend: lead, aluminum, chloride, and copper. The trend analysis for these parameters is summarized in Table 4.3-18.

Table 4.3-17: Marmora Water Quality Standards Exceedances

Parameter	Water Type[1]	Years on Record	Exceedances		Standard		Source	Drinking Water Issue?	Rationale
			%	#	Value	Type[2]			
Schedule 1									
Total Coliforms	Raw	64-07	98	468	0 cfu/100mL	MAC		NO	• Typical results for a surface water system • Adequate level of treatment in place
	Treated	07	0-1[a]						
E. coli	Raw	06-07	94	391	0 cfu/100mL	MAC		NO	• Typical results for a surface water system • Adequate level of treatment in place
Schedule 2									
Arsenic	Raw	72-94	1	1	0.005 mg/L	MAC		NO	• Single exceedance considered anomalous
Lead	Raw	80-98	15	16	0.01 mg/L	MAC		NO	• Exceedances before 1986 (none in recent data)
Mercury	Raw	80-93	2	1	0.001 mg/L	MAC		NO	• Single exceedance considered anomalous
THMs	Treated	00-08	13	3	0.100 mg/L	MAC		NO	• By-product of treatment
Table 4									
Aluminum	Raw	70-98	9	6	0.1 mg/L	OG		NO	• 6 exceedances (mostly from 1970s) • 1 exceedance in recent data considered anomalous
Colour	Raw	06-07	100	31	5 TCU	AO	Natural	YES	• Typical results for a surface water system • Outside acceptable aesthetic or operation guidelines
DOC	Raw	76	100	1	5 mg/L	AO	Natural	YES	• Exceeded standards (in treated water) • Exceeded standard (in raw water) – 1 sample only
Hardness	Raw	65-07	28	61	80-100 mg/L	OG	Natural	YES	• Typical results for a surface water system • Outside acceptable aesthetic or operation guidelines
Iron	Raw	65-74	5	8	0.3 mg/L	AO		NO	• Exceedances before 1975 • No exceedances in recent data (since 1981)
Manganese	Raw	70-98	6	4	0.05 mg/L	AO		NO	• Exceedances before 1976 (none in recent data)
Temperature	Raw	64-98	39	92	15°C	AO	Natural	YES	• Typical results for a surface water system • Outside acceptable aesthetic or operation guidelines
Turbidity	Raw	64-98	4	11	5 NTU	AO	Natural	YES	• Typical results for a surface water system • Outside acceptable aesthetic or operation guidelines

[a]Parameter reported as a range of results in cfu/100 mL

[1]Indicates if the data on record is for raw (untreated) or treated water
[2]Standard types: MAC=Maximum Acceptable Concentration; AO=Aesthetic Objective; OG=Operational Guideline

Table 4.3-18: Marmora Water Quality Trend Analysis

Parameter	Water Type[1]	Samples on Record	Trend		Extrapolation[4]		Standard		Drinking Water Issue?	Rationale
			Direction	p[3]	25 Years	50 Years	Value	Type[2]		
Lead	Treated	19	↑	0.023	0.005 mg/L	0.007 mg/L	0.010 mg/L	MAC	NO	• Trend does not exceed standards within 50 years
Aluminum	Treated	18	↑	0.026	0.04 mg/L	0.07 mg/L	0.1 mg/L	OG	NO	• Trend does not exceed standards within 50 years
Chloride	Treated	15	↑	0.017	18.9 mg/L	27.7 mg/L	250 mg/L	AO	NO	• Trend does not exceed standards within 50 years
Copper	Treated	68	↑	1.66E-4	0.54 mg/L	0.96 mg/L	1 mg/L	AO	NO	• Trend does not exceed standards within 50 years

[1]Indicates if the data on record is for raw (untreated) or treated water
[2]Standard types: MAC=Maximum Acceptable Concentration; AO=Aesthetic Objective; OG=Operational Guideline

4.3.2.1.11 Campbellford

Six drinking water issues were identified at the Campbellford intake. They are all related to natural sources, so the identification of contributing sources and the delineation of issue contributing areas were not required for these issues. The drinking water issues evaluation for Campbellford is summarized in Table 4.3-19, which lists the water quality parameters that exceeded the water quality standards and indicates whether or not they were considered issues and the rationale for the conclusion. No parameters that exceeded a secondary benchmark (25% of its water quality standard) showed statistically significant trends.

Table 4.3-19: Cambellford Water Quality Standards Exceedances

Parameter	Water Type[1]	Years on Record	Exceedances		Standard		Source	Drinking Water Issue?	Rationale
			%	#	Value	Type[2]			
Schedule 1									
Total Coliforms	Raw	64-08	100	335	0 cfu/100mL	MAC		NO	• Typical results for a surface water system • Adequate level of treatment in place
	Treated	04	0-25[a]						
E. coli	Raw	72-08	87	327	0 cfu/100mL	MAC		NO	• Typical results for a surface water system • Adequate level of treatment in place
	Treated	04	0-9[a]						
Schedule 2									
Lead	Raw	81-98	1	1	0.01 mg/L	MAC		NO	• Single exceedance considered anomalous
Table 4									
Alkalinity	Raw	65-98	0.4	1	30-500 mg/L	OG		NO	• Single outlier considered anomalous
Aluminum	Raw	70-98	26	14	0.1 mg/L	OG	Natural	YES	• Exceeded standards
Hardness	Raw	65-98	82	75	80-100 mg/L	OG	Natural	YES	• Typical results for a surface water system • Outside acceptable aesthetic or operation guidelines
Iron	Raw	65-74	5	11	0.3 mg/L	AO	Natural	YES	• Exceeded standards
Manganese	Raw	70-97	9	5	0.05 mg/L)	AO	Natural	YES	• Exceeded standards
Temperature	Raw	64-95	39	121	15°C	AO	Natural	YES	• Typical results for a surface water system • Outside acceptable aesthetic or operation guidelines
Turbidity	Raw	64-98	21	73	5 NTU	AO	Natural	YES	• Typical results for a surface water system • Outside acceptable aesthetic or operation guidelines

[a]Parameter reported as a range of results in cfu/100 mL

[1]Indicates if the data on record is for raw (untreated) or treated water
[2]Standard types: MAC=Maximum Acceptable Concentration; AO=Aesthetic Objective; OG=Operational Guideline

4.3.2.1.12 Warkworth

pH is the only drinking water issue identified at the Warkworth intake. It is related to natural sources, so the identification of contributing sources and the delineation of issue contributing areas were not required for this issue. The drinking water issues evaluation for Warkworth is summarized in Table 4.3-20, which lists the water quality parameters that exceeded the water quality standards and indicates whether or not they were considered issues and the rationale for the conclusion. No parameters that exceeded a secondary benchmark (25% of its water quality standard) showed statistically significant trends.

Table 4.3-20: Warkworth Water Quality Standards Exceedances

Parameter	Water Type[1]	Years on Record	Exceedances		Standard		Source	Drinking Water Issue?	Rationale
			%	#	Value	Type[2]			
Schedule 1									
Total Coliforms	Raw	01-06	99	633	0 cfu/100mL	MAC		NO	• Typical results for a surface water system • Adequate level of treatment in place
	Treated	08	0-1[a]		0 cfu/100mL	MAC		NO	
E. coli	Raw	01-08	98	630	0 cfu/100mL	MAC		NO	• Typical results for a surface water system • Adequate level of treatment in place
Schedule 2									
Lead	Raw	02-07	4	1	0.01 mg/L	MAC		NO	• Single exceedance considered anomalous
Table 4									
Aluminum	Treated	96-07	18	2	0.1 mg/L	OG		NO	• No exceedances in the raw water therefore it is likely a by-product of the treatment process
Manganese	Raw	02-07	4	1	0.05 mg/L	AO		NO	• Single exceedance considered anomalous
pH	Raw	02-07	50	14	6.5-8.5	MAC	Natural	YES	• Exceeded standards
Turbidity	Raw	02-06	4	1	5 NTU	AO		NO	• Single exceedance considered anomalous

[a]Parameter reported as a range of results in cfu/100 mL

[1]Indicates if the data on record is for raw (untreated) or treated water
[2]Standard types: MAC=Maximum Acceptable Concentration; AO=Aesthetic Objective; OG=Operational Guideline

4.3.2.1.13 Frankford

Four drinking water issues were identified at the Frankford intake. They are all related to natural sources, so the identification of contributing sources and the delineation of issue contributing areas were not required for these issues. The drinking water issues evaluation for Frankford is summarized in Table 4.3-21, which lists the water quality parameters that exceeded the water quality standards and indicates whether or not they were considered issues and the rationale for the conclusion. Two parameters exceeded the secondary benchmark (25% of its water quality standard) and showed a statistically significant upward trend: benzo(a)pyrene and sodium. The trend analysis for these parameters is summarized in Table 4.3-22.

Table 4.3-21: Frankford Water Quality Standards Exceedances

Parameter	Water Type[1]	Years on Record	Exceedances		Standard		Source	Drinking Water Issue?	Rationale
			%	#	Value	Type[2]			
Schedule 1									
Total Coliforms	Raw	00-08	79	219	0 cfu/100mL	MAC		NO	• Typical results for a surface water system • Adequate level of treatment in place
E. coli	Raw	80-08	48	157	0 cfu/100mL	MAC		NO	• Typical results for a surface water system • Adequate level of treatment in place
Schedule 2									
Cadmium	Raw	86-06	1	1	0.005 mg/L	MAC		NO	• Single exceedance considered anomalous
Chromium	Raw	86-06	2	2	0.05 mg/L	MAC		NO	• 2 exceedances considered anomalous
Table 4									
Colour	Raw	03-04	100	9	5 TCU	AO	Natural	YES	• Typical results for a surface water system • Outside acceptable aesthetic or operation guidelines
Hardness	Raw	88-06	85	94	80-100 mg/L	OG	Natural	YES	• Typical results for a surface water system • Outside acceptable aesthetic or operation guidelines
Iron	Raw	81-88	1	2	0.3 mg/L	AO		NO	• 2 exceedances considered anomalous (1979) • No exceedances in recent data • Decreasing trend
pH	Raw	83; 03-04	10	1	6.5-8.5	OG		NO	• Single exceedance considered anomalous
Temperature	Raw	80-88	52	34	15°C	AO	Natural	YES	• Typical results for a surface water system • Outside acceptable aesthetic or operation guidelines
Turbidity	Raw	80-06	19	33	5 NTU	AO	Natural	YES	• Typical results for a surface water system • Outside acceptable aesthetic or operation guidelines

Table 4.3-22: Frankford Water Quality Trend Analysis

Parameter	Water Type[1]	Samples on Record	Trend		Extrapolation[4]		Standard		Drinking Water Issue?	Rationale
			Direction	p[3]	25 Years	50 Years	Value	Type[2]		
Benzo(a)pyrene	Treated	5	↑	0.0017	0.0003 mg/L	0.0005 mg/L	0.00001 mg/L	MAC	NO	• Single exceedance due to typographical error
Sodium	Raw	61	↑	1.14E-13	12.6 mg/L	17.5 mg/L	200 mg/L	AO	NO	• Trend does not exceed standards in 50 years

[1]Indicates if the data on record is for raw (untreated) or treated water
[2]Standard types: MAC=Maximum Acceptable Concentration; AO=Aesthetic Objective; OG=Operational Guideline

4.3.2.1.14 Trenton

Six drinking water issues were identified at the Trenton intake. They are all related to natural sources, so the identification of contributing sources and the delineation of issue contributing areas were not required. The drinking water issues evaluation for Trenton is summarized in Table 4.3-23, which lists the water quality parameters that exceeded the water quality standards and indicates whether or not they were considered issues and the rationale for the conclusion. The only parameter that exceeded the secondary benchmark (25% of its water quality standard) and showed a statistically significant upward trend was sodium. The trend analysis for sodium is summarized in Table 4.3-24.

Table 4.3-23: Trenton Water Quality Standards Exceedances

Parameter	Water Type[1]	Years on Record	Exceedances		Standard		Source	Drinking Water Issue?	Rationale
			%	#	Value	Type[2]			
Schedule 1									
Total Coliforms	Raw	71-08	99	297	0 cfu/100mL	MAC		NO	• Typical results for a surface water system • Adequate level of treatment in place
E. coli	Raw	72-08	96	339	0 cfu/100mL	MAC		NO	• Typical results for a surface water system • Adequate level of treatment in place
Schedule 2									
Antimony	Raw	90-07	2	1	0.005 mg/L	MAC		NO	• Single exceedance considered anomalous
Lead	Raw	81-07	2	3	0.01 mg/L	MAC		NO	• 3 exceedances prior to 1988 • No exceedances in recent data • Decreasing trend
THMs	Treated	98-08	2	1	0.1 mg/L	MAC		NO	• 1 exceedance • By-product of treatment
Table 4									
Alkalinity	Raw	81-07	1	1	30-500 mg/L	OG		NO	• Single exceedance considered anomalous
Aluminum	Raw	90-07	7	5	0.1 mg/L	OG	Natural	YES	• 5 exceedances prior to 1995 • Recent data approaching guideline
Colour	Raw	98-07	100	28	5 TCU	AO	Natural	YES	• Typical results for a surface water system • Outside acceptable aesthetic or operation guidelines
DOC	Raw	71-07	98	47	5 mg/L	AO	Natural	YES	• Exceeded standards
Hardness	Raw	71-07	96	117	80-100 mg/L	OG	Natural	YES	• Typical results for a surface water system • Outside acceptable aesthetic or operation guidelines
Iron	Raw	71-07	2	3	0.3 mg/L	AO		NO	• 3 exceedances prior to 1996 • No exceedances in recent data
Manganese	Raw	90-07	4	3	0.05 mg/L	AO		NO	• 3 exceedances prior to 1996 • No exceedances in recent data
Temperature	Raw	71-07	48	91	15°C	AO	Natural	YES	• Typical results for a surface water system • Outside acceptable aesthetic or operation guidelines
Turbidity	Raw	71-07	17	41	5 NTU	AO	Natural	YES	• Typical results for a surface water system • Outside acceptable aesthetic or operation guidelines • Decreasing trend

Table 4.3-24: Trenton Water Quality Trend Analysis

Parameter	Water Type[1]	Samples on Record	Trend		Extrapolation[4]		Standard		Drinking Water Issue?	Rationale
			Direction	p[3]	25 Years	50 Years	Value	Type		
Sodium	Raw	47	↑	1.010E-9	14.5 mg/L	20.2 mg/L	200 mg/L	AO	NO	• Trend does not exceed standards in 50 years

[1]Indicates if the data on record is for raw (untreated) or treated water
[2]Standard types: MAC=Maximum Acceptable Concentration; AO=Aesthetic Objective; OG=Operational Guideline
[3]Indicates the statistical significance of the proposed hypothesis that the trend is occurring as reported (trends are generally considered statistically significant where p<0.05)
[4]Indicates the concentration that the parameter would reach in 25 and 50 years if the trend remains constant

4.3.2.1.15 Bayside

Seven drinking water issues were identified at the Bayside intake. These are all related to natural sources, so the identification of contributing sources and the delineation of issue contributing area were not required for these issues. The drinking water issues evaluation for Bayside is summarized in Table 4.3-25, which lists the water quality parameters that exceeded the water quality standards and indicates whether or not they were considered issues and the rationale for the conclusion. Two parameters exceeded the secondary benchmark (25% of its water quality standard) and showed a statistically significant upward trend: benzo(a)pyrene and sodium. The trend analysis for these parameters is summarized in Table 4.3-26.

Microcystin-LR, an algae toxin released from blue-green algae, is of concern in the Bay of Quinte and at the Bayside intake. It has not been identified as an issue at this time for several reasons:

- There has only been one exceedance of the drinking water standard; the data set for Microcystin is limited.
- There are no land use activities that contribute directly to the release of Microcystin; land uses that cause the formation of algal blooms (which in turn may produce Microcystin) cannot readily be identified.
- For the Bay of Quinte, biologically available phosphorus is the limiting factor for algal blooms. Environment Canada is currently conducting research to determine the factors contributing to harmful algal blooms, which produce toxins such as Microcystin. It is hopeful that this ongoing research would determine if the source of the biologically available phosphorus (which cause the algal bloom) is from watershed runoff (associated with human activity) or is from recycling of the nutrient in the bay itself.

The health concern, coupled with the lack of sufficient data and the lack of understanding of the factors contributing to the production of Microcystin, has led to the decision to identify Microcystin as a data gap under Technical Rule 114.

Table 4.3-25: Bayside Water Quality Standards Exceedances

Parameter	Water Type[1]	Years on Record	Exceedances		Standard		Source	Drinking Water Issue?	Rationale
			%	#	Value	Type[2]			
Schedule 1									
Total Coliforms	Raw	00-08	90	139	0 cfu/100 mL	MAC		NO	• Typical results for a surface water system • Adequate level of treatment in place
E. coli	Raw	00-08	52	80	0 cfu/100 mL	MAC		NO	• Typical results for a surface water system • Adequate level of treatment in place
Schedule 2									
Microcystin-LR	Raw	04-08	1	1	0.0015 mg/L	MAC		UNKNOWN	• Single exceedance
THMs	Treated	00-08	2	1	0.100 mg/L	MAC		NO	• By-product of treatment
Table 4									
Aluminum	Raw	97-07	5	3	0.1 mg/L	OG		NO	• Exceeded standards
Colour	Raw	01-08	100	127	5 TCU	AO	Natural	YES	• Typical results for a surface water system • Outside acceptable aesthetic or operation guidelines
DOC	Raw	97-07	83	40	5 mg/L	AO	Natural	YES	• Typical results for a surface water system • Outside acceptable aesthetic or operation guidelines
Hardness	Raw	97-08	81	126	80-100 mg/L	OG	Natural	YES	• Typical results for a surface water system • Outside acceptable aesthetic or operation guidelines
Manganese	Raw	97-06	22	12	0.05 mg/L	AO	Natural	YES	• Exceeded standards
pH, Lab	Raw	04-08	1	1	6.5-8.5	OG	Natural	YES	• Exceeded standards
pH, Field	Raw	97-08	4	6	6.5-8.5	OG			
Temperature	Raw	01-08	79	99	15°C	AO	Natural	YES	• Typical results for a surface water system • Outside acceptable aesthetic or operation guidelines
Turbidity	Raw	00-08	19	26	5 NTU	AO	Natural	YES	• Typical results for a surface water system • Outside acceptable aesthetic or operation guidelines • Decreasing trend

Table 4.3-26: Bayside Water Quality Trend Analysis

Parameter	Water Type[1]	Samples on Record	Trend		Extrapolation[4]		Standard		Drinking Water Issue?	Rationale
			Direction	p[3]	25 Years	50 Years	Value	Type[2]		
Benzo(a)pyrene	Treated	7	↑	0.021	0.02 ug/L	0.04 ug/L	0.01 ug/L	MAC	NO	• The trend was a result of changes to the detection limit
Sodium	Raw	157	↑	7.64E-14	15.6 mg/L	22.0 mg/L	200 mg/L	AO	NO	• Trend does not exceed standards in 50 years

CHAPTER 5: GROUNDWATER SYSTEMS: WATER QUALITY RISK ASSESSMENT

5.1 SUMMARY OF GROUNDWATER SYSTEMS

There are 33 municipal drinking water systems listed in the *Terms of Reference* for the 4 Trent source protection areas that draw water from groundwater sources. These include 31 existing systems and 2 planned systems. The 2 planned systems listed in the *Terms of Reference* are the Fraserville – Lansdowne Site and the Fraserville – Leahy Site. The Township of Cavan Monaghan has since abandoned its plans for the Leahy Site. The documentation to advise the public of this change is provided in Appendix A. Reference to the planned system in this report is to the Fraserville – Lansdowne Site.

General information regarding the existing municipal residential groundwater systems is provided in Table 5.1-1. Details regarding their wells and water treatment systems are summarized in Table 5.1-2. The average rates at which these systems pump water from their aquifers are provided in Table 5.1-3.

Table 5.1-1: Summary of Existing Municipal Residential Groundwater Systems in the Trent SPAs

System Name	Drinking Water System No.	Operating Authority	*Safe Drinking Water Act* Classification	Serviced Population (Approx.) [1]
Kawartha-Haliburton Source Protection Area				
Canadiana Shores	220006491	Ontario Clean Water Agency	Large Municipal Residential	475
Janetville	220006455	Ontario Clean Water Agency	Large Municipal Residential	300
King's Bay	260002954	Ontario Clean Water Agency	Small Municipal Residential	225
Manorview	260001864	Ontario Clean Water Agency	Small Municipal Residential	80
Mariposa Estates	220012322	Ontario Clean Water Agency	Small Municipal Residential	122
Omemee	210002227	Ontario Clean Water Agency	Small Municipal Residential	175
Pleasant Point	220006525	Ontario Clean Water Agency	Large Municipal Residential	365
Sonya	260006516	City of Kawartha Lakes	Small Municipal Residential	127
Woods of Manilla	210002218	City of Kawartha Lakes	Small Municipal Residential	200
Woodfield	220012251	Ontario Clean Water Agency	Small Municipal Residential	85
Victoria Place	220011895	Ontario Clean Water Agency	Large Municipal Residential	540
Blackstock	220003751	Reg. Munic. of Durham	Large Municipal Residential	527
Greenbank	220003760	Reg. Munic. of Durham	Large Municipal Residential	560
Port Perry	220004830	Reg. Munic. of Durham	Large Municipal Residential	9,723
Minden	210000194	Ontario Clean Water Agency	Large Municipal Residential	2,300
Lutterworth Pines[2]	260091936	Ontario Clean Water Agency	Small Municipal Residential	75
Otonabee-Peterborough Source Protection Area				
Alpine Village/Pirates Glen	220011154	Ontario Clean Water Agency	Large Municipal Residential	498
Birch Point Estates	220012572	Ontario Clean Water Agency	Large Municipal Residential	394
Buckhorn Lake Estates	220006437	Ontario Clean Water Agency	Large Municipal Residential	285
Crystal Springs	260064272	Ontario Clean Water Agency	Large Municipal Residential	265
Keene Heights	220006393	Ontario Clean Water Agency	Small Municipal Residential	75
Millbrook	220000781	PUG Services Corporation	Large Municipal Residential	1,200
Norwood	220000479	Township of Asphodel-Norwood	Large Municipal Residential	1,400
Pinewood	220006464	Ontario Clean Water Agency	Large Municipal Residential	447
Crowe Valley Source Protection Area				
Cardiff	220001682	Municipality of Highlands East	Large Municipal Residential	500
Dyno Estates	220013581	Municipality of Highlands East	Small Municipal Residential	25
Havelock	210000595	Ontario Clear Water Agency	Large Municipal Residential	1,400

[1]Data Source: Ministry of the Environment and Climate Change
[2]Refers to the new Lutterworth Pines system functional since March 15, 2010

Table 5.1-1 (cont'd): Summary of Existing Municipal Residential Groundwater Systems in the Trent SPAs

System Name	Drinking Water System No.	Operating Authority	*Safe Drinking Water Act* Classification	Serviced Population (Approx.)[1]
Lower Trent Source Protection Area				
Grafton	220009158	Lakefront Utilities	Large Municipal Residential	1,000
Brighton	220000807	Municipality of Brighton	Large Municipal Residential	5,850
Colborne	220000790	Aquatech Canadian Water Services Inc.	Large Municipal Residential	2,000
Stirling	220009158	Township of Stirling-Rawdon	Large Municipal Residential	2,000

[1]Data Source: Ministry of the Environment and Climate Change

Table 5.1-2: Summary of Wells and Water Treatment Systems for Existing Municipal Residential Groundwater Systems in the Trent Source Protection Areas

System Name	Well(s)								Water Treatment System	
	Location	No. Wells	Depths (m)					GUDI Status	Disinfection	Other Available Treatment Details
			1	2	3	4	5			
Kawartha-Haliburton Source Protection Area										
Canadiana Shores	North side of Lake Scugog	3	13.4	23.2	20.1	NA	NA	Yes	Sodium hypochlorite	Dual media (anthracite/silica sand) gravity filters, 1micron absolute filtration,
Janetville	Janetville	3	36.5	50	51	NA	NA	No	Sodium hypochlorite	Iron sequestration (sodium silicate)
King's Bay	West side of Lake Scugog	3	17.4	17.4	17.7	NA	NA	No	Sodium hypochlorite	
Manorview	Bethany	2	24.4	25	NA	NA	NA	Yes	UV irradiation	Cartridge filtration
Mariposa Estates	West side of Lake Scugog	2	15.5	25.2	NA	NA	NA	No	Sodium hypochlorite	Nitrate removal softening system
Omemee	Omemee	2	9.5	9.1	NA	NA	NA	No	Sodium hypochlorite	Iron sequestration
Pleasant Point	North side of Lake Scugog	2	15.2	17.1	NA	NA	NA	Yes	UV irradiation	1 micron cartridge filtration
Sonya	Sonya	2	16.76	22.9	NA	NA	NA	Yes	Sodium hypochlorite	cartridge filtration, iron sequestration (sodium silicate))
Woods of Manilla	Manilla	2	45.7	53.9	NA	NA	NA	No	Sodium hypochlorite	
Woodfield	Bethany	2	75	69	NA	NA	NA	No	Sodium hypochlorite	Iron sequestration (sodium silicate)
Victoria Place	West side of Pigeon Lake	4	4.9	7	7.3	16.8	NA	No	Sodium hypochlorite	
Blackstock	Blackstock	2	NA	58.9	51.5	NA	NA	No	Sodium hypochlorite	Iron sequestration (sodium silicate
Greenbank	Greenbank	5	26.1	24.0	34.0	31.6	27.7	No	Sodium hypochlorite	
Port Perry	Port Perry	3	36.2	34.9	69.5	NA	NA	No	Chlorine	Iron sequestration
Minden	Minden	2	49	47	NA	NA	NA	No	Sodium hypochlorite	Sodium silicate (iron and manganese sequestration)
Lutterworth Pines	East shore of Gull Lake	2	73	61	NA	NA	NA	No	Sodium hypochlorite	20µ cartridge filter, Kinetico filter with gravel, and Purolite A300E anion resin and polypropylene media for Uranium removal

Table 5.1-2 (cont.) Summary of Wells and Water Treatment Systems for Existing Municipal Residential Groundwater Systems in the Trent SPAs

System Name	Well(s)								Water Treatment System	
	Location	No. Wells	Depths (m)					GUDI Status	Disinfection	Other Available Treatment Details
			1	2	3	4	5			
Otonabee-Peterborough Source Protection Area										
Alpine Village/Pirates Glen	East of Bobcaygeon	2	82	100	NA	NA	NA	No	Sodium hypochlorite	2 µm cartridge filtration
Birch Point Estates	Birch Point	2	18.3	19.8	NA	NA	NA	No	Sodium hypochlorite	1 µm cartridge filtration
Buckhorn Lake Estates	Buckhorn	1	16.8	NA	NA	NA	NA	Yes	Sodium hypochlorite	Chemically assisted filtration (Kinetico Macrolite system)
Crystal Springs	Elgeti	2	19.8	26.5	NA	NA	NA	Yes[2]	UV irradiation Sodium hypochlorite	
Keene Heights	Keene	2	20.9	26.5	NA	NA	NA	No	Sodium hypochlorite	Sodium silicate (iron sequestration)
Millbrook	Millbrook	3	30	30	31	NA	NA	No	Sodium hypochlorite	
Norwood	Norwood	4	25	21.3	30.5	30.5	NA	No	Sodium hypochlorite	Sodium hypochlorite; phosphate-based corrosion control
Pinewood	Pinewood	3	107	118	NA	NA	NA	No	Sodium hypochlorite	
Crowe Valley Source Protection Area										
Cardiff	Cardiff	1	13.4	NA	NA	NA	NA	Yes	Sodium hypochlorite	2 µm cartridge filter for iron removal
Dyno Estates	Dyno Estates	1	11.8	NA	NA	NA	NA	No	Sodium hypochlorite	
Havelock	Northeast side of Havelock	3	15.2	13.7	15	NA	NA	Yes	Wells 1&4: UV irradiation; Chlorine; Sodium hypochlorite Well 3: Chlorine; Sodium hypochlorite; UV irradiation	Well 3: Dual media filtration
Lower Trent Source Protection Area										
Grafton	Grafton	2	78	78	NA	NA	NA	No	Sodium hypochlorite	Sodium silicate (iron sequestration)
Brighton	Brighton	3	40	40	40	NA	NA	No	Gaseous chlorine	
Colborne	Colborne	2	70	72	NA	NA	NA	No	Sodium hypochlorite	Sodium silicate (iron sequestration)
Stirling	Stirling	5	6.4	13.1	16.1	13.2	13.2	Yes	UV irradiation; Sodium hypochlorite	

Table 5.1-3: Pumping Rates for Existing Municipal Residential Groundwater Systems in the Trent Source Protection Areas

System Name	Monthly Average Pumping Rates (m³/day)[1]												Average Annual Pumping Rate (m³/day)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Kawartha-Haliburton Source Protection Area													
Canadiana Shores	58	66	63	64	77	68	72	64	56	52	52	58	62
Janetville	37	43	38	39	42	46	44	43	40	38	36	37	40
King's Bay	24	20	21	20	33	40	37	38	35	25	20	27	28
Manorview	19	17	17	19	23	27	19	20	21	18	15	15	19
Mariposa Estates	28	26	23	26	31	35	35	32	38	31	24	26	30
Omemee	38	40	32	34	36	38	32	43	35	33	36	39	36
Pleasant Point	54	54	54	62	76	82	73	70	62	59	65	62	64
Sonya	26	25	26	28	33	40	39	39	29	28	27	27	31
Woods of Manilla	47	46	46	47	60	75	66	59	51	45	44	46	53
Woodfield	13	14	13	14	16	18	17	16	14	11	11	14	14
Victoria Place	85	80	78	92	95	93	95	89	90	85	81	85	87
Blackstock	104	105	103	106	122	138	115	114	108	108	103	102	110
Greenbank	134	136	126	125	143	156	144	138	131	127	124	127	134
Port Perry	2408	2323	2305	2411	2814	3255	3064	2955	2662	2511	2501	2421	2636
Minden	428	435	421	427	479	514	571	554	477	447	408	399	428
Lutterworth Pines[4]	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Otonabee-Peterborough Source Protection Area[2]													
Alpine Village/Pirates Glen	158	133	135	145	163	156	175	175	148	160	164	165	156
Birch Point Estates	89	101	93	90	90	92	103	109	107	124	93	83	98
Buckhorn Lake Estates	88	75	74	75	82	92	105	112	107	89	86	98	90
Crystal Springs	99	93	96	105	129	147	129	122	112	114	110	116	114
Keene Heights[5]	27	25	25	28	31	35	33	31	30	29	26	28	29
Millbrook	538	520	505	516	614	760	673	641	598	567	569	587	591
Norwood[6]	994	1074	1035	872	872	943	930	871	861	835	819	863	914
Pinewood	142	146	141	145	180	185	168	166	149	151	142	149	155
Crowe Valley Source Protection Area[3]													
Cardiff	158	157	169	180	181	185	190	203	157	142	148	150	169
Dyno Estates	14	11	12	12	13	13	14	15	12	11	9	10	12
Havelock	542	576	569	547	584	604	639	627	575	517	544	576	594
Lower Trent Source Protection Area													
Grafton	157	160	157	171	205	254	209	196	180	170	160	170	183
Brighton	2333	2337	2296	2423	2854	3215	3022	3140	2795	2336	2289	2238	2628
Colborne	864	884	819	818	939	1118	1169	1112	1041	958	890	840	954
Stirling	940	898	874	814	897	989	949	1015	910	884	835	895	912

[1] Expressed as a total of all wells in the system using the last 5 years of available data (unless otherwise noted)

Data sources: operating authorities (see Table 1)

[2] Calculated from 2004-2008 data except Alpine/Pirates Glen (2005-2008); Buckhorn Lake Estates (2005-2008); and Birch Point Estates (2006-2008)

[3] Calculated last 2 years of available data

[4] Because this system is so new, the actual taking data is not available

[5] Calculated for the former primary well (well #4) because the current primary well (well #1) is so new (2012), the actual taking data is not available

[6] For Wells #1, 2, and 3

5.2 WELLHEAD PROTECTION AREAS: DELINEATION & VULNERABILITY

One objective of source protection planning is to minimize the potential that land-based activities could contaminate groundwater resources that are used as sources of drinking water. The delineation of wellhead protection areas (WHPAs) and the assessment of groundwater vulnerability together describe how vulnerable water in a well is to contamination from these types of activities. This section is a description of the delineation of WHPAs and the assessment of vulnerability for the 32 groundwater systems identified in the *Terms of Reference* for the Trent source protection areas. This work was completed under several separate studies that are documented in the following background reports:

- *Assessment of Drinking Water Threats – Havelock Water Supply, Township of Havelock-Belmont-Methuen* (GENIVAR Consultants, April 2010)
- *Assessment of Drinking Water Threats – Creighton Heights and Camborne Municipal Wellfields, Township of Hamilton* (GENIVAR Consultants, June 2010)
- *Assessment of Drinking Water Threats – Municipal Residential Groundwater Supplies – The City of Kawartha Lakes (3 Volumes)* (GENIVAR Consultants, August 2010)
- *Assessment of Drinking Water Threats – Municipal Groundwater Supplies – The Regional Municipality of Durham* (August 2010)
- *Vulnerability, Issues and Threats for Fourteen Groundwater Sourced Municipal Drinking Water Systems in the Trent Conservation Coalition Source Protection Region* (XCG Consultants, July 2010)
    - *Appendix 1: Updated Wellfield Vulnerability analysis for the Keene Heights Wells* (Earthfx Incorporated, November 2013)
- *Vulnerability, Issues and Threats for One Planned Groundwater Sourced Municipal Drinking Water System in the Trent Conservation Coalition Source Protection Region* (XCG Consultants, July 2010)
- *Vulnerability, Issues and Threats for the new Lutterworth Pines Municipal Groundwater Sourced Drinking Water System* (XCG Consultants, January 2011)
- *Final Report: Norwood Municipal Wells Updated Modelling: Township of Asphodel-Norwood (D.M. Wills Associates Limited, November, 2018)*
- *Technical Memorandum re: Groundwater Vulnerability Assessment – Section 34 Update, (Azimuth Environmental Consulting, April 25, 2019)*
- *Updated Well Vulnerability Analysis for the Town of Stirling-Rawdon, Ontario (BluMetric Environmental, July 10, 2019)*
- *Canadiana Shores Drinking Water System Replacement Well (Cambium Inc., Oct 2019)*

This section is a summary of the relevant sections of these reports. Where changes to the *Technical Rules* were made after the completion of a study, or where additional information was received after completion of the study, the Assessment Report reflects the most recent data.

5.2.1 OVERVIEW OF REQUIREMENTS

The *Technical Rules* requires the following main tasks for each groundwater system:

- Delineation of wellhead protection areas (WHPAs)

- Groundwater vulnerability assessment
- Uncertainty analysis.

The requirements for each of these tasks are discussed in the following sections.

5.2.1.1 DELINEATION OF WELLHEAD PROTECTION AREAS

The following four wellhead protection areas must be delineated for each groundwater system listed in the *Terms of Reference*:

- WHPA-A: The area within a 100-metre radius from a wellhead
- WHPA-B: The area within which the time of travel to the well (within the aquifer) is up to and including 2 years (excluding WHPA-A)
- WHPA-C: The area within which the time of travel to the well (within the aquifer) is up to and including 5 years (excluding WHPA-A and WHPA-B)
- WHPA-D: The area within which the time of travel to the well (within the aquifer) is up to and including 25 years (excluding WHPA-A, WHPA-B, and WHPA-C).

A fifth wellhead protection area (WHPA-E) is delineated to include the area in and around the surface waterbody that is influencing a GUDI well. WHPA-E is delineated the same way as the Intake Protection Zone 2 for a surface water intake (see Section 4.2) from the point of interaction between the aquifer and the surface waterbody. If the point of interaction is not known, the WHPA-E is delineated from the point in the surface waterbody that is nearest to the well.

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

5.2.1.1.1 Calculation of Time of Travel

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

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

The time of travel was calculated for all of the existing municipal groundwater systems in the Trent source protection areas using computer based three-dimensional groundwater flow models. For the planned system, the uniform flow method was used. The information required to construct a representative groundwater flow model that will calculate time of travel includes the following:

- Types, thickness, geometry, and interrelationships among geologic layers
- Hydraulic properties of geologic layers (porosity & hydraulic conductivity)
- Rate of groundwater recharge

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

Hydraulic conductivity is a measure of the ease with which water can move through the pore spaces or fractures in soil

Permeability is the ability of a material to transmit a fluid; a measure of how quickly fluid will flow through the rock or sediment. Determined by the size of open spaces and the

- Interaction of groundwater with streams and lakes.

The availability and quality of this information vary significantly throughout the source protection region, and both generally increase from north to south.

The time of travel associated with WHPA-B through WHPA-D does not necessarily represent a time of travel from the ground surface to the well intake. In many cases, the time of travel associated with WHPA-B through WHPA-D represents the time of travel within the aquifer. The extent of the WHPA is projected vertically to the ground surface.

5.2.1.2 GROUNDWATER VULNERABILITY ASSESSMENT

The vulnerability of groundwater resources is largely measured by how quickly a contaminant can percolate vertically through geological layers and enter a flow pathway to the well. Vulnerability, therefore, corresponds directly to a contaminant's velocity through a geological layer. Where downward movement is impeded by a geological layer such as clay, the vulnerability decreases and where downward movement is facilitated by relatively permeable layers such as sand and gravel, the vulnerability increases.

The *Technical Rules* allows the use of the following four methods for the estimation of groundwater vulnerability:

Index Methods:

1. Intrinsic susceptibility index (ISI)
2. Aquifer vulnerability index (AVI)

Advection Time Methods:

3. Surface to aquifer advection time (SAAT)
4. Surface to well advection time (SWAT).

All of these methods rely on estimates of the thickness of geological layers and their hydraulic properties. The two index methods provide relative estimates of vulnerability independent of vertical groundwater flow directions and velocity. The index value is calculated as the overall sum of the thickness of each layer times a K-Factor for that layer. The vulnerability is then categorized as high, medium, or low according to the ranges of index values given in Table 5.2-1.

Table 5.2-1: Vulnerability using Index Methods

Index Value	Vulnerability
< 30	High
30 - 80	Medium
> 80	Low

Table 5.2-2: Vulnerability using Advection Time Methods

Travel Time from Ground Surface to Well	Vulnerability
< 5 years	High
5 – 25 years	Medium
> 25 years	Low

The two advection time methods generally require the use of computer modeling and consider the direction and velocity of groundwater between the ground surface and the well. This is a two-step process: first, the time of travel from the ground surface to the water table (unsaturated zone advection time – UZAT) is calculated, and then the time of travel from the water table to the well (SWAT) or water table to aquifer (SAAT) must be calculated. The time of travel estimated by the computer model is then used for the categorization of vulnerability according to the ranges of travel times given in Table 5.2-2.

5.2.1.2.1 Transport Pathways

It is recognized that land use can increase the natural vulnerability of groundwater by creating transport pathways between a contaminant source and the aquifer. Transport pathways include features such as groundwater wells, excavations, and utility trenches. The *Technical Rules* allows for a transport pathway to increase the groundwater vulnerability of an area from low to either medium or high, and from medium to high. The following factors must be used when considering a change in vulnerability:

- Hydrogeological conditions
- Type and design of any transport pathways
- Cumulative impact of any transport pathways
- Extent of any assumptions used in the assessment of the vulnerability of the groundwater.

5.2.1.3 VULNERABILITY SCORES

The ultimate vulnerability score in a wellhead protection area is determined by both time of travel and its vulnerability rating (high, medium, or low). Vulnerability scores are assigned to WHPA A-D for each of the three groundwater vulnerability ratings. The vulnerability scores assigned when using index methods are given in Table 5.2-3 and scores assigned when using advection time methods are given in Table 5.2-4.

Table 5.2-3: Wellhead Protection Area Vulnerability Scores – Index Methods

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	2

Table 5.2-4: Wellhead Protection Area Vulnerability Scores – Advection Time Methods

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	2	2

5.2.1.4 UNCERTAINTY ANALYSIS

Uncertainty is inherent in all aspects of time of travel calculations and vulnerability determinations. The Director's Technical Rules require that the uncertainty be categorized as either high or low based on the following criteria:

- The distribution, variability, quality, and relevance of the available input data
- The ability of the methods and models used to accurately reflect the hydrologic system
- The quality assurance and quality control procedures applied

- The extent and level of calibration and validation achieved for any groundwater and surface water models used or calculations and general assessments completed.

Uncertainty ratings are assigned to both wellhead protection area delineation and groundwater vulnerability assessment. The overall uncertainty for a municipal well system is the highest uncertainty rating assigned to the delineation of the wellhead protection area or the groundwater vulnerability assessment.

5.2.2 RESULTS FOR EXISTING MUNICIPAL SYSTEMS

5.2.2.1 SUMMARY OF ANALYSIS

5.2.2.1.1 Time of Travel Methods

The groundwater vulnerability studies for the existing municipal groundwater systems used a three-dimensional groundwater flow model to calculate time of travel. The models used were based on the MODFLOW model platform, which is one of the industry standards for constructing numerical groundwater flow models. MODFLOW uses a finite-difference method developed by the United States Geological Survey to simulate groundwater flow patterns. The numerical models take into consideration rainfall (recharge), interactions with surface water features, porosity of the geological unit, thickness of the geological unit, and ability of the geological unit to conduct water (hydraulic conductivity).

Considering all of these factors requires complex and repetitive analysis best undertaken by a computer. The models prepared in the Trent source protection areas try to simplify and reduce the Earth's layers and surface features in a digital three-dimensional space. The layers in the model are representative of the unconsolidated materials (sands, gravels, clay, etc.) and consolidated bedrock, such as granites and gneisses of the Precambrian Shield area and/or the limestones and shales of the Paleozoic era. Digital data availability in Ontario has improved considerably in the past 10 years with easy access to precipitation data, topographic data, geological data, and water well information. All these data are manipulated by geoscientists and engineers to best represent known and inferred conditions.

A total of 19 separate models were used to establish groundwater vulnerability for the 32 municipal well systems in the Trent source protection areas. More than one community was included in a model if the communities were close to each other and had similar geologic conditions.

5.2.2.1.2 Vulnerability Methods

Groundwater vulnerability was determined using both index methods and advective transport methods. The use of an index method over an advective transport method or vice versa is somewhat dictated by the availability of geological information and complexity of geology. For example, an index method is preferred in areas of limited information (i.e., wells) whereas areas with adequate information are better suited for an advective transport method. The index methods and advective transport methods were applied using assumptions and approaches that were consistent with the *Technical Rules* and that would result in over-protection of the groundwater source.

For the following systems, the aquifer vulnerability index method was applied by designating geological layers as either an aquifer or an aquitard and applying a K-Factor of 1 for an aquifer and 4 for an aquitard: Greenbank, Port Perry, Birch Point, Canadiana Shores, Janetville, King's Bay, Manorview, Mariposa Estates, Victoria Glen, Pleasant Point, Pinewood, Sonya, Victoria Place, Woodfield, and Woods of Manilla. This method is considered to be a conservative application of the method described in the Ministry of the Environment and Climate Change Guidance Modules, and it was necessary due to the minimal data available to describe the subsurface in the areas around many of the municipal wells. The application of this method resulted in lower index values and thus produced higher vulnerability ratings.

For the Stirling, Grafton, Colborne, Brighton, Keene Heights, Crystal Springs, and Millbrook systems, an application of the surface to well advection time (SWAT) was used to determine groundwater vulnerability. SWAT consists of two components: the vertical travel time through the unsaturated zone above the water table (UZAT) and the travel time from the water table to the well through the saturated zone (WWAT). Determining the time of travel through the unsaturated zone is highly complex and depends on a number of parameters that have high uncertainties related to their estimates (unsaturated hydraulic conductivity, soil moisture content, competence of confining units, etc.). Furthermore, surface releases of fluid contaminants (through spills or leaks) can locally saturate the soils and move downward through the unsaturated zone in hours or days rather than years. Thus, because of the uncertainties related to the estimation of the unsaturated zone above the water table (UZAT) and because of the relatively shorter travel time attributed to UZAT (as compared to WWAT), the UZAT was not factored into the calculation of the surface to well advection time (SWAT). SWAT volumes calculated by disregarding UZAT provide lower travel times and thus produce higher vulnerability ratings.

For the Blackstock drinking water system, an application of the surface to well advection time (SWAT) was used to determine groundwater vulnerability. SWAT consists of two components: the vertical travel time through the unsaturated zone above the water table (UZAT) and the travel time from the water table to the well screen through saturated aquifers and aquitards (WWAT). Though determining UZAT can be complicated, the sophisticated semi-integrated surface water flow model (PRMS) – groundwater flow model (MODFLOW) constructed for the Durham region, provided a means for rigorously estimating UZAT related parameters such as soil moisture content and infiltration rates. Therefore, groundwater vulnerability for the Blackstock drinking water system was determined by the application of the complete SWAT method.

The following sections summarize the results of the WHPA delineation, groundwater vulnerability assessment, and uncertainty analysis for each municipal well system.

5.2.2.2 CITY OF KAWARTHA LAKES MUNICIPAL RESIDENTIAL WELL SYSTEMS

The City of Kawartha Lakes operates the following 13 municipal residential well systems in the Trent source protection areas:

- Birch Point
- Canadiana Shores
- Janetville
- King's Bay
- Manorview
- Mariposa Estates
- Pinewood
- Pleasant Point
- Sonya
- Victoria Glen
- Victoria Place
- Woodfield
- Woods of Manilla.

Water is obtained for these systems from a total of 6 bedrock wells and 26 overburden wells. In this area, 7 of the 32 wells are deemed to be GUDI. These systems are summarized in Table 5.2-6 along with the groundwater flow models used to delineate each WHPA.

5.2.2.2.1 Wellhead Protection Area Delineation

A consistent WHPA delineation methodology was used for the groundwater systems in the City of Kawartha Lakes. Each WHPA was delineated using a three-dimensional groundwater flow model based on the MODFLOW 2000 simulation code. Six regional groundwater models were developed to delineate WHPAs for these municipal systems; these models are summarized in Table 5.2-5.

Where a sub-regional model was developed for more than one municipal well system, model refinements made to improve the calibration at each municipal well system were incorporated into the sub-regional model. The data source for the sub-regional models was either Version 2 (8 layer) or Version 2.1 (12 layer) of the CAMC-YPDT hydrostratigraphic model. No modifications to the models were made.

The WHPAs delineated for the municipal systems in the City of Kawartha Lakes are shown on Maps 5-1a through 5-13a (for WHPA A-D). For systems with GUDI wells, the WHPA-E is shown on the following maps: 5-2d (Canadiana Shores), 5-5d (Manorview), and 5-8d (Pleasant Point). Note that although well #3 in Sonya is considered to be GUDI, there is no surface water feature nearby to short-circuit contaminants to the relevant well. Therefore, in accordance with Technical Rule 49(3), this condition would preclude the use of WHPA-E for the Sonya well system.

Table 5.2-5: Summary of Regional Groundwater Models for City of Kawartha Lakes Systems

Regional Model	Municipal Well System(s)	Data Source
Woodville / Woods of Manilla	Woods of Manilla	CAMC-YPDT Version 2 (8 layer)
Southwest	Sonya Mariposa Estates King's Bay Pleasant Point Canadiana Shores	CAMC-YPDT Version 2.1 (12 layer)
South	Janetville Pinewood Woodfield Manorview	CAMC-YPDT Version 2 (8 layer)
East	Victoria Place Birch Point	CAMC-YPDT Version 2 (8 layer)
Victoria Glen	Victoria Glen	CAMC-YPDT Version 2 (8 layer)

5.2.2.2.2 2019 Pinewood Wellhead Protection Studies Updates

City of Kawartha Lakes amended Pinewood Drinking Water System by removing existing well #2 and Well #3 from the system and adding a new production well #5 to the drinking water system. It is to be noted that bot well #2 and well #3 extracts water from the upper aquifer, also known as Oak Ridges Moraine Aquifer Complex (ORAC), whereas the new production well #5 and existing well #4 are screened within the deep aquifer known as the Thorncliffe Aquifer Complex (TAC). Updated wellhead protection studies were completed in April 2019 for Pinewood Well System.

5.2 The consultant hired by the city postulated that original modelling scenario, where well #4 pumping at the maximum permitted (i.e. 587,520 L/day), essentially illustrates concentric rings emulating out of the pumping well (i.e. Well #4), representing the theoretical Theis' (1935) model solution for homogeneous, infinite-acting radial flow. They further postulated that a second deep well introduced in the model at the location of Well #5, pumped at 587,520 L/day, implicitly would yield the same set of concentric rings emulating out from

Well #5; and go on to state that by super positioning the WHPAs generated for Well #4 on to the position of Well #5, it is possible to obtain the maximum extent groundwater capture, regardless of whether pumping occurs from Well #4 or Well #5.

The composite WHPA incorporates the greatest combined extent for each time of travel zone by overlaying the capture zones for Well #4 and Well #5

The assumptions made by the city's consultant was supported by the technical staff of SPPB/MECP as per the e-mail addressed by the Liaison Officer to Otonabee-Peterborough SPA (May 31, 2019).

5.2.2.2.3 2019 Canadiana Shores Wellhead Protection Studies Updates

City of Kawartha Lakes amended Canadiana Shores Drinking Water System by removing existing supply well 1 from the system and replacing it with the replacement supply well 1 (Northing: 4896713 m; Easting: 73229 m). This replacement well 1 is located 8 m to the west of the existing supply well 1, thus shifting the WHPA-A for the new well 8 m westwards and thereby overlapping more with the WHPA-A of the other two supply wells.

Consultant hired by the city reviewed the previously conducted model study produced by GENIVAR Consultants LP in March 2010 and found that the replacement well 1 is applied to the same model grid as the existing supply well 1. It was also determined that the replacement well 1 is screened at the same geological unit as the existing supply well 1. Given the similarities in the well performance, water quality, and the fact that the pumping rates will remain the same in addition to the above assessment, the consultant concluded further modelling is not warranted to delineate WHPA B through E and vulnerability scoring.

5.2.2.2.4 Groundwater Vulnerability Assessment

An aquifer vulnerability index method was used to determine groundwater vulnerability for each of the 13 municipal systems in the City of Kawartha Lakes. Each of the 8 or 12 model layers was categorized as either an aquifer or an aquitard according to the designations developed for the Conservation Authorities Moraine Coalition in 2006. The aquifer vulnerability index was calculated as a sum of the thickness of each layer multiplied by a K-Factor of either 1 for an aquifer or 4 for an aquitard.

The presence of transport pathways identified in the WHPAs resulted in modifications to the vulnerability assignments of most of the municipal systems. The majority of the transport pathways identified in the City of Kawartha Lakes systems were private water wells. Transport pathways associated with aggregate extraction were identified in the WHPA for Mariposa Estates. Two criteria were used to trigger an increase in vulnerability rating. If a water well penetrated to within 3 metres of the aquifer, then the vulnerability of the area within 30 metres of the well was increased by one level. Or, if there was a cluster of 6 wells or more within a 100-metre radius, then the vulnerability of the cluster was increased by one level.

The results of the groundwater vulnerability assessments for municipal well systems in the City of Kawartha Lakes are shown on Maps 5-1a through 5-13a. The range of groundwater vulnerability ratings in the WHPAs delineated for these systems is given in Table 5.2-7.

5.2.2.2.5 2019 Pinewood Wellhead Protection Studies Updates

As per the original study (Genivar, March 2010), groundwater (vertical) vulnerability was assessed by calculating Aquifer Vulnerability Index (AVI) based on the CAMC/YPDT regional hydrostratigraphic interpretations. However, since well #2 and well #3 (upper aquifer wells) were removed from the system, only the AVI values pertinent to the deep aquifer (supporting well #4 and well 35) were considered in the vertical vulnerability assessment over the WHPA footprint.

5.2.2.2.6 2019 Canadiana Shores Wellhead Protection Studies Updates

The replacement well is screened within the same geological unit as the replaced well. Therefore, the aquifer vulnerability mapping remains unchanged due to the replacement well and as such no new delineations are warranted.

5.2.2.2.7 Vulnerability Scores

The range of vulnerability scores for municipal well systems in the City of Kawartha Lakes is given in Table 5.2-7 and is shown on Maps 5-1a through 5-13a.

5.2.2.2.8 Uncertainty Analysis

A detailed process to evaluate and assign data uncertainty ratings for each municipal well system was performed in the City of Kawartha Lakes. A 40-criterion rating system was applied to the water table aquifer, target aquifer, and other aquifers associated with the municipal well. The criteria included the following:

- Evaluation of number of data points
- Spatial distribution of data
- Accuracy of measured data
- Variability of data
- Availability of pumping test reports and soil reports
- Complexity of flow system and topographical variability
- Confined/unconfined nature of the aquifer
- Pumping rate
- Presence of fractured rock.

Uncertainty ratings were developed for the WHPA delineation and for the vulnerability analysis. In general, the uncertainty ratings were high. The uncertainty ratings are listed in Table 5.2-8.

Table 5.2-6: Summary of City of Kawartha Lakes Municipal Well Systems

System	Well	Aquifer Type	Geology	GUDI Status	Groundwater Flow Model
Birch Point	Well #3	confined to semi-confined	overburden	non-GUDI	East Sub-Regional
	Well #4	confined to semi-confined	overburden	non-GUDI	
Canadiana Shores	Replacement Well #1	unconfined to semi-confined	overburden	GUDI	Southwest Sub-Regional
	Well #2	unconfined to semi-confined	overburden	GUDI	
	Well #3	unconfined to semi-confined	overburden	GUDI	
Janetville	Well #3	confined	overburden	non-GUDI	South Sub-Regional
	Well #4	confined	overburden	non-GUDI	
	Well #5	confined	overburden	non-GUDI	
King's Bay	Well #1	confined to semi-confined	overburden	non-GUDI	Southwest Sub-Regional
	Well #2	confined to semi-confined	overburden	non-GUDI	
	Well #3	confined to semi-confined	overburden	non-GUDI	
Manorview	Well #1	semi-confined	overburden	GUDI	South Sub-Regional
	Well #2	semi-confined	overburden	GUDI	
Mariposa Estates	Well #2	confined to semi-confined	overburden	non-GUDI	Southwest Sub-Regional
	TW1-03	confined to semi-confined	overburden	non-GUDI	
Victoria Glen	Well #1	confined	overburden	non-GUDI	Victoria Glen
	Well #2	confined	overburden	non-GUDI	
Pleasant Point	Well #1	confined	overburden	GUDI	Southwest Sub-Regional
	Well #2	confined	overburden	GUDI	
Pinewood	~~Well #2~~	~~semi-confined~~	~~overburden~~	~~non-GUDI~~	South Sub-Regional
	~~Well #3~~	~~semi-confined~~	~~overburden~~	~~non-GUDI~~	
	Well #4	confined	overburden	non-GUDI	
	Well #5	confined	overburden	Non-GUDI	Principle of Superposition
Sonya	Well #1	confined to semi-confined	overburden	non-GUDI	Southwest Sub-Regional
	Well #3	confined to semi-confined	overburden	GUDI	
Victoria Place	Well #1	semi-confined	bedrock	non-GUDI	East Sub-Regional
	Well #2	semi-confined	bedrock	non-GUDI	
	Well #3	semi-confined	bedrock	non-GUDI	
	Well #7	semi-confined to confined	bedrock	non-GUDI	
Woodfield	Well #1	Confined	bedrock	non-GUDI	South Sub-Regional
	Well #2	confined	bedrock	non-GUDI	
Woods of Manilla	Well #1	confined	overburden	non-GUDI	Woodville/Woods of Manilla
	Well #2	confined	overburden	non-GUDI	

Table 5.2-7: Vulnerability Scores for City of Kawartha Lakes Municipal Residential Well Systems

System	Well(s)	Method [1]	Transport Pathways by WHPA[2]					Range of Groundwater Vulnerability Ratings by WHPA				Range of Vulnerability Scores by WHPA				
			A	B	C	D	E	A	B	C	D	A	B	C	D	E
Birch Point	All	AVI	-	-	-	-	N/A	High	High	High	High	10	10	8	6	N/A
Canadiana Shores	All	AVI	-	-	-	W	-	Med-high	Low-high	Low-high	Low-high	10	6-10	4-8	2-6	5.6
Janetville	All	AVI	-	-	-	-	N/A	Low	Low	Low	Low	10	6	4	2	N/A
King's Bay	All	AVI	-	-	-	-	N/A	Med-high	Med-high	Med-high	Med-high	10	8-10	6-8	4-6	N/A
Manorview	All	AVI	-	-	-	-	-	Med-high	Med-high	Med-high	Low-high	10	10	4-8	2-6	5.6
Mariposa Estates	Well #2	AVI	-	-	-	-	N/A	Med-high	Med-high	Med-high	Low-med	10	8-10	6-8	2-4	N/A
	TW1-03					W/Q	N/A	Med-high	Med-high	Med-high	Med-high	10	10	6-8	4-6	N/A
Victoria Glen	All	AVI	-	W	W	W	N/A	High	Med-high	Med-high	Med-high	10	8-10	6-8	4-6	N/A
Pleasant Point	Well #1	AVI	-	-	-	W	SUC	Med	Low-med	Low-med	Low-med	10	6-8	4-6	2-4	5.6
	Well #2	AVI	-	-	-	W	D	Med	Low-med	Low-med	Low-med	10	6-8	4-6	2-4	5.6
Pinewood	All	AVI	-	-	-	-	N/A	Low	Low	Low	Low	10	6	4	2	N/A
Sonya	All	AVI	-	-	W	W	N/A	Med-high	Medium	Med-high	Med-high	10	8	6-8	4-6	N/A
Victoria Place	All	AVI	-	-	-	-	N/A	High	High	High	High	10	10	8	6	N/A
Woodfield	All	AVI	-	W	-	W	N/A	Low	Low-med	Low	Low-med	10	6-8	4	2-4	N/A
Woods of Manilla	All	AVI	-		-	W	N/A	Low	Low	Low	Low-med	10	6	4	2-4	N/A

Table 5.2-8: Uncertainty Ratings for City of Kawartha Lakes Municipal Residential Well Systems

Groundwater System	Method[1]	Uncertainty Ratings for WHPA Delineation					Uncertainty Ratings for Assignment of Vulnerability					Final Uncertainty Rating				
		A	B	C	D	E	A	B	C	D	E	A	B	C	D	E
Birch Point	AVI	Low	High	High	High	N/A	Low	High	High	High	N/A	Low	High	High	High	N/A
Canadiana Shores	AVI	Low	High	High	High	High	Low	High	High	High	High	Low	High	High	High	High
Janetville	AVI	Low	High	High	High	N/A	Low	High	High	High	N/A	Low	High	High	High	N/A
King's Bay	AVI	Low	High	High	High	N/A	Low	High	High	High	N/A	Low	High	High	High	N/A
Manorview	AVI	Low	High	High	High	Low	Low	High	High	High	Low	Low	High	High	High	Low
Mariposa Estates	AVI	Low	High	High	High	N/A	Low	High	High	High	N/A	Low	High	High	High	N/A
Victoria Glen	AVI	Low	High	High	High	N/A	Low	High	High	High	N/A	Low	High	High	High	N/A
Pleasant Point	AVI	Low	High	High	High	Low	Low	High	High	High	Low	Low	High	High	High	Low
Pinewood	AVI	Low	High	High	High	N/A	Low	~~High~~ Low	~~High~~ Low	~~High~~ Low	N/A	Low	High	High	High	N/A
Sonya	AVI	Low	High	High	High	N/A	Low	High	High	High	N/A	Low	High	High	High	N/A
Victoria Place	AVI	Low	High	High	High	N/A	Low	High	High	High	N/A	Low	High	High	High	N/A
Woodfield	AVI	Low	High	High	High	N/A	Low	High	High	High	N/A	Low	High	High	High	N/A
Woods of Manilla	AVI	Low	High	High	High	N/A	Low	High	High	High	N/A	Low	High	High	High	N/A

[1]Indicates the method used to calculate groundwater vulnerability for the aquifer supplying the well (AVI = Aquifer Vulnerability Index)
[2]W = Well; Q = Quarry; SUC = Subsurface Utility Corridor; D = Ditch (dashes indicate no transport pathways)

5.2.2.3 REGION OF DURHAM MUNICIPAL WELL SYSTEMS

The Region of Durham operates three municipal well systems in the Trent source protection areas: Blackstock, Greenbank, and Port Perry. Each of these well systems obtains water from overburden sediments, and none of the wells are deemed to be GUDI (groundwater under the direct influence of surface water).

5.2.2.3.1 Wellhead Protection Area Delineation

Region of Durham has recently developed semi-integrated surface water flow model (PRMS) – groundwater flow model (MODFLOW) covering their entire region (SSPA & GPRA; June 2021). This updated 3-D numerical, semi-integrated, surface-groundwater flow model was used to delineate the wellhead protection areas (WHPAs) for the amended Blackstock drinking water system. However, WHPAs for the Port Perry and Greenbank drinking water systems were delineated in 2003 using system based 3D numerical groundwater flow model (MODFLOW). Both modelling approaches used different versions of CAMC-YPDT hydrostratigraphic interpretations (~~December~~ 2003 and 2018) and the Ministry of the Environment and Climate Change Water Well Information System as data sources. The WHPAs developed for the municipal systems in the Region of Durham are shown on Maps 5-14a through 5-16a.

5.2.2.3.2 Groundwater Vulnerability Assessment

An aquifer vulnerability index method was used to determine groundwater vulnerability for each of the municipal systems in the Region of Durham. Each of the model layers was categorized as either an aquifer or an aquitard according to the designations developed for the Conservation Authorities Moraine Coalition in December 2007. The aquifer vulnerability index was calculated as the sum of the thickness of each layer multiplied by a K-Factor of either 1 for an aquifer or 4 for an aquitard. However, as mentioned before (5.2.1.1.1), surface to well advection time (SWAT) estimated through the semi-integrated surface water flow – groundwater flow models were used to assess the groundwater vulnerability for the amended Blackstock drinking water system.

The presence of transport pathways identified in the WHPAs resulted in modifications to the vulnerability assignments of most of the municipal systems. The only transport pathways identified in the Region of Durham systems were private water wells. Two criteria were used to trigger an increase in vulnerability rating: if a water well penetrated to within 3 metres of the aquifer, then the vulnerability of the area within 30 metres of the well was increased by 1 level; if there was a cluster of 6 wells or more within a 100-metre radius, then the vulnerability of the cluster was increased by one level.

In the case of amended Blackstock DWS, only the wells that were installed before 1998 and are within or below the MW7/MW8 aquifer were deemed to be transport pathways (WSP, August 2021). As mentioned before, in this case, the vulnerability of the area within 30 metres of these wells was increased by one level.

The results of the groundwater vulnerability assessment for the municipal well systems in the Region of Durham are shown on Maps 5-14a through 5-16a. The range of groundwater vulnerability ratings in the WHPAs delineated for these systems is given in Table 5.2-9.

5.2.2.3.3 Vulnerability Scores

The range of vulnerability scores assigned to the WHPAs delineated for the municipal groundwater systems in the Region of Durham is given in Table 5.2-9 and is shown on Maps 5-14a through 5-16a.

5.2.2.3.4 Uncertainty Analysis

A detailed process was used to evaluate and assign uncertainty ratings for each municipal well system in the Region of Durham. A 40-criteria rating system was applied to the water table aquifer, target aquifer, and other aquifers associated with the municipal well that included the following criteria:

- Evaluation of number of data points
- Spatial distribution of data
- Accuracy of measured data
- Variability of data
- Availability of pumping test reports & soil reports
- Complexity of flow system & topographical variability
- Confined/unconfined nature of the aquifer
- Pumping rate
- Presence of fractured rock

Uncertainty ratings were assigned to the WHPA delineation and for the vulnerability analysis. The ratings are summarized in Table 5.2-10. All of the wells for the Greenbank and Port Perry systems were assigned a low uncertainty.

As per the 2017 Technical Rules, the following factors were considered in the uncertainty assessment relating to the delineation of wellhead protection areas and the groundwater vulnerability scoring (SSPA &GPRA, 2021).

- Distribution, variability, quality and relevance of data used in the analyses.
- Ability of the methods and models used to accurately reflect the flow processes in the hydrological system.
- Quality assurance and quality control procedures applied.
- The extent and level of calibration and model testing achieved for model calculations or assessments completed.
- The accuracy to which the groundwater vulnerability categories effectively assess the relative vulnerability of the underlying hydrogeological features.

An overall low uncertainty rating is assigned for the delineation of the WHPAs for the Blackstock DWS. Furthermore, an overall low uncertainty rating is assigned for the Blackstock groundwater vulnerability scoring.

Table 5.2-9: Vulnerability Scores for Region of Durham Municipal Well Systems

System	Well	Method[1]	Transport Pathways By WHPA[2]				Range of Groundwater Vulnerability Ratings by WHPA				Range of Vulnerability Scores By WHPA			
			A	B	C	D	A	B	C	D	A	B	C	D
Blackstock	MW7	AVI	-	-	-	W	Low	Low	Low	Low	10	6	2	2-4
	MW8	AVI	-	-	-	W	Low	Low	Low	Low	10	6	2	2-4
Greenbank	MW1	AVI	-	-	-	-	Low-med	Low-med	Low-med	Low-med	10	6-8	4-6	4
	MW3	AVI	-	-	-	-	Low-med	Low-med	Low	Low	10	6-8	4	2
	MW4	AVI	-	-	-	-	Low	Low	Low	Low	10	6	4	2
	MW5	AVI	-	-	-	-	Low	Low	Low	Low	10	6	4	2
	MW6	AVI	-	-	-	-	Low	Low	Low	Low-med	10	6	4	2-4
Port Perry	MW3	AVI	-	-	W	W	Low	Low	Low	Low	10	6	4-6	2-4
	MW5	AVI	-	-	W	W	Low	Low	Low	Low	10	6	4-6	2-4
	MW6	AVI	-	-	W	W	Low	Low	Low	Low	10	6	4-6	2-4

Table 5.2-10: Uncertainty Ratings for Region of Durham Municipal Well Systems

System	Well	Method[1]	Uncertainty Ratings for WHPA Delineation				Uncertainty Ratings for Assignment of Vulnerability				Final Uncertainty Rating			
			A	B	C	D	A	B	C	D	A	B	C	D
Blackstock	MW7	AVI	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low
	MW8	AVI	Low	Low	Low	low	Low	Low	Low	Low	Low	Low	Low	Low
Greenbank	MW1	AVI	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low
	MW3	AVI	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low
	MW4	AVI	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low
	MW5	AVI	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low
	MW6	AVI	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low
Port Perry	MW3	AVI	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low
	MW5	AVI	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low
	MW6	AVI	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low

[1]Indicates the method used to calculate groundwater vulnerability for the aquifer supplying the well (ISI = Intrinsic Susceptibility Index; AVI = Aquifer Vulnerability Index)

[2]W = Well (dashes indicate no transport pathways)

5.2.2.4 NORTHERN GROUNDWATER SYSTEMS

The northern groundwater systems include the municipal residential groundwater supplies for the municipalities of Minden Hills, Highlands East, Galway-Cavendish & Harvey, and Asphodel-Norwood. These municipalities include 7 groundwater systems that consist of a total of 11 wells. Water for these wells is obtained from a variety of geological settings. The northern groundwater systems are summarized in Table 5.2-11.

Table 5.2-11: Summary of Northern Groundwater Systems

System	Well	Aquifer Type	Geology	GUDI Status	Groundwater Flow Model
Alpine Village	Well #1	unconfined	bedrock	non-GUDI	Alpine Village
	Well #2	unconfined	bedrock	non-GUDI	
Buckhorn Lake Estates	Well #1	unconfined	bedrock	GUDI	Buckhorn Lake Estates
Cardiff	Well #1	unconfined	overburden	GUDI	Cardiff
Dyno Estates	Well #1	confined	overburden	non-GUDI	Dyno Estates
Lutterworth Pines[1]	Well #1	unconfined	bedrock	non-GUDI	Lutterworth Pines
	Well #2	unconfined	bedrock	non-GUDI	
Minden	Well #1	confined	overburden	non-GUDI	Minden
	Well #2	confined	overburden	non-GUDI	
Norwood	Well #1b	unconfined	bedrock	non-GUDI	Norwood
	Well #2	unconfined	overburden	non-GUDI	
	Well #3	unconfined	overburden	non-GUDI	
	Well #4	unconfined	overburden	non-GUDI	

[1]Refers to the new Lutterworth Pines well system, which came online on March 15, 2010

5.2.2.4.1 Wellhead Protection Area Delineation

Each WHPA was delineated with a three-dimensional groundwater flow model using a version of the MODFLOW simulation code. Seven individual groundwater models were developed to delineate WHPAs for the municipal systems. All of the models used the Ministry of the Environment and Climate Change Water Well Information System database as a data source.

The consultants' approach for all of the northern groundwater site models was to use the provincially supplied surfaces (bedrock topography from the Ministry of Northern Development and Mines and a digital elevation model from the Ministry of Natural Resources and Forestry) and high resolution GIS layers (bedrock and Quaternary geology from the Ministry of Northern Development and Mines), as well as the interpolated water table and potentiometric surfaces. Once a conceptual subsurface model of the area was determined, the model space was defined and the surface layers were used to create the three-dimensional groundwater flow model. Locations of surface waterbodies were mapped as constant head boundaries within the groundwater flow model.

The consultants believe that the use of interpolated surfaces and provincially supplied data layers to define the properties of a three-dimensional groundwater flow model provides a higher level of understanding of subsurface condition as compared to earlier studies. The use of a three-dimensional groundwater flow model also provides an opportunity for continuous improvement as new and improved data become available.

The WHPAs delineated for the northern groundwater systems are shown on Maps 5-17a through 5-23a (for WHPA A-D). For systems with GUDI wells, the WHPA-E is shown on Map 5-18d (Buckhorn Lake Estates) and Map 5-19d (Cardiff).

Since the rationale behind the shape of the delineated WHPA for the Cardiff, Dyno Estates, and Lutterworth Pines drinking water systems may not be easily understood, additional explanation for these systems is provided in the following sections.

Furthermore updated wellhead protection studies were completed in 2018 for Norwood Municipal Well System. Two new wells Well 1B and Well 4 were recently drilled and tested and will be connected to system; whereas, existing Well 1 will be decommissioned. Relevant updates to this study is provided under the “2018 Norwood Wellhead Protection Studies Updates”.

5.2.2.4.2 Cardiff

Data used in the stratigraphic model development, in the form of well records, in the area of Cardiff are quite limited. The locations of the boreholes or wells in the Cardiff model area are shown on Figure 5.2-1. Due to the sparse borehole/well information within large parts of the model area, a formal calibration (through the use of calibration statistics) of the model was not attempted. Rather, a best fit of predicted heads to the interpolated potentiometric surface layer, along with a converging model with 2% discrepancy in the overall water budget of the model, was considered sufficient for calibration. Further, there are no flow records available for Mink Creek (the creek flowing within the wellhead) for calibrating the predicted groundwater discharge to the base flow observed in the creek.

The unconfined aquifer from which the Cardiff well draws water is quite limited in extent due to the local geological conditions. The well is located in a bedrock depression and is surrounded by bedrock outcrops. It is recharged mostly through localized precipitation rather than regional groundwater flow. The pumping rate of the well is also relatively very low. The shape of the WHPA reflects the above circumstances. The 2- and 5-year time of travel (WHPA-B and C) extend northwards from the well in the direction of the regional groundwater flow; this is consistent with the interpolated water table and potentiometric surfaces that closely follow the topography of the area. The 25-year time of travel extends further to the north, east, and slightly south, indicating localized recharge and the bedrock depression in which the Cardiff well is located.

The increased localized hydraulic conductivities, as evidenced in Figure 5.2-2, illustrate the localized recharge area very well with an almost classic “circular” WHPA delineation. The aquifer layers were “pinched out” beyond the localized recharge area due to the bedrock outcropping to the north and south.

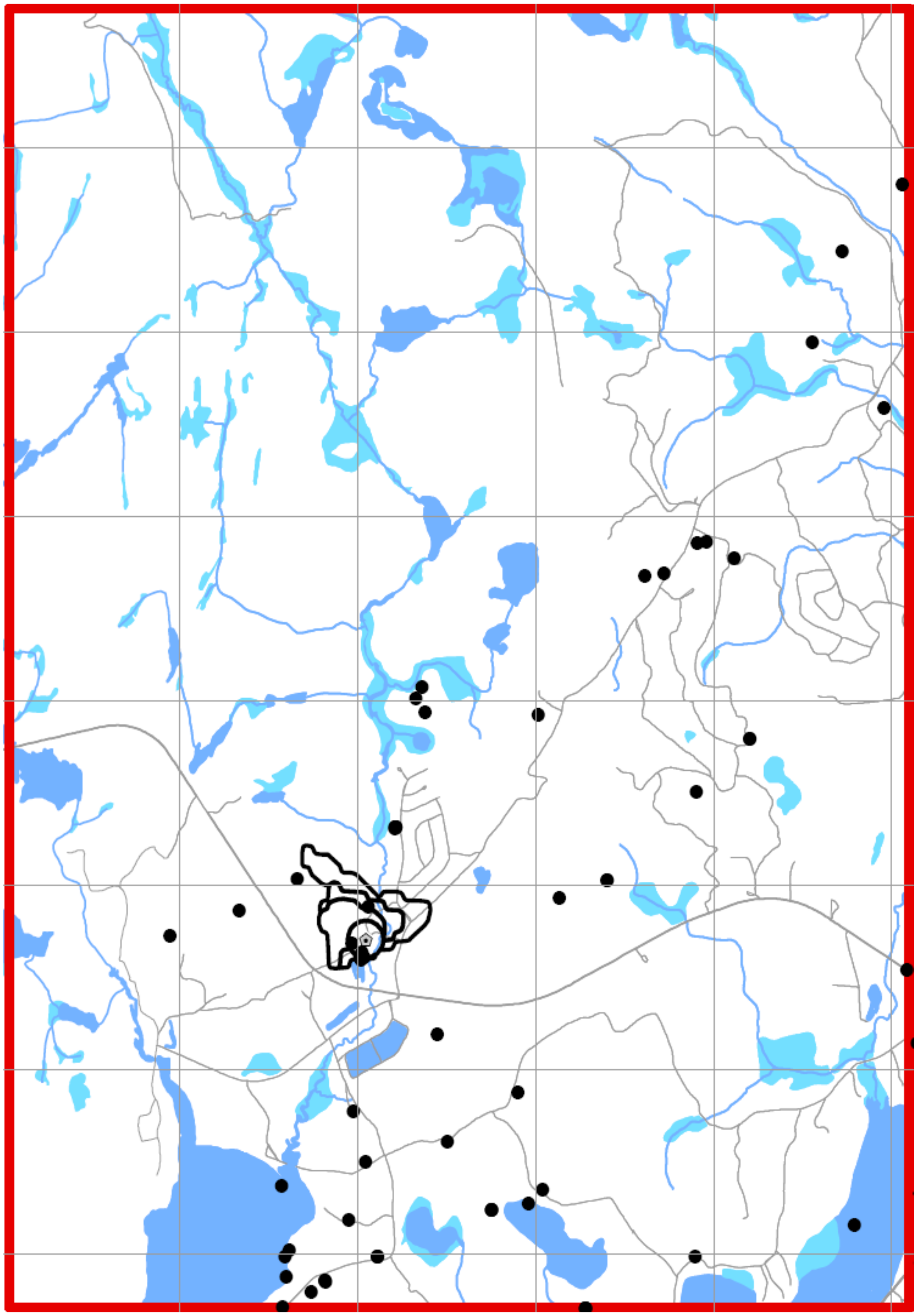

Figure 5.2-1: Boreholes in the Cardiff Model Area

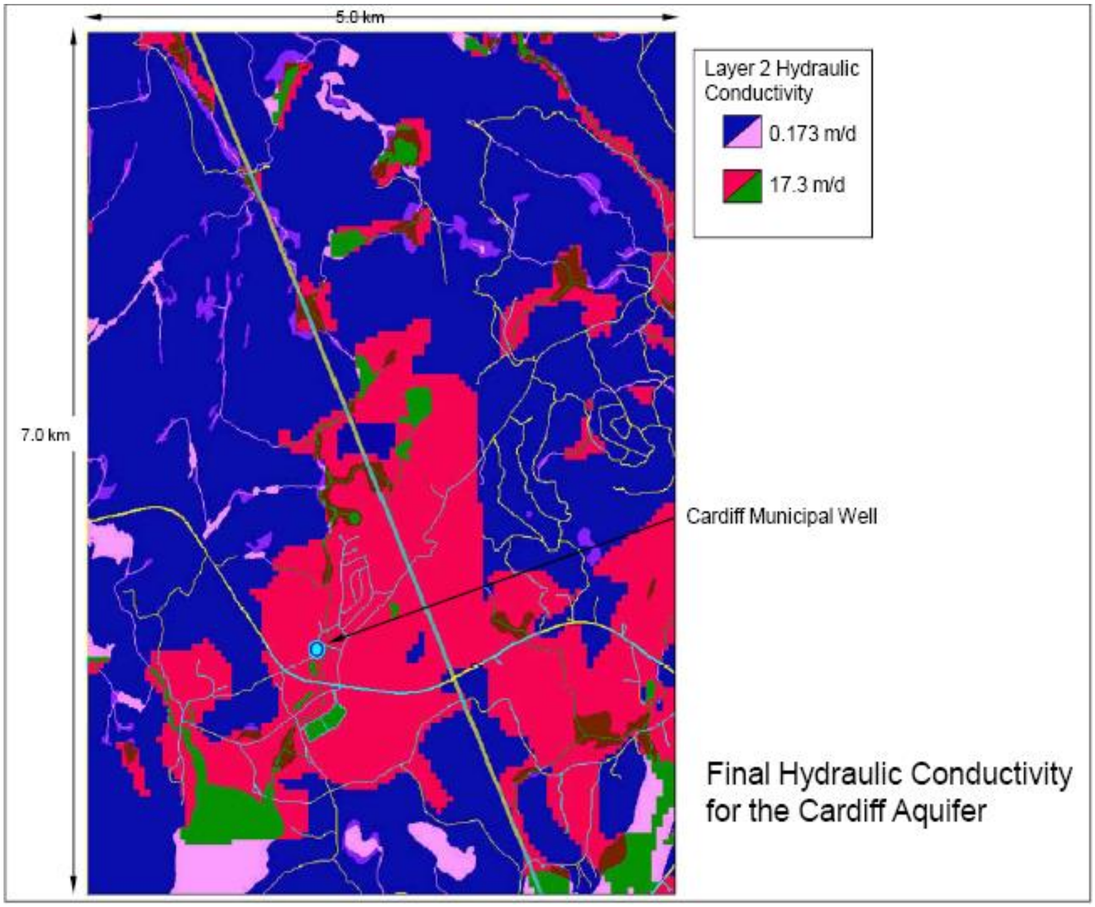

Figure 5.2-2: Hydraulic Conductivity for Cardiff Aquifer

5.2.2.4.3 Dyno Estates

Well record data in the area of Dyno Estates are quite limited. The locations of boreholes and wells in the Dyno Estates model area are shown on Figure 5.2-3.

Data used in the stratigraphic model development, in the form of well records, in the area of Dyno Estates are quite limited. The locations of the boreholes or wells in the Dyno Estates model area are shown on Figure 5.2-13. Due to the sparse borehole/well information within large parts of the model area, a formal calibration (through the use of calibration statistics) of the model was not attempted. Rather, a best fit of predicted heads to the interpolated potentiometric surface layer, along with a converging model with 2% discrepancy in the overall water budget of the model, was considered sufficient for calibration. Further, there are no flow records available for nearby surface waterbodies for calibrating the predicted groundwater discharge to the base flow observed.

In the Dyno Estates model, the surface waterbodies of Paudash Lake and Eels Lake provide constant head boundaries, while large Precambrian bedrock outcrops, such as the one in the southeastern portion of the model area, represent areas of very low hydraulic conductivity. The potentiometric and water table surfaces followed the general topography of the area with high points to the east and west and a bedrock trough running somewhat north and south. The groundwater flow is in a northwest to southeast direction in the vicinity of the Dyno Estates well.

In the immediate vicinity of the well, there are subsurface zones represented by both high and low hydraulic conductivities. The ground moraine and glacial outwash represent the higher conductivity zones while the bog to the west of the well represents a low conductivity zone and thus reduces the contributions from this area directly near the well.

With the very low withdrawal rates from the well, the extent of the 25-year time of travel is not much beyond the 100-metre radius for the WHPA-A. Thus the actual delineation of the 2- and 5-year time of travel zones is somewhat unorthodox. The irregular shapes of the various zones represent smoothed lines around the 50-metre x 50-metre grid squares of the model.

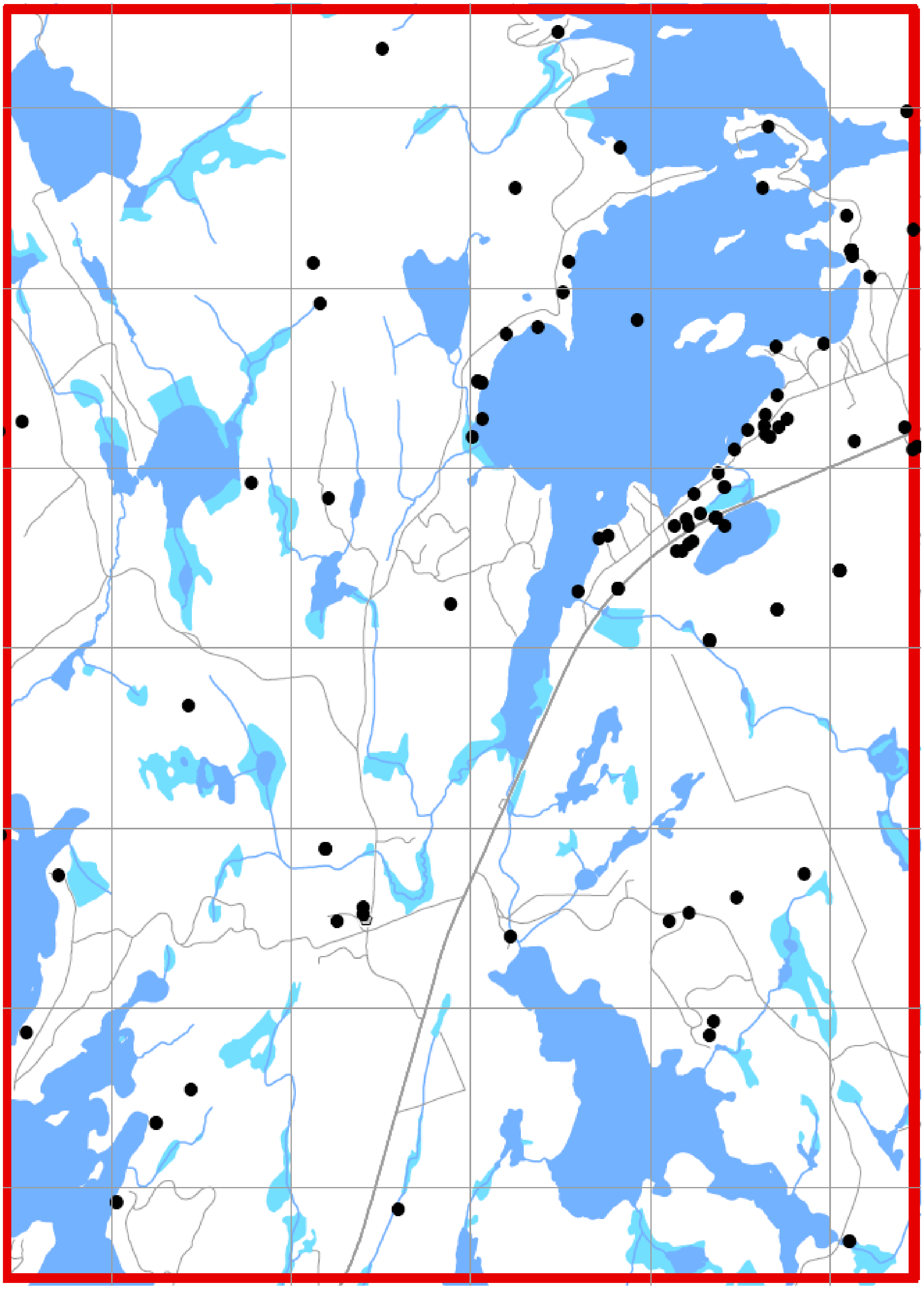

Figure 5.2-3: Boreholes in the Dyno Estates Model Area

5.2.2.4.4 Lutterworth Pines

Note that due to the low withdrawal rate from the well, the WHPA-A for the Lutterworth Pines drinking water system fully encompasses the WHPA-B (distance of 2-year time of travel), so the WHPA-B was not delineated for this system.

5.2.2.4.5 2018 Norwood Wellhead Protection Studies Updates

The existing 1-layer groundwater flow model constructed in MODFLOW-96 was updated to a 4-layer model in MODFLOW-2005. Municipal wells 1, 2, and 3 plus new wells 4, and 1B were added to the model. The grid extents were the same as the previous model, but was refined in the area of municipal wells to approx. 6m x 7m, in order to obtain a high resolution in the area of wells. Changes were also made to recharge, open water, and river boundary conditions.

The current model was calibrated to simulate 1993 pumping tests and 2018 step tests. Hydraulic conductivities derived from the 2018 hydrological review (Rannie 2018) were incorporated into the model. Pumping and step tests were simulated well providing confidence that the model adequately represents subsurface conditions. Subsequently, capture zones/WHPAs were generated through the traditional reverse particle track approach for two scenarios where Well 1B or Well 4 was pumped along with Wells 2 and 3 at their maximum allowed rates up to a maximum approved total flow of 1,965 m^3/d.

5.2.2.4.6 Groundwater Vulnerability Assessment

The intrinsic susceptibility index method was used to evaluate the vulnerability of municipal well systems with unconfined aquifers (Lutterworth Pines, Cardiff, Norwood, Buckhorn Estates, and Alpine Village), and the aquifer vulnerability index method was used to evaluate the vulnerability of municipal well systems with confined aquifers (Minden and Dyno Estates).

The presence of transport pathways resulted in the adjustment of vulnerability ratings in Minden. The transport pathways identified in Minden are the marble quarry at Workman's Falls and utility service trenches. The municipal well systems in Lutterworth Pines, Norwood, Buckhorn Estates, Alpine Village, Cardiff, and Dyno Estates are categorized with a high vulnerability and therefore no adjustment was made for transport pathways (i.e., the vulnerability rating cannot be increased above high).

The results of the groundwater vulnerability assessments for the seven northern groundwater systems are shown on Maps 5-17a through 5-23a. The range of groundwater vulnerability ratings in the WHPAs delineated for these systems is given in Table 5.2-14.

5.2.2.4.7 2018 Norwood Wellhead Protection Studies Updates

Aquifer vulnerability was assessed using the groundwater flow model and forward particle track approach to generate water table to well advection times (WWAT); which were then added to unsaturated zone advection time (UZAT) to obtain surface to well advection times (SWAT) over the updated WHPAs. The delineated SWAT contours were reclassified as < 1825 days (high vertical vulnerability), > 1825 days and <9125 days (medium vertical vulnerability), and > 9126 days (low vertical vulnerability) in order to assess vertical aquifer vulnerability over the WHPA footprint.

5.2.2.4.8 Vulnerability Scores

The range of vulnerability scores assigned to the WHPAs in the seven northern groundwater systems is given in Table 5.2-14 and shown on Maps 5-17a through 5-23a.

5.2.2.4.9 Uncertainty Analysis

Uncertainty ratings were assigned to the delineation and groundwater vulnerability assessment for the WHPAs in the seven northern groundwater systems. The ratings and justification for the assignment of these ratings are given in Table 5.2-12 and Table 5.2-13.

Table 5.2-12: Uncertainty Ratings for WHPA Delineation (Northern Groundwater Systems)

Area	Uncertainty Rating	Justification
WHPA-A	Low	• Well location was confirmed with GPS • 100-metre radius delineation was drawn
WHPA-B WHPA-C WHPA-D	High	• Limited field data for calibration • Literature values for K and leakance • Unknown impacts of adjacent surface waters • Limitations of 3D models
WHPA-E	High	• Desk top analysis only – no numerical models • No field measurements or observations • No specific information on Mink Creek flows or cross-sections • Regional wind used for lake systems

Table 5.2-13: Uncertainty Ratings for Groundwater Vulnerability Assessment (Northern Groundwater Systems)

Area	Uncertainty Rating	Justification
WHPA-A	Low	Prescribed vulnerability
WHPA-B WHPA-C WHPA-D	High	Data are through interpolations of Ministry of the Environment and Climate Change Water Well Records database
WHPA-E	Low	Regional Approach to scoring limited available options

Table 5.2-14: Vulnerability Scores for Minden Hills, Highlands East, Galway-Cavendish and Harvey, and Asphodel-Norwood Municipal Well Systems

System	Well	Method[1]	Transport Pathways By WHPA[2]					Range of Groundwater Vulnerability Ratings by WHPA				Range of Vulnerability Scores By WHPA				
			A	B	C	D	E	A	B	C	D	A	B	C	D	E
Alpine Village	Well #1	ISI	-	-	-	-	-	High	High	High	High	10	10	8	6	N/A
	Well #2	ISI	-	-	-	-	-	High	High	High	High	10	10	8	6	N/A
Buckhorn Lake Estates	Well #1	ISI	-	-	-	-	-	High	High	High	High	10	10	8	6	8.0
Cardiff	Well #1	ISI	-	-	-	-	-	High	High	High	High	10	10	8	6	7.0
Dyno Estates	Well #1	AVI	-	-	-	-	-	High	High	High	High	10	10	8	6	N/A
Lutterworth Pines[3]	Well #1	ISI	-	N/A	-	-	-	High	N/A	High	High	10	N/A	8	6	N/A
	Well #2	ISI	-	N/A	-	-	-	High	N/A	High	High	10	N/A	8	6	N/A
Minden	Well #1	AVI	-	SUC	SUC	SUC/Q	-	Low-High	Low-high	Low-high	Low-high	10	6-10	4-8	2-6	N/A
	Well #2	AVI	-	SUC	SUC	SUC/Q	-	Low-High	Low-high	Low-high	Low-high	10	6-10	4-8	2-6	N/A
Norwood	Well #1B	SWAT	-	-	-	-	N/A	Medium	Low-High	Medium	Low-High	10	10, 8, 6	6	6, 4, 2	N/A
	Well #2	SWAT	-	-	-	-	N/A	Medium	Low-High	Medium	Low-High	10	10, 8, 6	6	6, 4, 2	N/A
	Well #3	SWAT	-	-	-	-	N/A	Medium	Low-High	Medium	Low-High	10	10, 8, 6	6	6, 4, 2	N/A
	Well #4	SWAT	-	-	-	-	N/A	Medium	Low-High	Medium	Low-High	10	10, 8, 6	6	6, 4, 2	N/A

Table 5.2-15: Uncertainty Ratings for Minden Hills, Highlands East, Galway-Cavendish and Harvey, and Asphodel-Norwood Municipal Well Systems

System	Well	Method[1]	Uncertainty Ratings for WHPA Delineation					Uncertainty Ratings for Assignment of Vulnerability					Final Uncertainty Rating				
			A	B	C	D	E	A	B	C	D	E	A	B	C	D	E
Alpine Village	Well #1	ISI	Low	High	High	High	High	Low	High	High	High	Low	Low	High	High	High	N/A
	Well #2	ISI	Low	High	High	High	High	Low	High	High	High	Low	Low	High	High	High	N/A
Buckhorn Lake Estates	Well #1	ISI	Low	High	High	High	High	Low	High	High	High	Low	Low	High	High	High	High
Cardiff	Well #1	ISI	Low	High	High	High	High	Low	High	High	High	Low	Low	High	High	High	High
Dyno Estates	Well #1	AVI	Low	High	High	High	N/A	Low	High	High	High	N/A	Low	High	High	High	N/A
Lutterworth Pines[3]	Well #1	ISI	Low	N/A	High	High	N/A	Low	N/A	High	High	N/A	Low	N/A	High	High	N/A
	Well #2	ISI	Low	N/A	High	High	N/A	Low	N/A	High	High	N/A	Low	N/A	High	High	N/A
Minden	Well #1	AVI	Low	High	High	High	N/A	Low	High	High	High	N/A	Low	High	High	High	N/A
	Well #2	AVI	Low	High	High	High	N/A	Low	High	High	High	N/A	Low	High	High	High	N/A
Norwood	Well #1B	SWAT	Low	Low	Low	High	N/A	Low	Low	Low	High	N/A	Low	Low	Low	High	N/A
	Well #2	SWAT	Low	Low	Low	High	N/A	Low	Low	Low	High	N/A	Low	Low	Low	High	N/A
	Well #3	SWAT	Low	Low	Low	High	N/A	Low	Low	Low	High	N/A	Low	Low	Low	High	N/A
	Well #4	SWAT	Low	Low	Low	High	N/A	Low	Low	Low	High	N/A	Low	Low	Low	High	N/A

[1]Indicates the method used to calculate groundwater vulnerability for the aquifer supplying the well (ISI = Intrinsic Susceptibility Index; AVI = Aquifer Vulnerability Index)
[2]SUC = Subsurface Utility Corridor; Q = Quarry (dashes indicate no transport pathways)
[3]WHPA-B (distance of two-year time of travel) is not delineated for this system because it falls entirely within the WHPA-A (100-m radius around well)

5.2.2.5 HAVELOCK-BELMONT-METHUEN MUNICIPAL WELL SYSTEM

The Township of Havelock-Belmont-Methuen region operates one municipal well system in the community of Havelock. This system consists of three wells that draw water from unconfined bedrock aquifers. All three wells are considered to be GUDI (groundwater under the direct influence of surface water).

5.2.2.5.1 Wellhead Protection Area Delineation

Wellhead protection areas were delineated for the community of Havelock municipal wells using a three-dimensional computer groundwater model based on the MODFLOW simulation code. The model was comprised of two overburden layers and one bedrock layer. The data source used to develop this model was the Ministry of the Environment and Climate Change Water Well Information System (WWIS) database. The WHPAs delineated for the Havelock municipal groundwater system are shown on Map 5-24b (for WHPA A-D) and on Map 5-24d (for WHPA-E).

5.2.2.5.2 Groundwater Vulnerability Assessment

Groundwater vulnerability for the Havelock system was determined using the aquifer vulnerability index method. No adjustments to the vulnerability were made due to transport pathways, because the vulnerability rating is high in much of the delineated WHPA (i.e., the vulnerability rating cannot be increased beyond high).

The results of the groundwater vulnerability assessment for the Havelock municipal groundwater systems are shown on Map 5-24a. The range of groundwater vulnerability ratings in the WHPAs delineated for these systems is given in Table 5.2-16.

5.2.2.5.3 Vulnerability Scores

The range of vulnerability scores assigned to the WHPAs delineated for the Havelock municipal well system is given in Table 5.2-16 and shown on Map 5-24a.

5.2.2.5.4 Uncertainty Analysis

A detailed process to evaluate and assign uncertainty ratings was carried out for the municipal well system in Havelock. A 40-criteria rating system was applied to the water table aquifer, target aquifer, and other aquifers associated with the municipal well. The criteria included the following:

- Evaluation of number of data points
- Spatial distribution of data
- Accuracy of measured data
- Variability of data
- Availability of pumping test reports and soil reports
- Complexity of flow system and topographical variability
- Confined/unconfined nature of the aquifer
- Pumping rate
- Presence of fractured rock.

Uncertainty ratings were assigned for the WHPA delineation and for the groundwater vulnerability analysis. The ratings are summarized in Table 5.2-17. The final uncertainty rating for the Havelock municipal wells is high as a result of a limited number of wells available to assess vulnerability.

Table 5.2-16: Vulnerability Scores for Havelock Well System

System	Well	Method[1]	Transport Pathways By WHPA[2]					Range of Groundwater Vulnerability Ratings by WHPA				Range of Vulnerability Scores By WHPA				
			A	B	C	D	E	A	B	C	D	A	B	C	D	E
Havelock	Well #1	AVI	-	-	-	-	-	High	Med-high	Med-high	Med-high	10	8-10	4-8	4-6	7.2
	Well #3	AVI	-	-	-	-	-	High	Med-high	Med-high	Med-high	10	8-10	4-8	4-6	7.2
	Well #4	AVI	-	-	-	-	-	High	Med-high	Med-high	Med-high	10	8-10	4-8	4-6	7.2

Table 5.2-17: Uncertainty Ratings for Havelock Well System

System	Well	Method[1]	Uncertainty Ratings for WHPA Delineation					Uncertainty Ratings for Assignment of Vulnerability					Final Uncertainty Rating				
			A	B	C	D	E	A	B	C	D	E	A	B	C	D	E
Havelock	Well #1	AVI	Low	High	High	High	High	Low	High	High	High	High	Low	High	High	High	High
	Well #3	AVI	Low	High	High	High	High	Low	High	High	High	High	Low	High	High	High	High
	Well #4	AVI	Low	High	High	High	High	Low	High	High	High	High	Low	High	High	High	High

[1]Indicates the method used to calculate groundwater vulnerability for the aquifer supplying the well (AVI = Aquifer Vulnerability Index)
[2]Dashes indicate no transport pathways

5.2.2.6 CAVAN MONAGHAN & OTONABEE-SOUTH MONAGHAN MUNICIPAL WELL SYSTEMS

The Townships of Cavan Monaghan and Otonabee-South Monaghan operate three existing municipal well systems: Crystal Springs, Keene Heights, and Millbrook. These systems were studied together because of the similarity in their geologic and hydrogeologic settings. They include a total of seven wells that are all located in confined overburden aquifers. Both wells in the Crystal Springs system are considered to be GUDI (groundwater under the direct influence of surface water).

In November 2013, the model for Keene Heights was updated as a result of the construction of a new well in 2012. The new well (well #1) will act as the primary water supply for the Keene Heights Subdivision, and the older well (well #4) will be maintained as a back-up water supply. The transition to the new well is expected to occur in 2014. The technical study completed as part of this update resulted in revisions to the WHPA delineation and vulnerability scoring for both wells.

There is an additional municipal groundwater system planned for the Township of Cavan Monaghan (Fraserville – Lansdowne Site); this planned system is discussed separately in Section 5.2.3.

5.2.2.6.1 Wellhead Protection Area Delineation

Wellhead protection areas were delineated for the Millbrook, Crystal Springs, and Keene Heights municipal wells using a single three-dimensional computer groundwater model (the “Rice Lake” model). The model contains six geological layers: five layers in the overburden and one layer in the bedrock. The data sources for the model were the Ministry of the Environment and Climate Change Water Well Information System database and other geotechnical and consultant well data. The WHPAs delineated for the Millbrook, Crystal Springs, and Keene Heights municipal groundwater systems are shown on Maps 5-25a through 5-27a (for WHPA A-D); the WHPA-E for the Crystal Springs system is shown on Map 5-25d.

5.2.2.6.2 Vulnerability Assessment

Groundwater vulnerability for the Millbrook, Crystal Springs, and Keene Heights systems was assessed using a water table to well advection time (WWAT) method.

Since unsaturated zone travel time (UZAT) was not included in the analysis of surface to well advection time (SWAT), the identification of transport pathways that could modify the groundwater vulnerability focused on identifying constructed pathways that could reduce travel times in the saturated zone. These included the following:

- Clusters of deep wells (more than 5 wells within 100 m) that were constructed prior to 1990 (when the *Ontario Wells Regulation (O. Reg. 903)* made under the *Ontario Water Resources Act* set out minimum standards for the construction and decommissioning of all types of wells)
- Gravel pits and quarries that breach the upper confining unit
- Landfills located in former pits and quarries that reach through the upper confining unit.

The results of the groundwater vulnerability assessment for the Millbrook, Crystal Springs, and Keene Heights systems are shown on Maps 5-25a through 5-27a. The range of groundwater vulnerability ratings in the WHPAs delineated for these systems is given in Table 5.2-18.

5.2.2.6.3 Vulnerability Scores

The range of vulnerability scores assigned to the WHPAs delineated for the Cavan Monaghan and Otonabee-South Monaghan municipal well systems is given in Table 5.2-18 and shown on Maps 5-25a through 5-27a.

Table 5.2-18: Vulnerability Scores for Cavan Monaghan & Otonabee-South Monaghan Well Systems

System	Transport Pathways By WHPA[1]					Range of Groundwater Vulnerability Ratings by WHPA				Range of Vulnerability Scores By WHPA				
	A	B	C	D	E	A	B	C	D	A	B	C	D	E
Crystal Springs	-	-	-	W	-	Med-High	Med-High	Low-High	Low-High	10	8-10	6-8	2-8	9
Keene Heights	-	-	-	-	N/A	Low-High	Low-High	Low-High	Low-High	10	6-10	2-8	2-6	N/A
Millbrook	-	-	-	W/Q	N/A	High	High	Low-High	Low-High	10	10	4-8	2-6	N/A

5.2.2.6.4 Uncertainty

Uncertainty ratings were assigned to the WHPA delineation and groundwater vulnerability assessment. The Millbrook, Crystal Springs, and Keene Heights municipal well systems were assigned a high uncertainty. The uncertainty ratings are listed in Table 5.2-19.

Table 5.2-19: Uncertainty Ratings for Cavan Monaghan & Otonabee-South Monaghan Well Systems

System	Uncertainty Ratings for WHPA Delineation					Uncertainty Ratings for Assignment of Vulnerability					Final Uncertainty Rating				
	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E
Crystal Springs	Low	High	High	High	High	Low	High	High	High	Low	Low	High	High	High	High
Keene Heights	Low	Low	Low	Low	N/A	Low	High	High	High	NA	Low	High	High	High	N/A
Millbrook	Low	High	High	High	N/A	Low	High	High	High	NA	Low	High	High	High	N/A

5.2.2.7 STIRLING MUNICIPAL WELL SYSTEM

The Stirling municipal well system consists of four wells that draw water from sand and gravel deposits adjacent to Rawdon Creek. Wells 4 and 5 are considered to be GUDI (groundwater under the direct influence of surface water).

5.2.2.7.1 Wellhead Protection Area Delineation

The WHPAs for the Stirling municipal well system were delineated based on time of travel determined through the application of a three-dimensional groundwater flow model. The data source used to develop this model was the Ministry of the Environment and Climate Change Water Well Information System database. The model that represented the geologic system was six geological layers: five in the overburden and one in the bedrock.

The WHPAs delineated for the Stirling municipal groundwater system are shown on Map 5-28a.

5.2.2.7.2 2019 Stirling Wellhead Protection Studies Updates

Township of Stirling-Rawdon recently added a new production well (well #6) to the Stirling municipal drinking water system. This new well is intended serve as backup and/or future replacement source for the existing production wells. No other changes are planned for the existing drinking water system and the maximum approved capacity of 2,687.7 m^3/d for the Stirling Water Treatment Plant remains unchanged. The newly installed well #6 has very similar properties as the existing well #5, with a depth of 13.2m. Updated wellhead protection studies were completed in July 2019 for Stirling Well System.

The consultant hired by the city used alternative pumping scenario (see table below) in order to define composite WHPA zones. Scenario 1 was developed to be similar to the original model (Earthfx, 2010); scenarios 2-4 include various combinations of extraction rates, using two groups of wells: well 31 and well #3 in group 1 and well #4, well #5, and well #6 in group 2. For all scenarios, the total extraction rates corresponds to the maximum permitted rate 2,687.7 m^3/d.

Table: Groundwater Extraction Scenario

SCENARIO	Well #	EXTRACTION RATE (m^3/d)	PTTW MAX WELL (m^3/d)	PTTW MAX SYSTEM
1	Well #1	544.32	1304.6	2687.7
	Well #3	544.32	1304.6	
	Well #4	951.06	1944.0	
	Well #5	0	648.0	
	Well #6	648.00	648.0	
2	Well #1	1304.6	1304.6	2687.7
	Well #3	0	1304.6	
	Well #4	1383.1	1944.0	
	Well #5	0	648.0	
	Well #6	0	648.0	
3	Well #1	0	1304.6	2687.7
	Well #3	395.7	1304.6	
	Well #4	1644.0	1944.0	
	Well #5	0	648.0	
	Well #6	648.0	648.0	
4	Well #1	1304.6	1304.6	2687.7
	Well #3	1304.6	1304.6	
	Well #4	0	1944.0	
	Well #5	78.5	648.0	
	Well #6	0	648.0	

The consultant has determined that as per Technical Rule 49(3), the interaction between the surface water and groundwater has the effect of decreasing the time of travel of water to the well, thus a WHPA-E needs to be added to the wellhead protection areas.

Using Water Survey of Canada (WSC) stream gauge at Rawdon Creek near West Huntingdon (02HK008), stream flow statistics were prorated for Rawdon Creek in the immediate vicinity of Stirling Wells. The 2-year return flow (assessed to be the Bankfull flow) was calculated to be 14.31 m^3/s; whereas, the existing WHPA-E (XCG, 2009) was delineated using an estimated 2-year flow of 44.3 m^3/s (Kilborn, 1985). Empirical methodologies were used by Kilborn due to insufficient data at the gauge station in 1985.

The 2-hour time of travel distance on Rawdon Creek used by XCG (2009) using 2-year return flow of 44.3 m^3/s was determined to be 10,260m. Assuming the actual 2-year return flow to be 14.31 m^3/s, the 2-hour time of travel can be expected to be significantly shorter than 10,260m. Therefore, the existing WHPA-E being a conservative estimate, the consultant recommended to retain the existing WHPA-E and its vulnerability score.

5.2.2.7.3 Groundwater Vulnerability Assessment

Vulnerability of the groundwater was assessed using a water table to well advection time (WWAT) method.

Since unsaturated zone travel time (UZAT) was not included in the analysis of surface to well advection time (SWAT), the identification of transport pathways that could modify the groundwater vulnerability focused on identifying constructed pathways that could reduce travel times in the saturated zone. These included the following:

- Clusters of deep wells (more than 5 wells within 100 m) that were constructed prior to 1990 (when the *Ontario Wells Regulation (O. Reg. 903)* made under the *Ontario Water Resources Act* set out minimum standards for the construction and decommissioning of all types of wells)
- Gravel pits and quarries that breach the upper confining unit
- Landfills located in former pits and quarries that reach through the upper confining unit.

The results of the groundwater vulnerability assessment for the Stirling municipal well system are shown on Map 5-28a. The range of groundwater vulnerability ratings in the WHPAs delineated for these systems is given in Table 5.2-20.

5.2.2.7.4 2019 Stirling Wellhead Protection Studies Updates

As per the original study (Earthfx, 2010), groundwater (vertical) vulnerability was assessed using the water table to well advection time (WWAT) method.

5.2.2.7.5 Vulnerability Scores

The range of vulnerability scores assigned to the WHPAs delineated for the Stirling municipal well system is given in Table 5.2-20 and shown on Map 5-28a.

5.2.2.7.6 Uncertainty

The Stirling municipal well system was assigned a high uncertainty (see Table 5.2-21).

Table 5.2-20: Vulnerability Scores for Stirling Well System

Well	Method	Transport Pathways By WHPA[1]					Range of Groundwater Vulnerability Ratings by WHPA				Range of Vulnerability Scores By WHPA				
		A	B	C	D	E	A	B	C	D	A	B	C	D	E
Well #1	SWAT	-	-	-	W / Q	-	Low	Low-high	Low-high	Low-high	10	6-10	24-8	2-6	8

Well #3	SWAT	-	-	-	W / Q	-	High	Low-high	Low-high	Low-high	10	6-10	24-8	2-6	8
Well #4	SWAT	-	-	-	W / Q	-	Low	Low-high	Low-high	Low-high	10	6-10	24-8	2-6	8
Well #5	SWAT	-	-	-	W / Q	-	Low	Low-high	Low-high	Low-high	10	6-10	24-8	2-6	8
Well #6	SWAT	-	-	-	W/Q	-	Low-high	Low-high	Low-high	Low-high	10	6-10	2-8	2-6	8

Table 5.2-21: Uncertainty Ratings for Stirling Well System

Wells	Uncertainty Ratings for WHPA Delineation					Uncertainty Ratings Assignment of Vulnerability					Final Uncertainty Rating				
	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E
Well #1	Low	High	High	High	High	Low	High	High	High	Low	Low	High	High	High	High
Well #3	Low	High	High	High	High	Low	High	High	High	Low	Low	High	High	High	High
Well #4	Low	High	High	High	High	Low	High	High	High	Low	Low	High	High	High	High
Well #5	Low	High	High	High	High	Low	High	High	High	Low	Low	High	High	High	High
Well #6	Low	High	High	High	High	Low	High	High	High	Low	Low	High	High	High	High

5.2.2.8 GRAFTON, COLBORNE, AND BRIGHTON MUNICIPAL WELL SYSTEMS

The Grafton, Colborne, and Brighton municipal well systems consist of a total of seven wells. These well systems were studied together because of the similarity in their geologic and hydrogeologic settings. Each of the seven wells obtains water from overburden sediments on the south slope of the Oak Ridges Moraine. Additional information about these well systems is provided in Table 5.2-22.

Table 5.2-22: Grafton, Colborne, and Brighton Municipal Well Systems

System	Aquifer Type	Geology	Classification	Groundwater Flow Model
Brighton	Unconfined	Overburden	non-GUDI	South Slope
Colborne	Confined	Overburden	non-GUDI	South Slope
Grafton	Confined	Overburden	non-GUDI	South Slope

5.2.2.8.1 Wellhead Protection Area Delineation

The WHPAs for the updated Colborne municipal well system were delineated based on time of travel assessed through the application of a 3D groundwater model, extracted from the existing “South Slope” model. This extraction process consisted of following refinements:

1. The model domain was reduced to focus on the Colborne wells. The northern boundary was set as the eastward flowing Cold Creek. The western boundary is the southward flowing Shelter Valley Creek. The eastern boundary is Smithville Creek west of Brighton and Lake Ontario is the southern boundary to the model domain. A constant head boundary was incorporated in the northwest extent of the model domain in the Thornhill Aquifer, representing groundwater flow-through from Oak Ridges Moraine in the north.
2. The model grid was refined around municipal wells, in order to better represent steeply declining groundwater elevations in the immediate vicinity of the municipal wells.
3. The transient mode of the groundwater model was used to simulate drawdowns from 2016 pumping tests. Model adjustments to improve results included increasing and decreasing hydraulic conductivity and storativity of layer 5 (Thornhill Aquifer Complex) and layer 4 (Lower Newmarket Till).
4. The updated model was run to determine new well capture zones under the maximum permitted rate (6566.4 m^3/d), unlike the earlier model, which used 3283.2 m^3/d, with both wells operating.

The WHPAs for the Grafton, Colborne, and Brighton municipal well systems were delineated based on time of travel determined through the application of a single three-dimensional groundwater flow model (the “South Slope” model). The model that represented the geologic system contained six geological layers: five in the overburden and one in the bedrock. The data source for the model was the Ministry of the Environment and Climate Change Water Well Information System database. The WHPAs delineated for Grafton, Colborne, and Brighton municipal well systems are shown on Maps 5-29a through 5-31a.

5.2.2.8.2 Vulnerability Assessment

Groundwater vulnerability was assessed for these systems using a water table to well advection time (WWAT) method. This is an application of the surface to well advection time (SWAT) method that does not include the travel time through the unsaturated zone (see Section 5.2.2)

Since unsaturated zone travel time (UZAT) was not included in the analysis of surface to well advection time (SWAT), the identification of transport pathways that could modify the groundwater vulnerability focused on identifying constructed pathways that could reduce travel times in the saturated zone. These included the following:

- Clusters of deep wells (more than 5 wells within 100 m) that were constructed prior to 1990 (when the *Ontario Wells Regulation (O. Reg. 903)* made under the *Ontario Water Resources Act* set out minimum standards for the construction and decommissioning of all types of wells)
- Gravel pits and quarries that breach the upper confining unit
- Landfills located in former pits and quarries that reach through the upper confining unit.

The results of the groundwater vulnerability assessment for the Grafton, Colborne, and Brighton municipal well systems are shown on Maps 5-29a through 5-31a. The range of groundwater vulnerability ratings in the WHPAs delineated for these systems is given in Table 5.2-23.

5.2.2.8.3 Vulnerability Scores

The range of vulnerability scores assigned to the WHPAs delineated for the Grafton, Colborne, and Brighton municipal well systems is given in Table 5.2-23 and shown on Maps 5-29a through 5-31a.

Table 5.2-23: Vulnerability Scores for Grafton, Colborne, and Brighton Municipal Well Systems

System	Transport Pathways By WHPA					Range of Groundwater Vulnerability Ratings by WHPA				Range of Vulnerability Scores By WHPA				
	A	B	C	D	E	A	B	C	D	A	B	C	D	E
Brighton	-	-	Q	Q	N/A	High	High	Low-High	Low-Med	10	10	6-8	2-6	-
Colborne	-	-		L / Q	N/A	High	Low-High	Low-Med	Low-Med	10	6-10	2-8	2-4	-
Grafton	-	-	-	-	-	Low	Low	Low-Med	Low	10	6	2-4	2	-

[1] Q = Quarry; L = Landfill

5.2.2.8.4 Uncertainty

The Grafton, Colborne, and Brighton municipal well systems are assigned an uncertainty rating of low to high. The uncertainty ratings are given in Table 5.2-24.

Table 5.2-24: Uncertainty Ratings for Grafton, Colborne, and Brighton Municipal Well Systems

System	Uncertainty Ratings for WHPA Delineation					Uncertainty Ratings for Assignment of Vulnerability					Final Uncertainty Rating				
	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E
Brighton	Low	High	High	High	N/A	High	High	High	High	N/A	Low	High	High	High	N/A
Colborne	Low	High	High	High	N/A	High	High	High	High	N/A	Low	High	High	High	N/A
Grafton	Low	High	High	High	N/A	High	High	High	High	N/A	Low	High	High	High	N/A

5.2.3 RESULTS FOR PLANNED MUNICIPAL SYSTEM

5.2.3.1 PLANNED FRASERVILLE – LANSDOWNE SITE MUNICIPAL WELL SYSTEM

The Township of Cavan Monaghan has one planned municipal well system: the Fraserville – Lansdowne Site. The Fraserville – Leahy Site is no longer being considered by the municipality (see Appendix A). The work discussed in this section refers to the Fraserville – Lansdowne Site.

5.2.3.1.1 Wellhead Protection Area Delineation

The WHPAs for the planned Fraserville municipal well system were delineated using the uniform flow method, based on the Ministry of the Environment and Climate Change Water Well Information System database. The WHPAs delineated for the planned Fraserville system are shown on Map 5-32a.

5.2.3.1.2 Vulnerability Assessment

The groundwater vulnerability for the planned Fraserville municipal well system was determined using the intrinsic susceptibility index method. The vulnerability was adjusted in areas with high concentrations of private wells. The results of the groundwater vulnerability assessment for this system are shown on Map 5-32a.

5.2.3.1.3 Vulnerability Scores

The vulnerability scores assigned to the planned Fraserville municipal well system are shown on Map 5-32a.

5.2.3.1.4 Uncertainty Analysis

Uncertainty ratings were assigned to the delineation and groundwater vulnerability assessment for the WHPAs for the planned Fraserville system. The ratings and justification for the assignment of these ratings are given in Table 5.2-25 and Table 5.2-26.

Table 5.2-25: Summary of Uncertainty in WHPA Delineation for Planned Fraserville System

Area	Uncertainty Rating	Major Reasons
WHPA-A	Low	• Well location was confirmed with GPS • 100-m radius delineation was drawn
WHPA-B, C, and D	High	• Literature values for K, porosity • Limitations of analytical model • Limited field data for calibration
WHPA-E	High	• Desk top analysis only – no numerical models • No field measurements or observations • No specific information on Jackson Creek flows or cross-sections • Regional wind used for lake systems

Table 5.2-26: Summary of Uncertainty in Groundwater Vulnerability Assessment for Planned Fraserville System

Area	Uncertainty Rating	Major Reasons
WHPA-A	Low	Prescribed vulnerability

WHPA-B, C, and D	High	Data are through interpolations of Ministry of the Environment and Climate Change Water Well Records

5.2.4 INFORMATION TO SUPPORT CONTINUAL IMPROVEMENT

5.2.4.1.1 IMPROVEMENT TO THE CHARACTERIZATION OF GROUNDWATER FLOW (FRACTURED FLOW) SYSTEM IN THE NORTH

There is a lack of information on fracture orientation or density within the supply aquifer for the northern groundwater systems. Due to this lack of information, the groundwater flow was simulated as flow through a porous media with a hydraulic conductivity taken from literature values for that geologic unit. Pumping test data from the wells was used to determine order of magnitude. It is acknowledged that with this representation there is an inferred assumption that the fracture network is dense and isotropic without any preferential orientation. Given that there was no available data to determine the density or orientation of the fracture network, the simulation of the aquifer as a porous media is a simplification of the natural fracture network. If the fracture network did have a preferential orientation, the WHPA zones could see significant orientation modifications and possibly increased size. This is considered a limitation of the model for these systems that could be remedied with a detailed field program.

5.3 ISSUES ASSESSMENT

Drinking water issues exist where the concentration of chemical or pathogen parameters 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 identification of drinking water issues for the municipal groundwater systems in the Trent source protection areas was completed under several separate studies that are documented in the following reports:

- *Vulnerability, Issues and Threats for Fourteen Groundwater Sourced Municipal Drinking Water Systems in the Trent Conservation Coalition Source Protection Region* (XCG Consultants, July 2010)
- *Vulnerability, Issues and Threats for One Planned Groundwater Sourced Municipal Drinking Water System in the Trent Conservation Coalition Source Protection Region* (XCG Consultants, July 2010)
- *Assessment of Drinking Water Threats – Havelock Water Supply, Township of Havelock-Belmont-Methuen* (GENIVAR Consultants, April 2010)
- *Assessment of Drinking Water Threats – Creighton Heights and Camborne Municipal Wellfields, Township of Hamilton* (GENIVAR Consultants, June 2010)
- *Assessment of Drinking Water Threats – Municipal Residential Groundwater Supplies – The City of Kawartha Lakes (3 Volumes)* (GENIVAR Consultants, August 2010)
- *Assessment of Drinking Water Threats – Municipal Groundwater Supplies – The Regional Municipality of Durham* (August 2010)
- *Vulnerability, Issues and Threats for the new Lutterworth Pines Municipal Groundwater Sourced Drinking Water System* (XCG Consultants Ltd, January 2011)
- *Hydrogeological Assessment for PTTW Application: Keene, Ontario* (Alpha Environmental Services Inc., February 2013)
- *Notice of De-commissioning of a Municipal Well in the Blackstock Drinking Water System – Region of Durham, January 2014*

This section is a summary of the relevant sections of these reports.

5.3.1 METHODOLOGY

The *Technical Rules* defines a drinking water issue as the presence of a parameter listed in Schedule 1, 2, or 3 of the *Ontario Drinking Water Quality Standards* or Table 4 of the *Technical Support Document for Ontario Drinking Water Standards - Objectives and Guidelines* at a concentration that may result in the deterioration of the quality of the water for use as a source of drinking water. Upward trends in concentration that may result in a similar deterioration are also considered drinking water issues.

Exceedances of the standards and trends were identified through a review of the available water quality data. The determination as to whether an exceedance or trend would result in the deterioration of the quality of the water for use as a source of drinking water was made on a parameter-by-parameter basis. The Ontario Drinking Water Quality Standards, available sources of data, and the review of water quality data are discussed in more detail below.

5.3.1.1 ONTARIO DRINKING WATER QUALITY STANDARDS

The *Ontario Drinking Water Quality Standards* indicate the maximum acceptable concentrations of a variety of water quality parameters in treated drinking water. The *Technical Rules* requires that the drinking water issues assessment consider the parameters listed in Schedules 1 to 3 of these standards, which include microbiological, chemical, and radiological parameters, and in 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. No data for radiological parameters were available, so Schedule 3 parameters were not considered in the issues assessment. Additional notes about selected parameters are included below.

Parameters with Multiple Benchmarks

Eight organic parameters are listed in both Schedule 2 of the Standards and Table 4 of the support document; in these cases, the aesthetic objectives and operational guidelines in Table 4 are always lower, so they were used for the issues assessment.

Standards Expressed as Ranges

The operational guidelines for alkalinity, hardness, and pH are listed as ranges rather than maximum limits. When reviewing this parameter as a drinking water issue, any data outside of the ranges were considered issues.

Escherichia coli (E. coli)

The standard for E. coli in treated water is "not detectable" (i.e., 0 cfu/100 mL or 0 colony forming units per 100 millilitres). E. coli is not expected to be found in groundwater under natural conditions and therefore the presence of E. coli in groundwater sourced systems is considered to be anthropogenic only. For source water coming from groundwater under the direct influence of surface water (GUDI), treatment by filtration and disinfection by irradiation from ultraviolet light are required to deal with the potential presence of E. coli, in a manner similar to a surface water system. As such, E. coli detected in the source water would not be considered an issue because of the ability to treat it. For groundwater systems where there is only primary disinfection used in the treatment process, persistent E. coli presence in the source water would be considered an issue since there is no filtration system in place to remove or destroy the fecal associated pathogens.

Sodium

Sodium in groundwater can be naturally occurring, although elevated levels can be caused by anthropogenic activity (road salting, water softener discharge, etc.). Sodium appears in Table 4 of the *Technical Support Document for Ontario Drinking Water Standards, Objectives and Guidelines* under the aesthetic objective column. The aesthetic objective for sodium is 200 mg/L – this is when a salty taste is obvious in the water. Under O. Reg. 170/03 of the *Safe Drinking Water Act*, sodium levels above 20 mg/L require that the Public Health Unit be contacted so that people on sodium restricted diets are aware of the sodium levels in the water. For this assessment, the aesthetic objective level of 200 mg/L is used as the benchmark for identifying potential drinking water issues, but any concentrations over the 20 mg/L notice level are documented.

Turbidity

The standard for turbidity is 5 NTU. However, under the *Drinking-Water Systems Regulation (*O. Reg. 170/03) of the *Safe Drinking Water Act,* turbidity levels above 1 NTU in treated water trigger an adverse water quality report to the Ministry of the Environment and Climate Change Spills Action Centre and the Public Health Unit. The aesthetic objective of 5 NTU was used as the benchmark for turbidity in this assessment of drinking water.

5.3.1.2 REVIEW OF AVAILABLE WATER QUALITY DATA

The water quality data available for each system were reviewed to identify those parameters that should be considered drinking water issues. The available data included the following:

- Municipal groundwater study reports
- Watershed characterization reports
- Certificates of Approval
- Permits to Take Water
- Municipal water supply water quality data
- Annual water supply water quality monitoring reports
- Ministry of the Environment and Climate Change water supply inspection reports
- Water Supply System Engineer's Reports
- Provincial Groundwater Monitoring Program data (background conditions)
- Microbial Control Plans (where available).

The sources of data used to identify drinking water issues at each municipal groundwater system are summarized in Table 5.3-1 (for the GENIVAR studies) and Table 5.3-2 (for the XCG and Alpha Environmental Services studies). For groundwater systems, the amount of data available for raw groundwater quality was very limited. In most cases, the only reported testing of the raw groundwater is for bacteriological presence. All other analytical testing is completed on treated water prior to distribution and consumption. Data for water in distribution systems were only considered where there were no measured values for raw or treated water. When considering distribution system data, it was acknowledged that the presence of certain contaminants may not be related to the source water, but rather to changes in water quality that typically occur in normally functioning treatment and distribution systems (i.e., disinfection by-products such as trihalomethanes, bacterial regrowth in old piping systems, leaching of metals from old plumbing fixtures, etc.).

XCG Consultants and GENIVAR used slightly different approaches to setting benchmarks for the purpose of identifying potential drinking water issues. Both XCG and GENIVAR set primary benchmarks for chemical parameters according to the ones listed in Schedules 1, 2, and 3 of the *Ontario Drinking Water Quality Standards* and Table 4 of the *Technical Support Document for Ontario Drinking Water Standards, Objectives and Guidelines*. The water quality data for parameters that exceeded the benchmark were evaluated to make sure there was enough data to justify including them as issues and to exclude anomalous data points. These parameters were included on the preliminary issues list. Some preliminary issues were also delisted based on operational considerations (e.g., trihalomethanes are a by-product of treatment).

GENIVAR used the decision process outlined in Figure 5.3-1 to determine if a parameter should be considered a drinking water issue. A preliminary list of parameters was compiled that consisted of parameters that exceeded the standards, potential naturally occurring parameters with concentrations above local background levels, and anthropogenic parameters with concentrations above the detection limit. Parameters on the preliminary list were evaluated in accordance with the decision process. The GENIVAR investigation included a trend analysis to determine if the parameters would exceed the standards within 50 years. Since the *Technical Rules* is silent on this issue, the consultants used a 50-year period for trend analysis for precautionary purposes.

XCG Consultants reviewed the available data to identify parameters that exceeded the method detection limit but were below the primary benchmark (i.e., the drinking water standards). They did a trend analysis for these parameters where sufficient data were available. If the parameter showed a statistically significant upward trend that would result in an exceedance of the primary benchmark in 50 years, it was added to the list of issues. Since the *Technical Rules* is silent on this issue, the consultants used a 50-year period for trend analysis for precautionary purposes.

5.3.1.3 WATER TREATMENT PLANT OPERATOR INTERVIEWS

The next step in the issue evaluation process was to seek a qualitative opinion based on operational experience as to whether the identified parameters (that exceed the benchmarks) meet the requirement of Technical Rule 114 (i.e., deterioration of the water as a source of drinking water). Interviews were held with representatives of the municipality and the operating authority familiar with the operation of the water supply. This step allowed information from the operators to be incorporated into the analysis, particularly for parameters with aesthetic objectives or operational guidelines.

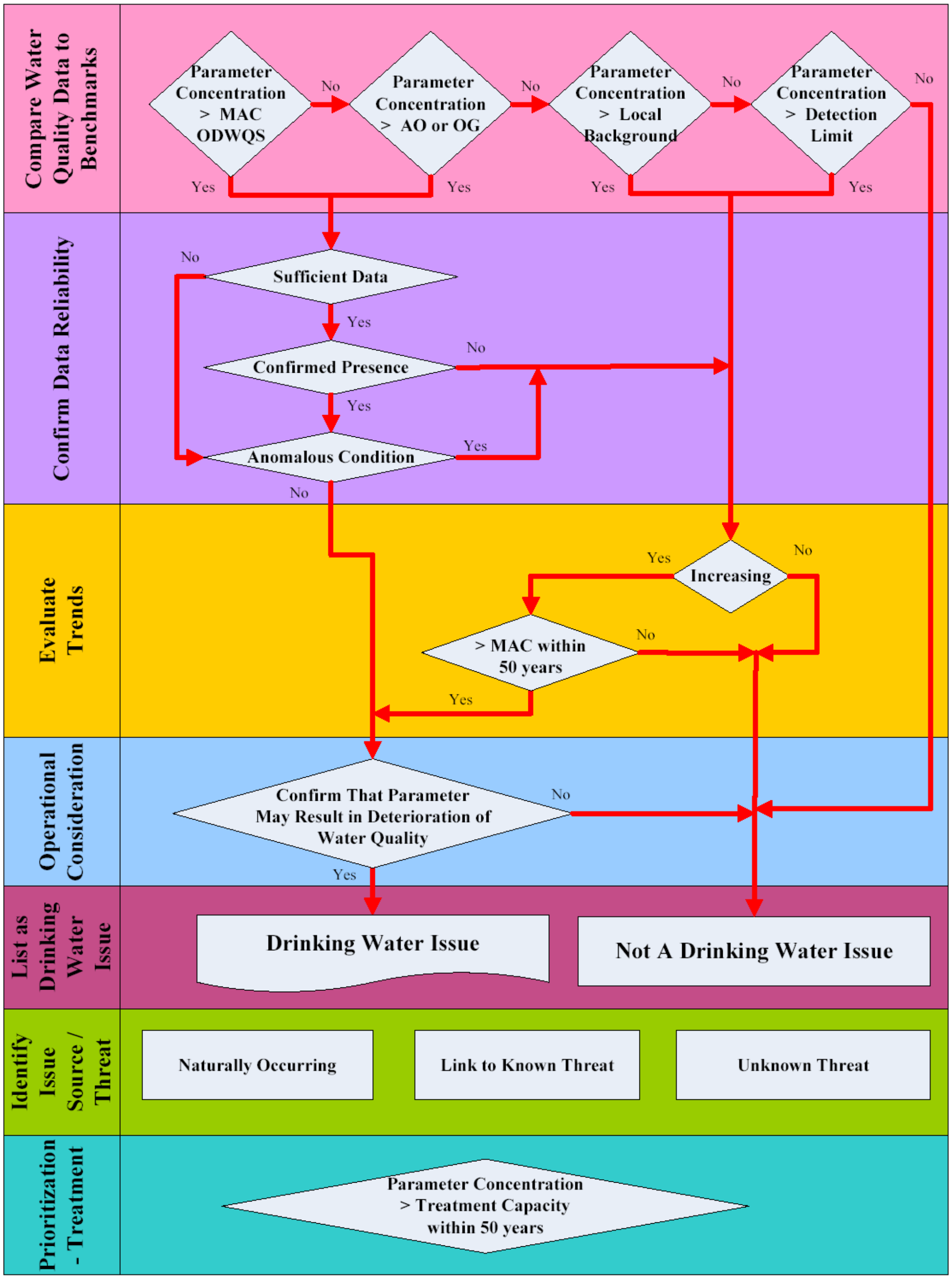

Figure 5.3-1: Methodology for Evaluating Drinking Water Issues (GENIVAR)

Table 5.3-1: Data Sources Used for Assessment of Drinking Water Issues (GENIVAR)

Data Source	Water Type	Woods of Manilla	Sonya	Mariposa Estates	King’s Bay	Pleasant Point	Canadiana Shores	Janetville	Woodfield	Manorview Estates	Victoria Glen	Victoria Place	Birch Point	Pinewood[1]	Blackstock	Greenbank	Port Perry	Havelock
Annual Reports	Raw & Treated	03-07	03-07	03-07	03-07	03-07	03-07	03-07	03-07	03-07	03-07	03-07	03-07	03-07	04-08	04-07	04-07	05-08
SWIP Data (MOECC’s Drinking Water Inspection/Compliance Program)	Raw & Treated	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓				06
Trent Coalition Conservation Aquifer Characterization Reports																		05-06
Well 1 and 2 Effective In-Situ Treatment Investigation (Jagger Hims Ltd.)																		02
Township of Havelock-Belmont-Methuen Municipal Groundwater Study Report (Morrison Environmental Ltd.)																		04
Permit to Take Water Study, Well 1 and Well 4 (Jagger Hims Ltd.)																		03
Supplementary Hydraulic Testing, Well 1 and Well 4 (Jagger Hims Ltd.)																		03
Production Wells 1 and 4 In-Situ Filtration Assessment Reports (Jagger Hims Ltd.)																		08-09
Havelock Wells 1 and 4 remedial Work Status (Jagger Hims Ltd.)																		08
Community of Port Perry Wellhead Protection Program Numerical Model Development Report																	03	
Kawartha Conservation Watershed Characterization Report		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	
Municipal Raw Water Quality Data															91-01		91-01	
Municipal Water Supply Water Quality Data		03-07													02-08	02-08	02-08	
Municipal Water Supply Treated Water Quality Data		03-07	03-07	03-07	03-07	03-07	03-07	03-07	03-07	03-07	03-07	03-07	03-07	03-07				
Municipal Servicing Study			✓	✓		✓	✓		✓	✓	✓	✓		✓	✓			

[1]Data not available for Well #5, data shown is for Wells #2, #3, and #4.

Table 5.3-1 (cont’d): Sources Used for Assessment of Drinking Water Issues (GENIVAR)

Data Source	Water Type	Woods of Manilla	Sonya	Mariposa Estates	King’s Bay	Pleasant Point	Canadiana Shores	Janetville	Woodfield	Manorview Estates	Victoria Glen	Victoria Place	Birch Point	Pinewood	Blackstock	Greenbank	Port Perry	Havelock
Engineer’s Report			✓	✓	✓	✓				✓			✓		✓			
Otonabee Conservation Watershed Characterization Report														✓				
Community of Blackstock Wellhead Protection Program Numerical Model Development Report (Jagger Hims Ltd.)															03			
Sentry Well Groundwater Quality Monitoring Reports (Jagger Hims Ltd.)															07-08			
Sentry Well Groundwater Quality data															08			
Permit to Take Water Applications and Technical Reports															✓			

Table 5.3-2: Data Sources Used for Assessment of Drinking Water Issues (XCG and Alpha Environmental Services)

Data Source	Water Type	Years on Record													
		Minden	Lutterworth Pines	Cardiff	Dyno Estates	Alpine Village / Pirates Glen	Buckhorn Lake Estates	Norwood[1]	Stirling	Keene Heights	Crystal Springs	Millbrook	Brighton	Colborne	Grafton
Annual Reports	Raw & Treated	04-06; 08		06-08	06-08	06-08	06-07	03-08	03-08	03-07	03-07	05-08	03; 06-08	06; 08	08
Ministry of the Environment and Climate Change Drinking Water System Inspection Reports	Raw & Treated	00-03; 05-08		00-07	00-07	02-08	03-08	02; 05-06; 08-09	00-02; 04-05; 07-08	01-03; 05-07; 09	03; 05; 08	01; 03-06; 08	00-03; 05; 08	95; 01-08	00-01; 03-08
Certificates of Analysis	Raw & Treated	00-07	10	01-07	02-04	98;00; 06-07	06-07	05-08					02		
Drinking Water Information System	Raw & Treated	05-08		05-08	05-08	05-08	05-08	00-05	05-08	05-08	05-08	05-08	05-08	05-08	05-08
SWIP Data (MOECC's Drinking Water Inspection/Compliance Program)	Raw & Treated	00-07		00-07	00-07	00-07	03-07		01-07	00-07	00-07	00-07	00-07	03-05	00-07
Water Treatment Plant Water Quality	Raw & Treated	06-07		06-08									00-05	03-07	03-08
Ministry of the Environment and Climate Change Laboratory Analysis	Raw & Treated	03; 06; 07		05-06	02-04	00; 03-05; 07-08	03-04; 06; 08						02; 04	03-05; 07	03-04
Great Lakes Index Station Network (GLISN) – Station 462	Raw & Treated														
Ontario Clean Water Agency	Raw & Treated				06	03-08	06-08	02			02; 06				
Grafton Hydrogeological Reports: Production Well Monitoring Program															00-07
Lutterworth Pines Wellfield Evaluation Report	Raw		08												
Keene Hydrogeological Assessment for PTTW Application	Raw									13					

[1]Data not available for Norwood Wells #1B and #4.

5.3.2 RESULTS

The results of the issues assessment for each municipal well system in the Trent source protection areas are summarized in the following subsections (5.3.2.1 to 5.3.2.31). Each subsection includes a table that summarizes the data used to identify the preliminary list of issues based on exceedances of the standards and the rationale for the conclusion.

For the 3 GENIVAR studies, the tables of exceedances include the trends analyses and indicate whether or not the expected concentration will exceed the primary benchmark in 50 years.

For the XCG study, where parameters are above the method detection limit but below the primary benchmark (and where sufficient data are available), a trend analysis was completed. A second table is provided that summarizes the trend analysis (including the direction and statistical significance of the trend and the expected concentration of the parameter 25 and 50 years in the future).

These tables indicate whether or not the parameter was considered a result of natural sources (requiring no further investigation under the source protection program) or from anthropogenic causes. Issue contributing areas are mapped for drinking water issues from anthropogenic sources, and activities contributing to the issue are included as significant threats in the threats assessment.

5.3.2.1 WOODS OF MANILLA

The drinking water issues evaluation for the Woods of Manilla municipal well system is summarized in Table 5.3-3 (standby well) and Table 5.3-4 (lead well), which list the water quality parameters that exceeded the primary or secondary benchmarks and indicate whether or not they were considered issues and the rationale for the conclusion. No drinking water issues were identified. The sodium concentration data display an increasing trend, but concentrations are not projected to exceed the drinking water standard in 50 years. Concentrations occasionally exceeded the guideline of 20 mg/L for sodium restricted diets.

Table 5.3-3: Woods of Manilla Water Quality Standards Exceedances – TW1 (Standby Well)

Parameter	Water Type[1]	Years on Record	Benchmark Exceedances			Standard		Extrapolation		Drinking Water Issue	Rationale
			Exceeds ODWQS	Above detection limit	Above local background level	Value	Type[2]	Trend	Exceed within 50 years		
Schedule 1											
Coliforms	Raw	2003/ 2007	Yes			0 cfu/100mL	MAC	-	No	No	• Rare exceedances in low numbers • Adequate treatment
Coliforms	Treated	2003/ 2007	Yes			0 cfu/100mL	MAC	-	No	No	• Adequate treatment
E. coli	Raw	2003/ 2007	Yes			0 cfu/100mL	MAC	-	No	No	• Rare exceedances in low numbers • Adequate treatment
E. coli	Treated	2003/ 2007				0 cfu/100mL	MAC	-	No	No	• Adequate treatment
Schedule 2 & Table 4											
Nitrate	Treated	2003/ 2007		Yes		10 mg/L	MAC	_	No	No	• Consistently less than standard • Slight increase in mid-2006
Sodium	Treated	2003/ 2007		Yes		200 mg/L	AO	↑	No	No	• No exceedance of standard in 50 years
Turbidity	Raw	2003/ 2007	Yes			5 NTU	OG	_	No	No	• Rare exceedance of standards
Turbidity	Treated	2003/ 2007	yes			5 NTU	OG	_	No	No	• Rare exceedance of standards

[1]Indicates if the data on record is for raw (untreated) or treated water
[2]Standard types: MAC=Maximum Acceptable Concentration; AO=Aesthetic Objective; OG=Operational Guideline

Table 5.3-4: Woods of Manilla Water Quality Standards Exceedances – TW2 (Lead Well)

Parameter	Water Type[1]	Years on Record	Benchmark Exceedances			Standard		Extrapolation		Drinking Water Issue	Rationale
			Exceeds ODWQS	Above detection limit	Above local background level	Value	Type[2]	Trend	Exceed within 50 years		
Schedule 1											
Coliforms	Raw	2003/ 2007	Yes			0 cfu/100mL	MAC	-	No	No	• Rare exceedances in low numbers • Adequate treatment
Coliforms	Treated	2003/ 2007	Yes			0 cfu/100mL	MAC	-	No	No	• Adequate treatment
E. coli	Raw	2003/ 2007	Yes			0 cfu/100mL	MAC	-	No	No	• Rare exceedances in low numbers • Adequate treatment
E. coli	Treated	2003/ 2007	Yes			0 cfu/100mL	MAC	-	No	No	• Adequate treatment
Schedule 2 & Table 4											
Nitrate	Treated	2003/ 2007		Yes		10 mg/L	MAC	_	No	No	• Consistently less than standard • Slight increase in mid-2006
Sodium	Treated	2003/ 2007		Yes		200 mg/L	AO	↑	No	No	• No exceedance of standard in 50 years
Turbidity	Treated	2003/ 2007	Yes			5 NTU	OG	_	No	No	• Anomalous data

[1]Indicates if the data on record is for raw (untreated) or treated water

[2]Standard types: MAC=Maximum Acceptable Concentration; AO=Aesthetic Objective; OG=Operational Guideline

5.3.2.2 SONYA

The drinking water issues evaluation for the Sonya municipal well system is summarized in Table 5.3-5, which lists the water quality parameters that exceeded the primary or secondary benchmarks and indicates whether or not they were considered issues and the rationale for the conclusion. No drinking water issues were identified. Uranium concentrations display a slightly increasing trend but there are very little data for this parameter to confirm the trend. Concentrations are not expected to exceed the drinking water standard within 50 years.

Table 5.3-5: Sonya Water Quality Standards Exceedances

Parameter	Water Type[1]	Years on Record	Benchmark Exceedances			Standard		Extrapolation		Drinking Water Issue	Rationale
			Exceeds ODWQS	Above detection limit	Above local background level	Value	Type[2]	Trend	Exceed within 50 years		
Schedule 1											
Coliforms	Raw	2003-2007	Yes			0 cfu/100mL	MAC	-	No	No	• Rare exceedances • Adequate treatment
Coliforms	Treated	2003-2007	Yes			0 cfu/100mL	MAC	-	No	No	• Considered Anomalous
E. coli	Raw	2003-2007	Yes			0 cfu/100mL	MAC	-	No	No	• Rare exceedances
Schedule 2 & Table 4											
Turbidity	Raw	2003-2007	Yes			5 NTU	OG	-	No	No	• Adequate treatment
Turbidity	Treated	2003-2007	Yes			5 NTU	OG	-	No	No	• Anomalous data
Uranium	Raw	2003-2007		Yes		0.02 mg/L	MAC	↑	No	No	• Very little data

[1]Indicates if the data on record is for raw (untreated) or treated water
[2]Standard types: MAC=Maximum Acceptable Concentration; AO=Aesthetic Objective; OG=Operational Guideline

5.3.2.3 MARIPOSA ESTATES

The drinking water issues evaluation for the Mariposa Estates municipal well system is summarized in Table 5.3-6, which lists the water quality parameters that exceeded the primary or secondary benchmarks and indicates whether or not they were considered issues and the rationale for the conclusion. No drinking water issues were identified. Concentrations of sodium are consistently less than the drinking water standard of 200 mg/L in the treated water at both wells. Concentrations are potentially projected to exceed the standard within 50 years, however the quantity of data available is not sufficient to confirm the projected trend. Concentrations have persistently exceeded the 20 mg/L guideline at which the Medical Officer of Health is to advise individuals on low sodium diets.

Table 5.3-6: Mariposa Estates Water Quality Standards Exceedances

Parameter	Water Type[1]	Years on Record	Benchmark Exceedances			Standard		Extrapolation		Drinking Water Issue	Rationale
			Exceeds ODWQS	Above detection limit	Above local background level	Value	Type[2]	Trend	Exceed within 50 years		
Schedule 1											
Coliforms	Raw	2003/ 2004	Yes			0 cfu/100mL	MAC	_		No	• Rare exceedances • Adequate treatment
E. coli	Raw	2003/ 2004	Yes			0 cfu/100mL	MAC	_		No	• Rare exceedances • Adequate treatment
Schedule 2 & Table 4											
Hardness	Unknown	2003/ 2004	Yes			80-100 mg/L $CaCO_3$	OG	_		No	• No deterioration of drinking water quality • Does not hinder Water Treatment Plant operations
Nitrate	Raw	2003/ 2004	Yes			10 mg/L	MAC	_	No	No	• Rare exceedances • No significant upward trend
Sodium	Raw	2003/ 2004	Yes			200 mg/L	AO	↑	Possible	No	• Potential exceedance in 50 years (insufficient data to confirm)
Turbidity	Raw	2003/ 2004		Yes		5 NTU	OG	_	No	No	• Not persistent

[1]Indicates if the data on record is for raw (untreated) or treated water
[2]Standard types: MAC=Maximum Acceptable Concentration; AO=Aesthetic Objective; OG=Operational Guideline

5.3.2.4 KING'S BAY

The drinking water issues evaluation for the King's Bay municipal well system is summarized in Table 5.3-7, which lists the water quality parameters that exceeded the primary or secondary benchmarks and indicates whether or not they were considered issues and the rationale for the conclusion. No drinking water issues were identified. No upward trends were noted for the parameters present.

Table 5.3-7: King's Bay Water Quality Standards Exceedances

Parameter	Water Type[1]	Years on Record	Benchmark Exceedances			Standard		Extrapolation		Drinking Water Issue	Rationale
			Exceeds ODWQS	Above detection limit	Above local background level	Value	Type[2]	Trend	Exceed within 50 years		
Schedule 1											
Coliforms	Raw	2003/ 2004	Yes			0 cfu/100mL	MAC	_	No	No	• Rare exceedances in low numbers • Adequate treatment
Coliforms	Treated	2003/ 2004	Yes			0 cfu/100mL	MAC	_	No	No	• Adequate treatment
Schedule 2 & Table 4											
NDMA	Raw	2003/ 2004		Yes		0.009 ug/L	MAC	_	No	No	• Rare exceedances in trace concentrations
Turbidity	Treated	2003/ 2004	Yes			5 NTU	OG	_	No	No	• Rare exceedances in low numbers

[1]Indicates if the data on record is for raw (untreated) or treated water
[2]Standard types: MAC=Maximum Acceptable Concentration; AO=Aesthetic Objective; OG=Operational Guideline

5.3.2.5 PLEASANT POINT

The drinking water issues evaluation for the Pleasant Point municipal well system is summarized in Table 5.3-8, which lists the water quality parameters that exceeded the primary or secondary benchmarks and indicates whether or not they were considered issues and the rationale for the conclusion. No drinking water issues were identified. The sodium concentration data display an increasing trend, but concentrations are not projected to exceed the drinking water standard in 50 years. Concentrations are consistently less than the guideline of 20 mg/L for sodium restricted diets, but are projected to exceed this guideline within 50 years.

Table 5.3-8: Pleasant Point Water Quality Standards Exceedances

Parameter	Water Type[1]	Years on Record	Benchmark Exceedances			Standard		Extrapolation		Drinking Water Issue	Rationale
			Exceeds ODWQS	Above detection limit	Above local background level	Value	Type[2]	Trend	Exceed within 50 years		
Schedule 1											
Coliforms	Raw	2003/ 2007	Yes			0 cfu/100mL	MAC	_	No	No	• Rare exceedances in low numbers • Adequate treatment
Coliforms	Treated	2003/ 2007	Yes			0 cfu/100mL	MAC	_	No	No	• Adequate treatment
Schedule 2 & Table 4											
Sodium	Treated	2003/ 2007		Yes		200 mg/L	AO	↑	No	No	• No exceedance of standard in 50 years
Turbidity	Treated	2003/ 2007	Yes			5 NTU	OG	_	No	No	• Rare exceedances in low numbers

[1]Indicates if the data on record is for raw (untreated) or treated water
[2]Standard types: MAC=Maximum Acceptable Concentration; AO=Aesthetic Objective; OG=Operational Guideline

5.3.2.6 CANADIANA SHORES

The drinking water issues evaluation for the Canadiana Shores municipal well system is summarized in Table 5.3-9, which lists the water quality parameters that exceeded the primary or secondary benchmarks and indicates whether or not they were considered issues and the rationale for the conclusion. No drinking water issues were identified. No upward trends were noted for the parameters present.

Table 5.3-9: Canadiana Shores Water Quality Standards Exceedances

Parameter	Water Type[1]	Years on Record	Benchmark Exceedances			Standard		Extrapolation		Drinking Water Issue	Rationale
			Exceeds ODWQS	Above detection limit	Above local background level	Value	Type[2]	Trend	Exceed within 50 years		
Schedule 1											
Coliforms	Raw	2003/ 2007	Yes			0 cfu/100mL	MAC	_	No	No	• Rare exceedances in low numbers • Adequate treatment
Coliforms	Treated	2003/ 2007	Yes			0 cfu/100mL	MAC	_	No	No	• Adequate treatment
Clostridium perfringens	Treated	2003/ 2007	Yes			N/A	N/A	_	No	No	• Rare exceedances • Not persistent • Likely related to Well 3 • Adequate treatment
Schedule 2 & Table 4											
Turbidity	Treated	2003/ 2007	Yes			5 NTU	OG	_	No	No	• Occasional exceedance of standard

[1]Indicates if the data on record is for raw (untreated) or treated water
[2]Standard types: MAC=Maximum Acceptable Concentration; AO=Aesthetic Objective; OG=Operational Guideline

5.3.2.7 JANETVILLE

The drinking water issues evaluation for the Janetville municipal well system is summarized in Table 5.3-10, which lists the water quality parameters that exceeded the primary or secondary benchmarks and indicates whether or not they were considered issues and the rationale for the conclusion. No drinking water issues were identified. No upward trends were noted for the parameters present.

Table 5.3-10: Janetville Water Quality Standards Exceedances

Parameter	Water Type[1]	Years on Record	Benchmark Exceedances			Standard		Extrapolation		Drinking Water Issue	Rationale
			Exceeds ODWQS	Above detection limit	Above local background level	Value	Type[2]	Trend	Exceed within 50 years		
Schedule 1											
Coliforms	Raw	2003/ 2007	Yes			0 cfu/100mL	MAC	_	No	No	• Rare exceedances in low numbers • Adequate treatment
Coliforms	Treated	2003/ 2007	Yes			0 cfu/100mL	MAC	_	No	No	• Adequate treatment
E. coli	Raw	2003/ 2007	Yes			0 cfu/100mL	MAC	_	No	No	• Rare exceedances in low numbers • Adequate treatment
Schedule 2 & Table 4											
Turbidity	Treated	2003/ 2007	Yes			5 NTU	OG	_	No	No	• Occasional exceedance of standard

[1]Indicates if the data on record is for raw (untreated) or treated water

[2]Standard types: MAC=Maximum Acceptable Concentration; AO=Aesthetic Objective; OG=Operational Guideline

5.3.2.8 WOODFIELD

The drinking water issues evaluation for the Woodfield municipal well system is summarized in Table 5.3-11, which lists the water quality parameters that exceeded the primary or secondary benchmarks and indicates whether or not they were considered issues and the rationale for the conclusion. No drinking water issues were identified. Concentrations of sodium are consistently less than the drinking water standard of 200 mg/L, but occasionally exceeded the guideline of 20 mg/L for sodium restricted diets. No upward trends were noted for the parameters present.

Table 5.3-11: Woodfield Water Quality Standards Exceedances

Parameter	Water Type[1]	Years on Record	Benchmark Exceedances			Standard		Extrapolation		Drinking Water Issue	Rationale
			Exceeds ODWQS	Above detection limit	Above local background level	Value	Type[2]	Trend	Exceed within 50 years		
Schedule 1											
Coliforms	Raw	2003/ 2007	Yes			0 cfu/100mL	MAC	_	No	No	• Rare exceedances in low numbers • Adequate treatment
Coliforms	Treated	2003/ 2007	Yes			0 cfu/100mL	MAC	_	No	No	• Adequate treatment
Schedule 2 & Table 4											
Turbidity	Treated	2003/ 2007	Yes			5 NTU	OG	_	No	No	• Occasional exceedance of standard
Sodium	Treated	2003/ 2007	Yes			200 mg/L	AO	_	No	No	• No exceedance of standard in 50 years

[1]Indicates if the data on record is for raw (untreated) or treated water

[2]Standard types: MAC=Maximum Acceptable Concentration; AO=Aesthetic Objective; OG=Operational Guideline

5.3.2.9 MANORVIEW ESTATES

The drinking water issues evaluation for the Manorview Estates municipal well system is summarized in Table 5.3-12, which lists the water quality parameters that exceeded the primary or secondary benchmarks and indicates whether or not they were considered issues and the rationale for the conclusion. No drinking water issues were identified. The sodium concentration data display an increasing trend, but concentrations are not projected to exceed the drinking water standard in 50 years. Concentrations are consistently less than the guideline of 20 mg/L for sodium restricted diets, but are projected to exceed this guideline within 50 years.

Table 5.3-12: Manorview Estates Water Quality Standards Exceedances

Parameter	Water Type[1]	Years on Record	Benchmark Exceedances			Standard		Extrapolation		Drinking Water Issue	Rationale
			Exceeds ODWQS	Above detection limit	Above local background level	Value	Type[2]	Trend	Exceed within 50 years		
Schedule 1											
Coliforms	Raw	2003/ 2007	Yes			0 cfu/100mL	MAC	–	No	No	• Rare exceedances in low numbers • Adequate treatment
Coliforms	Treated	2003/ 2007	Yes			0 cfu/100mL	MAC	–	No	No	• Adequate treatment
Schedule 2 & Table 4											
Dichloromethane	Treated	2003/ 2007		Yes		0.05 mg/L	MAC	–	No	No	• Present on rare occasions (in trace concentrations) • Not persistent
Lead	Treated	2003/ 2007		Yes		0.01 mg/L	MAC	–	No	No	• Significantly less than standard • May be slight increasing trend but insufficient data to confirm
Sodium	Treated	2003/ 2007		Yes		200 mg/L	AO	?	No	No	• No exceedance of standard in 50 years

[1]Indicates if the data on record is for raw (untreated) or treated water

[2]Standard types: MAC=Maximum Acceptable Concentration; AO=Aesthetic Objective; OG=Operational Guideline

5.3.2.10 VICTORIA GLEN

The drinking water issues evaluation for the Victoria Glen municipal well system is summarized in Table 5.3-13, which lists the water quality parameters that exceeded the primary or secondary benchmarks and indicates whether or not they were considered issues and the rationale for the conclusion. No drinking water issues were identified. The sodium concentration data display an increasing trend, but concentrations are not projected to exceed the drinking water standard in 50 years. Concentrations are consistently less than the guideline of 20 mg/L for sodium restricted diets, but are projected to exceed this guideline within 50 years.

Table 5.3-13: Victoria Glen Water Quality Standards Exceedances

Parameter	Water Type[1]	Years on Record	Benchmark Exceedances			Standard		Extrapolation		Drinking Water Issue	Rationale
			Exceeds ODWQS	Above detection limit	Above local background level	Value	Type[2]	Trend	Exceed within 50 years		
Schedule 1											
Coliforms	Raw	2003/ 2007	Yes			0 cfu/100mL	MAC	_	No	No	• Rare exceedances in low numbers • Adequate treatment
Coliforms	Treated	2003/ 2007	Yes			0 cfu/100mL	MAC	_	No	No	• Adequate treatment
Schedule 2 & Table 4											
Sodium	Treated	2003/ 2007		Yes		200 mg/L	AO	↑	No	No	• No exceedance of standard in 50 years
Nitrate	Treated	2003/ 2007		Yes		10 mg/L	MAC	_	No	No	• Less than drinking water standard • No upward trend observed
Turbidity	Treated	2003/ 2007	Yes			5 NTU	OG	_	No	No	• Occasional exceedance of standard

[1]Indicates if the data on record is for raw (untreated) or treated water
[2]Standard types: MAC=Maximum Acceptable Concentration; AO=Aesthetic Objective; OG=Operational Guideline

5.3.2.11 VICTORIA PLACE

The drinking water issues evaluation for the Victoria Place municipal well system is summarized in Table 5.3-14, which lists the water quality parameters that exceeded the primary or secondary benchmarks and indicates whether or not they were considered issues and the rationale for the conclusion. No drinking water issues were identified. Concentrations of sodium are consistently less than the drinking water standard of 200 mg/L but consistently above the guideline of 20 mg/L for sodium restricted diets. No upward trends were noted for the parameters present.

Table 5.3-14: Victoria Place Quality Standards Exceedances

Parameter	Water Type[1]	Years on Record	Benchmark Exceedances			Standard		Extrapolation		Drinking Water Issue	Rationale
			Exceeds ODWQS	Above detection limit	Above local background level	Value	Type[2]	Trend	Exceed within 50 years		
Schedule 1											
Coliforms	Raw	2003/ 2007	Yes			0 cfu/100mL	MAC	_	No	No	• Rare exceedances in low numbers • Adequate treatment
Coliforms	Treated	2003/ 2007	Yes			0 cfu/100mL	MAC	_	No	No	• Adequate treatment
E. coli	Raw	2003/ 2007	Yes			0 cfu/100mL	MAC	_	No	No	• Rare exceedances in low numbers • Adequate treatment
Schedule 2 & Table 4											
Sodium	Treated	2003/ 2007		Yes		200 mg/L	AO	_	No	No	• Less than drinking water standard • No discernable trend observed
Turbidity	Treated	2003/ 2007	Yes			5 NTU	OG	_	No	No	• Occasional exceedance of standard

[1]Indicates if the data on record is for raw (untreated) or treated water
[2]Standard types: MAC=Maximum Acceptable Concentration; AO=Aesthetic Objective; OG=Operational Guideline

5.3.2.12 BIRCH POINT

The drinking water issues evaluation for the Birch Point municipal well system is summarized in Table 5.3-15, which lists the water quality parameters that exceeded the primary or secondary benchmarks and indicates whether or not they were considered issues and the rationale for the conclusion. No drinking water issues were identified. Concentrations of sodium are consistently less than the drinking water standard of 200 mg/L but occasionally exceeded the guideline of 20 mg/L for sodium restricted diets. No upward trends were noted for the parameters present.

Table 5.3-15: Birch Point Water Quality Standards Exceedances

Parameter	Water Type[1]	Years on Record	Benchmark Exceedances			Standard		Extrapolation		Drinking Water Issue	Rationale
			Exceeds ODWQS	Above detection limit	Above local background level	Value	Type[2]	Trend	Exceed within 50 years		
Schedule 1											
Coliforms	Raw	2003/ 2007	Yes			0 cfu/100mL	MAC	_	Yes	No	• Rare exceedances in low numbers • Adequate treatment
Coliforms	Treated	2003/ 2007	Yes			0 cfu/100mL	MAC	_	Yes	No	• Adequate treatment
Schedule 2 & Table 4											
Sodium	Treated	2003/ 2007		Yes		200 mg/L	AO	_	No	No	• Less than drinking water standard • Uncertain trend • No exceedance of standard in 50 years
Turbidity	Treated	2003/ 2007	Yes			5 NTU	OG	_	No	No	• Occasional exceedance of standard

[1]Indicates if the data on record is for raw (untreated) or treated water
[2]Standard types: MAC=Maximum Acceptable Concentration; AO=Aesthetic Objective; OG=Operational Guideline

5.3.2.13 PINEWOOD

The drinking water issues evaluation for the Pinewood municipal well system is summarized in Table 5.3-16, which lists the water quality parameters that exceeded the primary or secondary benchmarks and indicates whether or not they were considered issues and the rationale for the conclusion. No drinking water issues were identified. The sodium concentration data display an increasing trend, but concentrations are not projected to exceed the drinking water standard in 50 years. Concentrations are consistently less than the guideline of 20 mg/L for sodium restricted diets, but are projected to exceed this guideline within 50 years.

Table 5.3-16: Pinewood Water Quality Standards Exceedances

Parameter	Water Type[1]	Years on Record[2]	Benchmark Exceedances			Standard		Extrapolation		Drinking Water Issue	Rationale
			Exceeds ODWQS	Above detection limit	Above local background level	Value	Type[3]	Trend	Exceed within 50 years		
Schedule 1											
Coliforms	Raw	2003/ 2007	Yes			0 cfu/100mL	MAC	_	No	No	• Rare exceedances in low numbers • Adequate treatment
Coliforms	Treated	2003/ 2007	Yes			0 cfu/100mL	MAC	_	No	No	• Adequate treatment
E. coli	Raw	2003/ 2007	Yes			0 cfu/100mL	MAC	_	No	No	• Rare exceedances in low numbers • Adequate treatment
Schedule 2 & Table 4											
Sodium	Treated	2003/ 2007		Yes		200 mg/L	AO	↑	No	No	• No exceedance of standard in 50 years
Turbidity	Treated	2003/ 2007	Yes			5 NTU	OG	_	No	No	• Occasional exceedance of standard

[1]Indicates if the data on record is for raw (untreated) or treated water

[2] Data not available for Well #5, data shown is for Wells #2, #3, and #4.

[3] Standard types: MAC=Maximum Acceptable Concentration; AO=Aesthetic Objective; OG=Operational Guideline

5.3.2.14 BLACKSTOCK

The drinking water issues evaluation for the Blackstock municipal well system is summarized in Table 5.3-17, which list the water quality parameters that exceeded the primary or secondary benchmarks and indicate whether or not they were considered issues and the rationale for the conclusion. Though, one drinking water issue was identified; nitrate has been confirmed as an issue as per Technical Rule 115 for well MW1 due to an increasing trend expected to exceed the standard in approximately 10 years, however, as per the 2014 notice issued by the Region of Durham, well MW1 was decommissioned from service. Therefore, currently this drinking water system does not have any issues.

Concentrations of sodium are consistently less than the drinking water standard of 200 mg/L in the treated water at both wells, but occasionally exceeded the guideline of 20 mg/L for sodium restricted diets.

The concentrations of the naturally occurring parameters colour, iron, and manganese were observed to exceed the aesthetic objectives at MW8. Total dissolved solids concentrations were observed to exceed the aesthetic objective at MW8. These parameters are not considered to be a drinking water issue because concentrations are not likely to impair the water for use as a source of drinking water. Treatment measures have been taken to minimize the effects of these parameters.

Table 5.3-17: Blackstock Water Quality Standards Exceedances (MW8)

Parameter	Water Type[1]	Years on Record	Benchmark Exceedances			Standard		Extrapolation		Drinking Water Issue	Rationale
			Exceeds ODWQS	Above detection limit	Above local background level	Value	Type[2]	Trend	Exceed within 50 years		
Schedule 1											
Coliforms	Raw	2004/ 2007	Yes			0 cfu/100mL	MAC	_	**	No	• Occasional exceedances • Considered anomalous
Schedule 2 & Table 4											
Chlordane	Unknown	2004/ 2007		Yes	Yes	7 µg/L	MAC	_		No	• Trace concentrations • Not consistently above detection limit • Insufficient data for trend analysis
Chloride	Raw	2004/ 2007		Yes	Yes	250 mg/L	AO	↑	No	No	• Occasional detection • No exceedance of standard in 50 years
Chloroform	Raw	2004/ 2007		Yes		0.1 mg/L+	MAC	↑	No	No	• Trace concentrations • By-products of disinfection by chlorination • Increasing trend/No exceedance of standard in 50 years
Chlorpyrifos	Unknown	2004/ 2007		Yes	Yes	0.09 mg/L	MAC	_		No	• Trace concentrations • Not consistently above detection limit • Insufficient data for trend analysis
Colour	Raw	2004/ 2007	Yes			5 TCU	AO	_		No	• Occasional exceedance of standard • No deterioration of drinking water quality
Dibromochloromethane	Raw	2004/ 2007		Yes		0.1 mg/L+	MAC	_		No	• Trace concentrations • By-products of disinfection by chlorination • No discernable trend

Parameter	Water Type[1]	Years on Record	Benchmark Exceedances			Standard		Extrapolation		Drinking Water Issue	Rationale
			Exceeds ODWQS	Above detection limit	Above local background level	Value	Type[2]	Trend	Exceed within 50 years		
Dioxin	Unknown	2004/ 2007		Yes	Yes	0.000015 µg/L*	IMAC	_		No	• Trace concentrations • Not consistently above detection limit • Insufficient data for trend analysis
Furan	Unknown	2004/ 2007		Yes	Yes	0.000015 µg/L*	IMAC	_		No	• Trace concentrations • Not consistently above detection limit • Insufficient data for trend analysis
Hardness	Raw	2004/ 2007	Yes			80-100 mg/L $CaCO_3$	OG	↑		No	• No deterioration of drinking water quality
Iron	Raw	2004/ 2007	Yes			0.3 mg/L	AO	_		No	• Occasional exceedance of standard • No deterioration of drinking water quality • Treatment in place
Lead	Raw	2004/ 2007	Yes			0.01 mg/L	MAC	_		No	• Occasional exceedances • Considered anomalous
Manganese	Raw	2004/ 2007	Yes			0.05 mg/L	AO	↑	No	No	• Occasional exceedance of standard • No deterioration of drinking water quality
NDMA	Unknown	2004/ 2007		Yes	Yes	0.009 ug/L	MAC	⇨		No	• Trace concentrations • Not consistently above detection limit • Insufficient data for trend analysis
Sodium	Raw	2004/ 2007		Yes	Yes	200 mg/L	AO	↑	No	No	• No exceedance of standard in 50 years
Total Dissolved Solids	Raw	2004/ 2007		Yes		500 mg/l	AO	↑	No	No	• Occasional exceedance of standard
Trihalomethane	Unknown	2004/ 2007		Yes	Yes	0.1 mg/L	MAC	_		No	• Trace concentrations • By-products of disinfection by chlorination • No discernable trend

*Measured as 2,3,7,8 – TEDD
+Applicable to chemicals under THM group
[1]Indicates if the data on record is for raw (untreated) or treated water
[2]Standard types: MAC=Maximum Acceptable Concentration; IMAC=Interim Maximum Acceptable Concentration AO=Aesthetic Objective; O G=Operational Guideline

5.3.2.15 GREENBANK

The drinking water issues evaluation for the Greenbank municipal well system is summarized in Table 5.3-18 through Table 5.3-23, which list the water quality parameters that exceeded the primary or secondary benchmarks and indicate whether or not they were considered issues and the rationale for the conclusion. No drinking water issues were identified.

Concentrations of sodium are consistently less than the drinking water standard of 200 mg/L but occasionally exceeded the guideline of 20 mg/L for sodium restricted diets. The trend analysis indicates that sodium levels are increasing at 3 of the wells but concentrations are not expected to exceed the standard within 50 years.

Table 5.3-18: Greenbank Water Quality Standards Exceedances (Water Supply)

Parameter	Water Type[1]	Years on Record	Benchmark Exceedances			Standard		Extrapolation		Drinking Water Issue	Rationale
			Exceeds ODWQS	Above detection limit	Above local background level	Value	Type[2]	Trend	Exceed within 50 years		
Schedule 1											
Coliforms	Treated	2002/ 2007	Yes			0 cfu/100mL	MAC	_	No	No	• Rare exceedances • Considered anomalous • Adequate treatment
Schedule 2 & Table 4											
Hardness	Treated	2002/ 2007	Yes			80-100 mg/L $CaCO_3$	OG	_	No	No	• Occasional exceedance of standard • No deterioration of drinking water quality
Iron	Treated	2002/ 2007	Yes			0.3 mg/L	AO	_	No	No	• Occasional exceedance of standard • No deterioration of drinking water quality
Sodium	Treated	2002/ 2007		Yes		200 mg/L	AO	_	No	No	• No exceedance of standard in 50 years
Trihalomethane	Treated	2002/ 2007		Yes		0.1 mg/L	MAC	_	No	No	• Trace concentrations in treated water • By-products of disinfection by chlorination • No discernable trend

[1]Indicates if the data on record is for raw (untreated) or treated water
[2]Standard types: MAC=Maximum Acceptable Concentration; AO=Aesthetic Objective; OG=Operational Guideline

Table 5.3-19: Greenbank Water Quality Standards Exceedances (Well MW1)

Parameter	Water Type[1]	Years on Record	Benchmark Exceedances			Standard		Extrapolation		Drinking Water Issue	Rationale
			Exceeds ODWQS	Above detection limit	Above local background level	Value	Type[2]	Trend	Exceed within 50 years		
Schedule 1											
Coliforms	Raw	2002/ 2007	Yes			0 cfu/100mL	MAC	_	No	No	• Rare exceedances • Considered anomalous • Adequate treatment
Schedule 2 & Table 4											
2,4,6-Tribromophenol	Raw	2002/ 2007		Yes		NA		_	No	No	• Occasionally present in trace concentrations • Insufficient data for trend analysis
2-nitrophenol	Raw	2002/ 2007		Yes		NA		_	No	No	• Occasionally present in trace concentrations • Insufficient data for trend analysis
4-bromofluorobenzene	Raw	2002/ 2007		Yes		NA		_	No	No	• Occasionally present in trace concentrations • Insufficient data for trend analysis
Colour	Raw	2002/ 2007	Yes			5 TCU	AO	_	No	No	• Occasional exceedance of standard • No deterioration of drinking water quality
Decachlorobiphenyl	Raw	2002/ 2007		Yes		0.003 mg/L◊	IMAC	_	No	No	• Occasionally present in trace concentrations • Insufficient data for trend analysis
Dibromofluoromethane	Raw	2002/ 2007		Yes		0.1 mg/L+	MAC	_	No	No	• Occasionally present in trace concentrations • Insufficient data for trend analysis
Dioxin and Furan	Raw	2002/ 2007		Yes		0.000015 µg/L*	IMAC	_	No	No	• Occasionally present in trace concentrations • Insufficient data for trend analysis
Ethylbenzene-d10	Raw	2002/ 2007		Yes		2.4 µg/L	AO	_	No	No	• Occasionally present in trace concentrations • Insufficient data for trend analysis
Hardness	Raw	2002/ 2007	Yes			80-100 mg/L $CaCO_3$	OG	_	No	No	• Occasional exceedance of standard • No deterioration of drinking water quality
Iron	Raw	2002/ 2007	Yes			0.3 mg/L	AO	↑	No	No	• Occasional exceedance of standard • No deterioration of drinking water quality • Treatment in place
Methane	Raw	2002/ 2007		Yes		3 L/m³	AO	_	No	No	• Occasionally present in trace concentrations • Insufficient data for trend analysis
Nitrate	Raw	2002/ 2007		Yes		10 mg/L	MAC	↑	No	No	• Persistent occurrences • No exceedance of standard in 50 years
Sodium	Raw	2002/ 2007		Yes		200 mg/L	AO	↑	No	No	• Increasing trend • No exceedance of standard in 50 years
Toluene-d8	Raw	2002/ 2007		Yes		0.024 mg/L	AO	_	No	No	• Occasionally present in trace concentrations • Insufficient data for trend analysis
Total Dissolved Solids	Raw	2002/ 2007	Yes			500 mg/l	AO	_	No	No	• Occasional exceedance of standard • No deterioration of drinking water quality
Turbidity	Raw	2002/ 2007	Yes			5 NTU	OG	↑	No	No	• Occasional exceedance of standard • No deterioration of drinking water quality • Treatment in place

*Measured as 2,3,7,8 – TEDD
◊ Applicable to chemicals in PCB group
+Applicable to chemicals under THM group

[1]Indicates if the data on record is for raw (untreated) or treated water
[2]Standard types: MAC=Maximum Acceptable Concentration; IMAC=Interim Maximum Acceptable Concentration; AO=Aesthetic Objective; OG=Operational Guideline

Table 5.3-20: Greenbank Water Quality Standards Exceedances (Well MW3)

Parameter	Water Type[1]	Years on Record	Benchmark Exceedances			Standard		Extrapolation		Drinking Water Issue	Rationale
			Exceeds ODWQS	Above detection limit	Above local background level	Value	Type[2]	Trend	Exceed within 50 years		
Schedule 1											
Coliforms	Raw	2002/ 2007	Yes			0 cfu/100mL	MAC	_	No	No	• Rare exceedances • Considered anomalous • Adequate treatment
Schedule 2 & Table 4											
2,4,6-Tribromophenol	Raw	2002/ 2007		Yes		NA		_	No	No	• Occasionally present in trace concentrations • Insufficient data for trend analysis
2-nitrophenol	Raw	2002/ 2007		Yes		NA		_	No	No	• Occasionally present in trace concentrations • Insufficient data for trend analysis
4-bromofluorobenzene	Raw	2002/ 2007		Yes		NA		_	No	No	• Occasionally present in trace concentrations • Insufficient data for trend analysis
Colour	Raw	2002/ 2007	Yes			5 TCU	AO	_	No	No	• Occasional exceedance of standard • No deterioration of drinking water quality
Decachlorobiphenyl	Raw	2002/ 2007		Yes		0.003 mg/L◊	IMAC	_	No	No	• Occasionally present in trace concentrations • Insufficient data for trend analysis
Dibromofluoromethane	Raw	2002/ 2007		Yes		0.1 mg/L+	MAC	_	No	No	• Occasionally present in trace concentrations • Insufficient data for trend analysis
Dioxin and Furan	Raw	2002/ 2007		Yes		0.000015 µg/L*	IMAC	_	No	No	• Occasionally present in trace concentrations • Insufficient data for trend analysis
Ethylbenzene-d10	Raw	2002/ 2007		Yes		2.4 µg/L	AO	_	No	No	• Occasionally present in trace concentrations • Insufficient data for trend analysis
Hardness	Raw	2002/ 2007	Yes			80-100 mg/L $CaCO_3$	OG	_	No	No	• Occasional exceedance of standard • No deterioration of drinking water quality
Iron	Raw	2002/ 2007	Yes			0.3 mg/L	AO	↓	No	No	• Occasional exceedance of standard • No deterioration of drinking water quality • Treatment in place
Methane	Raw	2002/ 2007		Yes		3 L/m^3	AO	_	No	No	• Occasionally present in trace concentrations • Insufficient data for trend analysis
NDMA	Raw			Yes		0.009 ug/L	MAC	_	No	No	• Occasionally present in trace concentrations • Insufficient data for trend analysis
Nitrate	Raw	2002/ 2007		Yes		10 mg/L	MAC	↑	No	No	• Persistent occurrences • No exceedance of standard in 50 years
Sodium	Raw	2002/ 2007		Yes		200 mg/L	AO	↑	No	No	• Increasing trend • No exceedance of standard in 50 years
Sulphate	Raw	2002/ 2007		Yes		500 mg/L	AO	↑	No	No	• Persistent detection • No exceedance of standard in 50 years
Toluene-d8	Raw	2002/ 2007		Yes		0.024 mg/L	AO	_	No	No	• Occasionally present in trace concentrations • Insufficient data for trend analysis
Total Dissolved Solids	Raw	2002/ 2007	Yes			500 mg/l	AO	↑	No	No	• Occasional exceedance of standard • No deterioration of drinking water quality
Turbidity	Raw	2002/ 2007	Yes			5 NTU	OG	↓	No	No	• Occasional exceedance of standard • No deterioration of drinking water quality • Treatment in place

*Measured as 2,3,7,8 – TEDD
◊ Applicable to chemicals in PCB group
+Applicable to chemicals under THM group

[1]Indicates if the data on **record** is for raw (untreated) or treated water
[2]Standard types: MAC=Maximum Acceptable Concentration; IMAC=Interim Maximum Acceptable Concentration; AO=Aesthetic Objective; OG=Operational Guideline

Table 5.3-21: Greenbank Water Quality Standards Exceedances (Well MW4)

Parameter	Water Type[1]	Years on Record	Benchmark Exceedances			Standard		Extrapolation		Drinking Water Issue	Rationale
			Exceeds ODWQS	Above detection limit	Above local background level	Value	Type[2]	Trend	Exceed within 50 years		
Schedule 1											
Coliforms	Raw	2002/ 2007	Yes			0 cfu/100mL	MAC	_	No	No	• Rare exceedances • Considered anomalous • Adequate treatment
E. coli	Raw	2002/ 2007	Yes			0 cfu/100mL	MAC	_	No	No	• Rare exceedances • Considered anomalous • Adequate treatment
Schedule 2 & Table 4											
2,4,6-Tribromophenol	Raw	2002/ 2007		Yes		NA		_	No	No	• Occasionally present in trace concentrations • Insufficient data for trend analysis
2-nitrophenol	Raw	2002/ 2007		Yes		NA		_	No	No	• Occasionally present in trace concentrations • Insufficient data for trend analysis
4-bromofluorobenzene	Raw	2002/ 2007		Yes		NA		_	No	No	• Occasionally present in trace concentrations • Insufficient data for trend analysis
Colour	Raw	2002/ 2007	Yes			5 TCU	AO	_	No	No	• Occasional exceedance of standard • No deterioration of drinking water quality
Decachlorobiphenyl	Raw	2002/ 2007		Yes		0.003 mg/L◊	IMAC	_	No	No	• Occasionally present in trace concentrations • Insufficient data for trend analysis
Dibromofluoromethane	Raw	2002/ 2007		Yes		0.1 mg/L+	MAC	_	No	No	• Occasionally present in trace concentrations • Insufficient data for trend analysis
Dioxin and Furan	Raw	2002/ 2007		Yes		0.000015 µg/L*	IMAC	_	No	No	• Occasionally present in trace concentrations • Insufficient data for trend analysis
Ethylbenzene-d10	Raw	2002/ 2007		Yes		2.4 µg/L	AO	_	No	No	• Occasionally present in trace concentrations • Insufficient data for trend analysis
Hardness	Raw	2002/ 2007	Yes			80-100 mg/L $CaCO_3$	OG	↓	No	No	• Occasional exceedance of standard • No deterioration of drinking water quality
Iron	Raw	2002/ 2007	Yes			0.3 mg/L	AO	_	No	No	• Occasional exceedance of standard • No deterioration of drinking water quality • Treatment in place
Manganese	Raw	2002/ 2007		Yes		0.05 mg/L	AO	↑	Yes	No	• Projected to exceed standard in 50 years • No deterioration of drinking water quality
Methane	Raw	2002/ 2007		Yes		3 L/m³	AO	_	No	No	• Occasionally present in trace concentrations • Insufficient data for trend analysis
Nitrate	Raw	2002/ 2007		Yes		10 mg/L	MAC	↑	No	No	• Persistent occurrences • No exceedance of standard in 50 years
Sulphate	Raw	2002/ 2007		Yes		500 mg/L	AO	↑	No	No	• Persistent detection • No exceedance of standard in 50 years
Toluene-d8	Raw	2002/ 2007		Yes		0.024 mg/L	AO	_	No	No	• Occasionally present in trace concentrations • Insufficient data for trend analysis

*Measured as 2,3,7,8 – TEDD
◊ Applicable to chemicals in PCB group
+Applicable to chemicals under THM group

[1]Indicates if the data on record is for raw (untreated) or treated water
[2]Standard types: MAC=Maximum Acceptable Concentration; IMAC=Interim Maximum Acceptable Concentration; AO=Aesthetic Objective; OG=Operational Guideline

Table 5.3-22: Greenbank Water Quality Standards Exceedances (Well MW5)

Parameter	Water Type[1]	Years on Record	Benchmark Exceedances			Standard		Extrapolation		Drinking Water Issue	Rationale
			Exceeds ODWQS	Above detection limit	Above local background level	Value	Type[2]	Trend	Exceed within 50 years		
Schedule 1											
Coliforms	Raw	2002/ 2007	Yes			0 cfu/100mL	MAC	_	No	No	• Rare exceedances • Considered anomalous • Adequate treatment
Schedule 2 & Table 4											
2,4,6-Tribromophenol	Raw	2002/ 2007		Yes		NA		_	No	No	• Occasionally present in trace concentrations • Insufficient data for trend analysis
2-nitrophenol	Raw	2002/ 2007		Yes		NA		_	No	No	• Occasionally present in trace concentrations • Insufficient data for trend analysis
4-bromofluorobenzene	Raw	2002/ 2007		Yes		NA		_	No	No	• Occasionally present in trace concentrations • Insufficient data for trend analysis
Colour	Raw	2002/ 2007	Yes			5 TCU	AO	_	No	No	• Occasional exceedance of standard • No deterioration of drinking water quality
Decachlorobiphenyl	Raw	2002/ 2007		Yes		0.003 mg/L◊	IMAC	_	No	No	• Occasionally present in trace concentrations • Insufficient data for trend analysis
Dibromofluoromethane	Raw	2002/ 2007		Yes		0.1 mg/L+	MAC	_	No	No	• Occasionally present in trace concentrations • Insufficient data for trend analysis
Dioxin and Furan	Raw	2002/ 2007		Yes		0.000015 µg/L*	IMAC	_	No	No	• Occasionally present in trace concentrations • Insufficient data for trend analysis
Ethylbenzene-d10	Raw	2002/ 2007		Yes		2.4 µg/L	AO	_	No	No	• Occasionally present in trace concentrations • Insufficient data for trend analysis
Hardness	Raw	2002/ 2007	Yes			80-100 mg/L $CaCO_3$	OG	↓	No	No	• Occasional exceedance of standard • No deterioration of drinking water quality
Iron	Raw	2002/ 2007	Yes			0.3 mg/L	AO	_	No	No	• Occasional exceedance of standard • No deterioration of drinking water quality • Treatment in place
Methane	Raw	2002/ 2007		Yes		3 L/m^3	AO	_	No	No	• Occasionally present in trace concentrations • Insufficient data for trend analysis
Sulphate	Raw	2002/ 2007		Yes		500 mg/L	AO	↑	No	No	• Persistent detection • No exceedance of standard in 50 years
Toluene-d8	Raw	2002/ 2007		Yes		0.024 mg/L	AO	_	No	No	• Occasionally present in trace concentrations • Insufficient data for trend analysis
Turbidity	Raw	2002/ 2007		Yes		5 NTU	OG	↓	No	No	• Occasional exceedance of standard • No deterioration of drinking water quality • Treatment in place

*Measured as 2,3,7,8 – TEDD
◊ Applicable to chemicals in PCB group
+Applicable to chemicals under THM group

[1]Indicates if the data on record is for raw (untreated) or treated water
[2]Standard types: MAC=Maximum Acceptable Concentration; IMAC=Interim Maximum Acceptable Concentration; AO=Aesthetic Objective; OG=Operational Guideline

Table 5.3-23: Greenbank Water Quality Standards Exceedances (Well MW6)

Parameter	Water Type[1]	Years on Record	Benchmark Exceedances			Standard		Extrapolation		Drinking Water Issue	Rationale
			Exceeds ODWQS	Above detection limit	Above local background level	Value	Type[2]	Trend	Exceed within 50 years		
Schedule 2 & Table 4											
2,4,6-Tribromophenol	Raw	2002/ 2007		Yes		NA		–	No	No	• Occasionally present in trace concentrations • Insufficient data for trend analysis
2-nitrophenol	Raw	2002/ 2007		Yes		NA		–	No	No	• Occasionally present in trace concentrations • Insufficient data for trend analysis
4-bromofluorobenzene	Raw	2002/ 2007		Yes		NA		–	No	No	• Occasionally present in trace concentrations • Insufficient data for trend analysis
Decachlorobiphenyl	Raw	2002/ 2007		Yes		0.003 mg/L◊	IMAC	–	No	No	• Occasionally present in trace concentrations • Insufficient data for trend analysis
Dibromofluoromethane	Raw	2002/ 2007		Yes		0.1 mg/L+	MAC	–	No	No	• Occasionally present in trace concentrations • Insufficient data for trend analysis
Dioxin and Furan	Raw	2002/ 2007		Yes		0.000015 μg/L*	IMAC	–	No	No	• Occasionally present in trace concentrations • Insufficient data for trend analysis
Ethylbenzene-d10	Raw	2002/ 2007		Yes		2.4 μg/L	AO	–	No	No	• Occasionally present in trace concentrations • Insufficient data for trend analysis
Hardness	Raw	2002/ 2007	Yes			80-100 mg/L $CaCO_3$	OG	↓	No	No	• Occasional exceedance of standard • No deterioration of drinking water quality
Iron	Raw	2002/ 2007	Yes			0.3 mg/L	AO	↓	No	No	• Occasional exceedance of standard • No deterioration of drinking water quality • Treatment in place
Methane	Raw	2002/ 2007		Yes		3 L/m^3	AO	–	No	No	• Occasionally present in trace concentrations • Insufficient data for trend analysis
Sodium	Raw	2002/ 2007		Yes		200 mg/L	AO	↑	No	No	• Increasing trend • No exceedance of standard in 50 years
Sulphate	Raw	2002/ 2007		Yes		500 mg/L	AO	↑	No	No	• Persistent detection • No exceedance of standard in 50 years
Toluene-d8	Raw	2002/ 2007		Yes		0.024 mg/L	AO	–	No	No	• Occasionally present in trace concentrations • Insufficient data for trend analysis
Total Dissolved Solids	Raw	2002/ 2007	Yes			500 mg/L	AO	↓	No	No	• Occasional exceedance of standard • No deterioration of drinking water quality

*Measured as 2,3,7,8 – TEDD
◊ Applicable to chemicals in PCB group
+Applicable to chemicals under THM group
[1]Indicates if the data on record is for raw (untreated) or treated water
[2]Standard types: MAC=Maximum Acceptable Concentration; IMAC=Interim Maximum Acceptable Concentration; AO=Aesthetic Objective; OG=Operational Guideline

5.3.2.16 PORT PERRY

The drinking water issues evaluation for the Port Perry municipal well system is summarized in Table 5.3-24 through Table 5.3-26, which list the water quality parameters that exceeded the primary or secondary benchmarks and indicate whether or not they were considered issues and the rationale for the conclusion. No drinking water issues were identified.

Concentrations of sodium are consistently less than the drinking water standard of 200 mg/L as well as the guideline of 20 mg/L for sodium restricted diets. The trend analysis for Municipal Well 6 indicates that concentrations are projected to exceed the guideline of 20 mg/L within 50 years.

Table 5.3-24: Port Perry Water Quality Standards Exceedances (Well MW3)

Parameter	Water Type[1]	Years on Record	Benchmark Exceedances			Standard		Extrapolation		Drinking Water Issue	Rationale
			Exceeds ODWQS	Above detection limit	Above local background level	Value	Type[2]	Trend	Exceed within 50 years		
Schedule 1											
Coliforms	Raw	2004/ 2007	Yes			0 cfu/100mL	MAC	_		No	• Rare exceedances • Considered anomalous • Adequate treatment
E. coli	Raw	2004/ 2007	Yes			0 cfu/100mL	MAC	_		No	• Rare exceedances • Considered anomalous • Adequate treatment
Schedule 2 & Table 4											
Chloride	Raw	2004/ 2007		Yes	Yes	250 mg/L	AO	↑	No	No	• Persistent detection • No exceedance of standard in 50 years
Colour	Raw	2004/ 2007	Yes			5 TCU	AO	_		No	• Occasional exceedance of standard • No deterioration of drinking water quality
Hardness	Raw	2004/ 2007	Yes			80-100 mg/L $CaCO_3$	OG	↓		No	• No deterioration of drinking water quality
Iron	Raw	2004/ 2007	Yes			0.3 mg/L	AO	_		No	• Occasional detection • No deterioration of drinking water quality • Treatment in place
Lead	Raw	2004/ 2007	Yes			0.01 mg/L	MAC	_		No	• Occasional exceedances • Considered anomalous
Sodium	Raw	2004/ 2007		Yes	Yes	200 mg/L	AO	↑	No	No	• Increasing trend • No exceedance of standard in 50 years

[1]Indicates if the data on record is for raw (untreated) or treated water
[2]Standard types: MAC=Maximum Acceptable Concentration; AO=Aesthetic Objective; OG=Operational Guideline

Table 5.3-25: Port Perry Water Quality Standards Exceedances (Well MW5)

Parameter	Water Type[1]	Years on Record	Benchmark Exceedances			Standard		Extrapolation		Drinking Water Issue	Rationale
			Exceeds ODWQS	Above detection limit	Above local background level	Value	Type[2]	Trend	Exceed within 50 years		
Schedule 1											
Coliforms	Raw	2004/ 2007	Yes			0 cfu/100mL	MAC	_		No	• Rare exceedances • Considered anomalous • Adequate treatment
Schedule 2 & Table 4											
Chlordane	Unknown	2004/ 2007		Yes	Yes	7 µg/L	MAC	_		No	• Trace concentrations • Not consistently above detection limit • Trends not apparent
Chloride	Raw	2004/ 2007		Yes	Yes	250 mg/L	AO	↑	No	No	• Persistent detection • No exceedance of standard in 50 years
Chloroform	Raw	2004/ 2007		Yes		0.1 mg/L+	MAC	_		No	• Trace concentrations • By-products of disinfection by chlorination • No discernable trend
Chlorpyrifos	Unknown	2004/ 2007		Yes	Yes	0.09 mg/L	MAC	_		No	• Trace concentrations • Not consistently above detection limit • Trends not apparent
Colour	Raw	2004/ 2007	Yes			5 TCU	AO	_		No	• Occasional exceedance of standard • No deterioration of drinking water quality
Dibromochloromethane	Raw	2004/ 2007		Yes		0.1 mg/L+	MAC	_		No	• Trace concentrations • By-products of disinfection by chlorination • No discernable trend
Dioxin and Furan	Unknown	2004/ 2007		Yes	Yes	0.000015 µg/L*	IMAC	_		No	• Trace concentrations • Not consistently above detection limit • Trends not apparent
Hardness	Raw	2004/ 2007	Yes			80-100 mg/L $CaCO_3$	OG	↓		No	• No deterioration of drinking water quality
Lead	Raw	2004/ 2007	Yes			0.01 mg/L	MAC	_		No	• Occasional exceedances • Considered anomalous
NDMA	Unknown	2004/ 2007		Yes	Yes	0.009 ug/L	MAC	_		No	• Trace concentrations • Not consistently above detection limit • Trends not apparent
Sodium	Raw	2004/ 2007		Yes	Yes	200 mg/L	AO	↑	No	No	• Increasing trend • No exceedance of standard in 50 years
Trihalomethane	Raw	2004/ 2007		Yes	Yes	0.1 mg/L	MAC	↓		No	• Trace concentrations • By-products of disinfection by chlorination • No discernable trend

*Measured as 2,3,7,8 – TEDD
+Applicable to chemicals under THM group
[1]Indicates if the data on record is for raw (untreated) or treated water
[2]Standard types: MAC=Maximum Acceptable Concentration; IMAC=Interim Maximum Acceptable Concentration; AO=Aesthetic Objective; OG=Operational Guideline

Table 5.3-26: Port Perry Water Quality Standards Exceedances (Well MW6)

Parameter	Water Type[1]	Years on Record	Benchmark Exceedances			Standard		Extrapolation		Drinking Water Issue	Rationale
			Exceeds ODWQS	Above detection limit	Above local background level	Value	Type[2]	Trend	Exceed within 50 years		
Schedule 1											
Coliforms	Raw	2004/ 2007	Yes			0 cfu/100mL	MAC	_	No	No	• Rare exceedances • Considered anomalous • Adequate treatment
Schedule 2 & Table 4											
Chlordane	Unknown	2004/ 2007		Yes	Yes	7 µg/L	MAC	_		No	• Trace concentrations • Not consistently above detection limit • Trends not apparent
Chloride	Raw	2004/ 2007		Yes	Yes	250 mg/L	AO	↑	No	No	• Persistent detection • No exceedance of standard in 50 years
Chloroform	Raw	2004/ 2007		Yes		0.1 mg/L+	MAC	↑	No	No	• Trace concentrations • By-products of disinfection by chlorination • No discernable trend
Chlorpyrifos	Unknown	2004/ 2007		Yes	Yes	0.09 mg/L	MAC	_		No	• Trace concentrations • Not consistently above detection limit • Trends not apparent
Dibromochloromethane	Raw	2004/ 2007		Yes		0.1 mg/L+	MAC	_		No	• Trace concentrations • By-products of disinfection by chlorination • No discernable trend
Dioxin and Furan	Unknown	2004/ 2007		Yes	Yes	0.000015 µg/L*	IMAC	_		No	• Trace concentrations • Not consistently above detection limit • Trends not apparent
Hardness	Raw	2004/ 2007	Yes			80-100 mg/L $CaCO_3$	OG	↑		No	• No deterioration of drinking water quality
Lead	Raw	2004/ 2007	Yes			0.01 mg/L	MAC	_		No	• Occasional exceedances • Considered anomalous
Manganese	Raw	2004/ 2007		Yes		0.05 mg/L	AO	↑	No	No	• Occasional detection • No deterioration of drinking water quality • Treatment in place
NDMA	Unknown	2004/ 2007		Yes	Yes	0.009 ug/L	MAC	_		No	• Trace concentrations • Not consistently above detection limit • Trends not apparent
Sodium	Raw	2004/ 2007		Yes	Yes	200 mg/L	AO	↑	No	No	• Increasing trend • No exceedance of standard in 50 years
Total Dissolved Solids	Raw	2004/ 2007		Yes		500 mg/L	AO	↑	Yes	No	• Occasional detection • Projected to exceed standard in 50 years • No deterioration of drinking water quality
Trihalomethane	Raw	2004/ 2007		Yes	Yes	0.1 mg/L	MAC	↓		No	• Trace concentrations • By-products of disinfection by chlorination • No discernable trend

*Measured as 2,3,7,8 – TEDD
+Applicable to chemicals under THM group

[1]Indicates if the data on record is for raw (untreated) or treated water
[2]Standard types: MAC=Maximum Acceptable Concentration; IMAC=Interim Maximum Acceptable Concentration; AO=Aesthetic Objective; OG=Operational Guideline

5.3.2.17 HAVELOCK

The drinking water issues evaluation for the Havelock municipal well system is summarized in Table 5.3-27 through Table 5.3-30, which list the water quality parameters that exceeded the primary or secondary benchmarks and indicate whether or not they were considered issues and the rationale for the conclusion. No drinking water issues were identified. Concentrations of sodium are consistently less than the drinking water standard of 200 mg/L, but have exceeded the guideline of 20 mg/L for sodium restricted diets. No upward trends were noted for the parameters present.

Table 5.3-27: Havelock Water Quality Standards Exceedances - Well 1 and Well 4 (Treated Water)

Parameter	Water Type[1]	Years on Record	Benchmark Exceedances			Standard		Extrapolation		Drinking Water Issue	Rationale
			Exceeds ODWQS	Above detection limit	Above local background level	Value	Type[2]	Trend	Exceed within 50 years		
Schedule 2 & Table 4											
Sodium	Treated	2005/ 2008		Yes		200 mg/L	AO	_	No	No	• No exceedance of standard in 50 years
Trihalomethane	Treated	2005/ 2008		Yes		0.1 mg/L	MAC	_	No	No	• Trace concentrations in treated water • By-product of treatment

[1]Indicates if the data on record is for raw (untreated) or treated water
[2]Standard types: MAC=Maximum Acceptable Concentration; AO=Aesthetic Objective; OG=Operational Guideline

Table 5.3-28: Havelock Water Quality Standards Exceedances - Well 3 (Raw and Treated Water)

Parameter	Water Type[1]	Years on Record	Benchmark Exceedances			Standard		Extrapolation		Drinking Water Issue	Rationale
			Exceeds ODWQS	Above detection limit	Above local background level	Value	Type[2]	Trend	Exceed within 50 years		
Schedule 1											
Coliforms	Raw	2005/ 2008	Yes			0 cfu/100mL	MAC	_	No	No	• Occasional exceedances • Adequate treatment
E. coli	Raw	2005/ 2008	Yes			0 cfu/100mL	MAC	_	No	No	• Occasional exceedances • Adequate treatment
Schedule 2 & Table 4											
Alkalinity	Treated	2005/ 2008	Yes			30-500 mg/L	OG	_	No	No	• No deterioration of drinking water quality
Diesel	-	2005/ 2008				NA		-	-	No	• Presence due to anomalous event • Corrective action taken
Colour	Raw	2005/ 2008	Yes			5 TCU	AO	_	No	No	• No deterioration of drinking water quality • Treatment in place
Iron	Raw	2005/ 2008	Yes			0.3 mg/L	AO	_	No	No	• No deterioration of drinking water quality • Treatment in place
Manganese	Raw/Treated	2005/ 2008	Yes			0.05 mg/L	AO	_	No	No	• No deterioration of drinking water quality • Treatment in place
Sodium	Raw/Treated	2005/ 2008		Yes		200 mg/L	AO	_	No	No	• No exceedance of standard in 50 years
Trihalomethane	Treated	2005/ 2008		Yes		0.1 mg/L	MAC	_	No	No	• Trace concentrations in treated water • By-product of treatment

[1]Indicates if the data on record is for raw (untreated) or treated water
[2]Standard types: MAC=Maximum Acceptable Concentration; AO=Aesthetic Objective; OG=Operational Guideline

Table 5.3-29: Havelock Water Quality Standards Exceedances - Well 1 (Raw Water)

Parameter	Water Type[1]	Years on Record	Benchmark Exceedances			Standard		Extrapolation		Drinking Water Issue	Rationale
			Exceeds ODWQS	Above detection limit	Above local background level	Value	Type[2]	Trend	Exceed within 50 years		
Schedule 1											
Coliforms	Raw	2005/ 2008	Yes			0 cfu/100mL	MAC	_	No	No	• Occasional exceedances • Adequate treatment
E. coli	Raw	2005/ 2008	Yes			0 cfu/100mL	MAC	_	No	No	• Occasional exceedances • Adequate treatment
Schedule 2 & Table 4											
Turbidity	Raw	2005/ 2008	Yes			5 NTU	OG	_	No	No	• Occasional exceedances • Considered anomalous (due to operations)

Table 5.3-30: Havelock Water Quality Standards Exceedances - Well 4 (Raw Water)

Parameter	Water Type[1]	Years on Record	Benchmark Exceedances			Standard		Extrapolation		Drinking Water Issue	Rationale
			Exceeds ODWQS	Above detection limit	Above local background level	Value	Type[2]	Trend	Exceed within 50 years		
Schedule 1											
Coliforms	Raw	2005/ 2008	Yes			0 cfu/100mL	MAC	_	No	No	• Occasional exceedances • Adequate treatment
E. coli	Raw	2005/ 2008	Yes			0 cfu/100mL	MAC	_	No	No	• Occasional exceedances • Adequate treatment

[1]Indicates if the data on record is for raw (untreated) or treated water
[2]Standard types: MAC=Maximum Acceptable Concentration; AO=Aesthetic Objective; OG=Operational Guideline

5.3.2.18 MINDEN

The drinking water issues evaluation for the Minden municipal well system is summarized in Table 5.3-31, which lists the water quality parameters that exceeded the primary benchmark and indicates whether or not they were considered issues and the rationale for the conclusion. Two issues related to natural sources were identified but no drinking water issues from anthropogenic sources were identified. No parameters that exceeded the secondary benchmark (method detection limit) showed statistically significant trends.

Table 5.3-31: Minden Water Quality Standards Exceedances

Parameter	Water Type[1]	Years on Record	Exceedances		Standard		Drinking Water Issue (Natural)	Drinking Water Issue (Anthropogenic)	Rationale
			%	#	Value	Type[2]			
Schedule 1									
Total Coliforms	Raw	2001 – 2008	52	Max 7	0 cfu/100mL	MAC	NO	NO	• Rare exceedances • Not GUDI; disinfection in place
Table 4									
Iron	Treated	2000 – 2008	55	6	0.3 mg/L	AO	YES	NO	• High background conditions
Manganese	Treated	2000 – 2008	100	12	0.05 mg/L	AO	YES	NO	• High background conditions

[1]Indicates if the data on record is for raw (untreated) or treated water
[2]Standard types: MAC=Maximum Acceptable Concentration; AO=Aesthetic Objective; OG=Operational Guideline

5.3.2.19 LUTTERWORTH PINES

The drinking water issues evaluation for the Lutterworth Pines municipal well system is summarized in Table 5.3-32, which lists the water quality parameters that exceeded the primary benchmark and indicates whether or not they were considered issues and the rationale for the conclusion. Four issues related to natural sources were identified but no drinking water issues from anthropogenic sources were identified. No parameters that exceeded the secondary benchmark (method detection limit) showed statistically significant trends.

Table 5.3-32: Lutterworth Pines Water Quality Standards Exceedances

Parameter	Water Type[1]	Years on Record	Exceedances		Standard		Drinking Water Issue (Natural)	Drinking Water Issue (Anthropogenic)	Rationale
			%	#	Value	Type[2]			
Schedule 2									
Uranium	Raw	2008, 2010	100	6	0.02 mg/L	MAC (Health)	YES	NO	• Not unexpected in Canadian Shield bedrock; Treatment system installed to remove Uranium
Table 4									
Manganese	Raw	2008	100	4	0.05 mg/L	AO	YES	NO	• High background conditions
Sulphate	Raw	2008	100	4	500 mg/L	AO	YES	NO	• High background conditions
Hardness	Raw	2008	100	4	10 mg/L as $CaCO_3$	OG	YES	NO	• High background conditions

[1]Indicates if the data on record is for raw (untreated) or treated water

[2]Standard types: MAC=Maximum Acceptable Concentration; AO=Aesthetic Objective; OG=Operational Guideline

5.3.2.20 CARDIFF

The drinking water issues evaluation for the Cardiff municipal well system is summarized in Table 5.3-33 and Table 5.3-34, which list the water quality parameters that exceeded the primary benchmark and indicate whether or not they were considered issues and the rationale for the conclusion. One issue related to natural sources was identified but no drinking water issues from anthropogenic sources were identified.

The only parameter that exceeded the secondary benchmark (method detection limit) and showed a statistically significant upward trend was trihalomethanes. The trend analysis for trihalomethanes is summarized in Table 5.3-34. Extrapolation of the trend to 25 and 50 years indicated that the standard for drinking water (0.1 mg/L) would be exceeded within this timeframe. Because this parameter is measured on the distribution water, it may not reflect the quality of the raw source water and is an indicator for the operation of the drinking water system. Therefore, trihalomethanes are not identified as an issue.

Table 5.3-33: Cardiff Water Quality Standards Exceedances

Parameter	Water Type[1]	Years on Record	Exceedances		Standard		Drinking Water Issue (Natural)	Drinking Water Issue (Anthro-pogenic)	Rationale
			%	#	Value	Type[2]			
Schedule 1									
Total Coliforms	Raw	2003-2008	1	5	0 cfu/100mL	MAC	NO	NO	• Rare exceedances • GUDI system; filtration and disinfection in place
Table 4									
Manganese	Treated	2000-2009	63	5	0.05 mg/L	AO	YES	NO	• High background conditions

[1]Indicates if the data on record is for raw (untreated) or treated water, or water from the distribution system
[2]Standard types: MAC=Maximum Acceptable Concentration; AO=Aesthetic Objective; OG=Operational Guideline

Table 5.3-34: Cardiff Water Quality Trend Analysis

Parameter	Water Type[1]	Samples on Record	Trend		Extrapolation		Standard		Drinking Water Issue (Natural)	Drinking Water Issue (Anthro-pogenic)	Rationale
			Direction	p[3]	25 Years	50 years	Value	Type[2]			
Trihalomethanes	Distribution Water	8	↑	0.019	0.168	0.28	0.1 mg/L	MAC	NO	NO	• Trend exceeds standards within 25 & 50 years • By-product of treatment

[1]Indicates if the data on record is for raw (untreated) or treated water, or water from the distribution system
[2]Standard types: MAC=Maximum Acceptable Concentration; AO=Aesthetic Objective; OG=Operational Guideline
[3]Indicates the statistical significance of the proposed trend (trends are generally considered statistically significant where $p<0.05$)

5.3.2.21 DYNO ESTATES

No drinking water exceedances or issues were identified for the Dyno Estates municipal well system. The only parameter that exceeded the secondary benchmark (method detection limit) and showed a statistically significant upward trend was aluminum. The trend analysis for aluminum is summarized in Table 5.3-35.

Table 5.3-35: Dyno Estates Quality Trend Analysis

Parameter	Water Type[1]	Samples on Record	Trend		Extrapolation		Standard		Drinking Water Issue (Natural)	Drinking Water Issue (Anthro-pogenic)	Rationale
			Direction	p[3]	25 Years	50 Years	Value	Type[2]			
Aluminum	Treated	9	↑	0.0058	0.007	0.010	0.1 mg/L	OG	NO	NO	• Trend does not exceed standards within 50 years

[1]Indicates if the data on record is for raw (untreated) or treated water, or water from the distribution system
[2]Standard types: MAC=Maximum Acceptable Concentration; AO=Aesthetic Objective; OG=Operational Guideline
[3]Indicates the statistical significance of the proposed trend (trends are generally considered statistically significant where $p<0.05$)

5.3.2.22 ALPINE VILLAGE

The drinking water issues evaluation for the Alpine Village/Pirates Glen municipal well system is summarized in Table 5.3-36, which lists the water quality parameters that exceeded the primary benchmark and indicates whether or not they were considered issues and the rationale for the conclusion. The only parameter that exceeded the secondary benchmark (method detection limit) and showed a statistically significant upward trend was nitrate. The trend analysis for nitrate is summarized in Table 5.3-37. No drinking water issues were identified.

Table 5.3-36: Alpine Village Glen Water Quality Standards Exceedances

Parameter	Water Type[1]	Years on Record	Exceedances		Standard		Drinking Water Issue (Natural)	Drinking Water Issue (Anthro-pogenic)	Rationale
			%	#	Value	Type[2]			
Schedule 1									
Total Coliforms	Raw	2000-2007	51	92	0 cfu/100mL	MAC	NO	NO	• Adequate treatment in place
E. coli	Raw	2000-2007	26	33	0 cfu/100mL	MAC	NO	NO	• Adequate treatment in place

Table 5.3-37: Alpine Village Glen Water Quality Trend Analysis

Parameter	Water Type[1]	Samples on Record	Trend		Extrapolation		Standard		Drinking Water Issue (Natural)	Drinking Water Issue (Anthro-pogenic)	Rationale
			Direction	P[3]	25 Years	50 Years	Value	Type			
Nitrate	Treated	16	↑	0.0009	5.79	9.77	10 mg/L	MAC	NO	NO	• Trend does not exceed standards within 50 years

[1]Indicates if the data on record is for raw (untreated) or treated water, or water from the distribution system
[2]Standard types: MAC=Maximum Acceptable Concentration; AO=Aesthetic Objective; OG=Operational Guideline
[3]Indicates the statistical significance of the proposed trend (trends are generally considered statistically significant where $p<0.05$)

5.3.2.23 BUCKHORN LAKE ESTATES

The drinking water issues evaluation for the Buckhorn Lake Estates municipal well system is summarized in Table 5.3-38, which lists the water quality parameters that exceeded the primary benchmark and indicates whether or not they were considered issues and the rationale for the conclusion. Two parameters exceeded the secondary benchmark (method detection limit) and showed a statistically significant upward trend: boron and trihalomethanes. The trend analysis for these parameters is summarized in Table 5.3-39. No drinking water issues were identified.

Table 5.3-38: Buckhorn Lake Estates Water Quality Standards Exceedances

Parameter	Water Type[1]	Years on Record	Exceedances		Standard		Drinking Water Issue (Natural)	Drinking Water Issue (Anthro-pogenic)	Rationale
			%	#	Value	Type			
Schedule 1									
Total Coliforms	Raw	2000-2008	39	17	0 cfu/100mL	MAC	NO	NO	• Occasional exceedances • GUDI system; filtration and disinfection in place
E. coli	Raw	2000-2008	9	4	0 cfu/100mL	MAC	NO	NO	• Occasional exceedances • GUDI system; filtration and disinfection in place
Table 4									
Manganese	Treated	2000-2008	6	1	0.05 mg/L	AO	NO	NO	• Single exceedance considered anomalous

[1]Indicates if the data on record is for raw (untreated) or treated water, or water from the distribution system
[2]Standard types: MAC=Maximum Acceptable Concentration; AO=Aesthetic Objective; OG=Operational Guideline

Table 5.3-39: Buckhorn Lake Estates Water Quality Trend Analysis

Parameter	Water Type[1]	Samples on Record	Trend		Extrapolation		Standard		Drinking Water Issue (Natural)	Drinking Water Issue (Anthropogenic)	Rationale
			Direction	p[3]	25 Years	50 Years	Value	Type			
Boron	Treated	11	↑	0.0077	0.062	0.103	5 mg/L	IMAC	NO	NO	• Trend does not exceed standards within 50 years
Trihalomethanes	Treated	10	↑	0.013	0.051	0.088	0.1 mg/L	MAC	NO	NO	• Trend does not exceed standards within 50 years • By-product of treatment

[1]Indicates if the data on record is for raw (untreated) or treated water, or water from the distribution system
[2]Standard types: MAC=Maximum Acceptable Concentration; IMAC = Interim Maximum Acceptable Concentration; AO=Aesthetic Objective ; OG=Operational Guideline
[3]Indicates the statistical significance of the proposed trend (trends are generally considered statistically significant where $p<0.05$)

5.3.2.24 NORWOOD

The drinking water issues evaluation for the Norwood municipal well system is summarized in Table 5.3-40, which lists the water quality parameters that exceeded the primary benchmark and indicates whether or not they were considered issues and the rationale for the conclusion. The only parameter that exceeded the secondary benchmark (method detection limit) and showed a statistically significant upward trend was aluminum. The trend analysis for aluminum is summarized in Table 5.3-41. One issue related to natural sources was identified but no drinking water issues from anthropogenic sources were identified. The Operations Manager for the plant indicated that elevated sodium levels are of concern (from natural sources and plant operations.) The Ministry of Health and consumers have been notified.

Table 5.3-40: Norwood Water Quality Standards Exceedances

Rationale	Water Type	Years on Record	No. Exceedances[4]	Standard		Drinking Water Issue (Natural)	Drinking Water Issue (Anthropogenic)	Rationale
				Value	Type			
Total Coliforms[3]	Raw	2000 – 2008	Well #1: 0 – 7 Well #2: 0 – 4 Well #3: 0 – 3	0 cfu/100mL	MAC (Health)	YES	NO	• No detections since 2006 • Naturally occurring

[1]Indicates if the data on record is for raw (untreated) or treated water, or water from the distribution system
[2]Standard types: MAC=Maximum Acceptable Concentration; AO=Aesthetic Objective; OG=Operational Guideline
[3]Parameter reported as a range of results in cfu/100mL
[4] Data not available for Wells #1B and #4

Table 5.3-41: Norwood Water Quality Trend Analysis

Parameter	Water Type[1]	Samples on Record[4]	Trend		Extrapolation		Standard		Drinking Water Issue (Natural)	Drinking Water Issue (Anthro-pogenic)	Rationale
			Direction	p[3]	25 Years	50 Years	Value	Type			
Aluminum	Treated	7	↑	0.0075	0.011	0.020	0.1 mg/L	OG	NO	NO	• Trend does not exceed standards within 50 years

[1]Indicates if the data on record is for raw (untreated) or treated water, or water from the distribution system
[2]Standard types: MAC=Maximum Acceptable Concentration; AO=Aesthetic Objective; OG=Operational Guideline
[3]Indicates the statistical significance of the proposed trend (trends are generally considered statistically significant where $p<0.05$)
[4]Data not available for Wells #1B and #4

5.3.2.25 STIRLING

The drinking water issues evaluation for the Stirling municipal well system is summarized in Table 5.3-42, which lists the water quality parameters that exceeded the primary benchmark and indicates whether or not they were considered issues and the rationale for the conclusion. Two parameters exceeded the secondary benchmark (method detection limit) and showed a statistically significant upward trend: fluoride and copper. The trend analysis for these parameters is summarized in Table 5.3-43.

One issue related to natural sources was identified as well as one drinking water issue from anthropogenic sources. E. coli has been confirmed as an issue from anthropogenic (and natural) sources since there have been exceedances and the water treatment facility for this GUDI system has no filtration system. (It has in-situ filtration.) The issue contributing area and activities contributing to the issue were identified for E. coli (see Map 5-28f).

Table 5.3-42: Stirling Water Quality Standards Exceedances

Parameter	Water Type[1]	Years on Record	No. Exceedances	Standard		Drinking Water Issue (Natural)	Drinking Water Issue (Anthro-pogenic)	Rationale
				Value	Type[2]			
Schedule 1								
Total Coliforms[3]	Raw	2003 – 2008	Well #1: 0-420; Well #3: 0-175 Well #4: 0-62; Well #5: 0-72	0 cfu/100mL	MAC (Health)	YES	NO	• Occasional exceedances • Naturally occurring
E. coli[3]	Raw	2003 – 2008	Well #1: 0-7; Well #3: 0-1 Well #4: 0-20; Well #5: 0-48	0 cfu/100mL	MAC (Health)	YES	YES	• Occasional exceedances • GUDI system; no filtration system in place
Table 4								
Turbidity	Raw	2004	Max 22.4	5 NTU	OG	NO	NO	• High readings due to operational issues with monitors

[1]Indicates if the data on record is for raw (untreated) or treated water, or water from the distribution system
[2]Standard types: MAC=Maximum Acceptable Concentration; AO=Aesthetic Objective; OG=Operational Guideline
[3]Parameter reported as a range of results in cfu/100mL

Table 5.3-43: Stirling Water Quality Trend Analysis

Parameter	Water Type[1]	Samples on Record	Trend		Extrapolation		Standard		Drinking Water Issue (Natural)	Drinking Water Issue (Anthro-pogenic)	Rationale
			Direction	p[3]	25 Years	50 Years	Value	Type[2]			
Fluoride	Treated	12	↑	0.011	0.32	0.50	1.5 mg/L	MAC	NO	NO	• Trend does not exceed standards within 50 years
Copper	Treated	11	↑	0.0016	1.62	2.90	1 mg/L	AO	NO	NO	• Trend does not exceed standards within 50 years (using recent data)

[1]Indicates if the data on record is for raw (untreated) or treated water, or water from the distribution system
[2]Standard types: MAC=Maximum Acceptable Concentration; AO=Aesthetic Objective; OG=Operational Guideline
[3]Indicates the statistical significance of the proposed trend (trends are generally considered statistically significant where $p<0.05$)

5.3.2.26 KEENE HEIGHTS

The drinking water issues evaluation for the Keene Heights municipal well system is summarized in Table 5.3-44, which lists the water quality parameters that exceeded the primary benchmark and indicates whether or not they were considered issues and the rationale for the conclusion. The only parameter that exceeded the secondary benchmark (method detection limit) and showed a statistically significant upward trend was uranium in well #4. The trend analysis for uranium is summarized in Table 5.3-45. Three issues related to natural sources were identified but no drinking water issues from anthropogenic sources were identified.

Table 5.3-44: Keene Heights Water Quality Standards Exceedances

Parameter	Water Type[1]	Years on Record	Exceedances		Standard		Drinking Water Issue (Natural)	Drinking Water Issue (Anthropogenic)	Rationale
			%	#	Value	Type[2]			
Schedule 1									
Total Coliforms[a]	Raw	2003 – 2008		Well #4: 0-1	0 cfu/100mL	MAC	NO	NO	• Rare exceedances • Maximum noted concentration was 1 cfu/100 mL, which may be attributable to sampling error
Table 4									
Iron	Treated Raw	2001-2009 2013	100 100	Well#4: 3 Well#1: 1	0.3 mg/L	AO	YES YES	NO	• High background conditions
Manganese	Treated	2001-2009	66	Well#4: 2	0.05 mg/L	AO	YES	NO	• High background conditions
Hardness	Raw	2013	100	Well#1: 1	80-100 mg/L $CaCO_3$	OG	YES	NO	• High background conditions

[1]Indicates if the data on record is for raw (untreated) or treated water, or water from the distribution system
[2]Standard types: MAC=Maximum Acceptable Concentration; AO=Aesthetic Objective; OG=Operational Guideline
[3]Parameter reported as a range of results in cfu/100mL

Table 5.3-45: Keene Heights Water Quality Trend Analysis

Parameter	Water Type[1]	Samples on Record	Trend		Extrapolation		Standard		Drinking Water Issue (Natural)	Drinking Water Issue (Anthro-pogenic)	Rationale
			Direction	p[3]	25 Years	50 Years	Value	Type[2]			
Uranium	Treated	5	↑	0.001	0.0005	0.0007	0.02 mg/L	MAC	NO	NO	• Trend does not exceed standards within 50 years

[1]Indicates if the data on record is for raw (untreated) or treated water, or water from the distribution system
[2]Standard types: MAC=Maximum Acceptable Concentration; AO=Aesthetic Objective; OG=Operational Guideline
[3]Indicates the statistical significance of the proposed trend (trends are generally considered statistically significant where $p<0.05$)

5.3.2.27 CRYSTAL SPRINGS

The drinking water issues evaluation for the Crystal Springs municipal well system is summarized in Table 5.3-46, which lists the water quality parameters that exceeded the primary benchmark and indicates whether or not they were considered issues and the rationale for the conclusion. Two parameters exceeded the secondary benchmark (method detection limit) and showed a statistically significant upward trend: barium and uranium. The trend analysis for these parameters is summarized in Table 5.3-47. No drinking water issues were identified.

Table 5.3-46: Crystal Springs Water Quality Standards Exceedances

Parameter	Water Type[1]	Years on Record	Exceedances		Standard		Drinking Water Issue (Natural)	Drinking Water Issue (Anthro-pogenic)	Rationale
			%	#	Value	Type[2]			
Schedule 1									
Total Coliforms[3]	Raw	2000-2007		Well #2: 0-10	0 cfu/100mL	MAC	NO	NO	• Rare exceedances • One occurrence since 2005 • Potential sampling error in 2003
Table 4									
Organic Nitrogen	Raw	2002-2004	17	1	0.15 mg/L	OG	NO	NO	• Limited sample size • Inconsistent results

[1]Indicates if the data on record is for raw (untreated) or treated water, or water from the distribution system
[2]Standard types: MAC=Maximum Acceptable Concentration; AO=Aesthetic Objective; OG=Operational Guideline
[3]Parameter reported as a range of results in cfu/100mL

Table 5.3-47: Crystal Springs Water Quality Trend Analysis

Parameter	Water Type[1]	Samples on Record	Trend		Extrapolation		Standard		Drinking Water Issue (Natural)	Drinking Water Issue (Anthro-pogenic)	Rationale
			Direction	p[3]	25 Years	50 Years	Value	Type[2]			
Barium	Unknown	18	↑	0.00014	0.356	0.524	1 mg/L	MAC	NO	NO	• Trend does not exceed standards within 50 years
Uranium	Unknown	18	↑	0.00327	0.0059	0.0095	0.02 mg/L	MAC	NO	NO	• Trend does not exceed standards within 50 years

[1]Indicates if the data on record is for raw (untreated) or treated water, or water from the distribution system
[2]Standard types: MAC=Maximum Acceptable Concentration; AO=Aesthetic Objective; OG=Operational Guideline
[3]Indicates the statistical significance of the proposed trend (trends are generally considered statistically significant where $p<0.05$)

5.3.2.28 MILLBROOK

The drinking water issues evaluation for the Millbrook municipal well system is summarized in Table 5.3-48, which lists the water quality parameters that exceeded the primary benchmark and indicates whether or not they were considered issues and the rationale for the conclusion. The only parameter that exceeded the secondary benchmark (method detection limit) and showed a statistically significant upward trend was trihalomethanes. The trend analysis for trihalomethanes is summarized in Table 5.3-49. One issue related to natural sources was identified but no drinking water issues from anthropogenic sources were identified.

Table 5.3-48: Millbrook Water Quality Standards Exceedances

Parameter	Water Type[1]	Years on Record	Exceedances		Standard		Drinking Water Issue (Natural)	Drinking Water Issue (Anthropogenic)	Rationale
			%	#	Value	Type[2]			
Schedule 1									
Total Coliforms[3]	Raw	2005 – 2008		Well #2: 0 – 1	0 cfu/100mL	MAC	NO	NO	• Rare exceedances • Maximum noted concentration was 1 or 2 cfu/100 mL, which may be attributable to sampling error
E. coli[3]	Raw	2005 – 2008		Well #2: 0 – 2	0 cfu/100mL	MAC	NO	NO	• Rare exceedances • Maximum noted concentration was 1 or 2 cfu/100 mL, which may be attributable to sampling error
Table 4									
Iron	Treated	2003-2005	100	2	0.3 mg/L	AO	YES	NO	• High background conditions
Turbidity	Treated	2003	100	1	5 NTU	OG	NO	NO	• Single sample considered anomalous

[1]Indicates if the data on record is for raw (untreated) or treated water, or water from the distribution system
[2]Standard types: MAC=Maximum Acceptable Concentration; AO=Aesthetic Objective; OG=Operational Guideline
[3]Parameter reported as a range of results in cfu/100mL

Table 5.3-49: Millbrook Water Quality Trend Analysis

Parameter	Water Type[1]	Samples on Record	Trend		Extrapolation		Standard		Drinking Water Issue (Natural)	Drinking Water Issue (Anthro-pogenic)	Rationale
			Direction	p[3]	25 Years	50 Years	Value	Type[2]			
Trihalomethanes	Treated	6	↑	0.049	0.028	0.050	0.1 mg/L	MAC	NO	NO	• Trend does not exceed standards within 50 years • By-product of treatment

[1]Indicates if the data on record is for raw (untreated) or treated water, or water from the distribution system
[2]Standard types: MAC=Maximum Acceptable Concentration; AO=Aesthetic Objective; OG=Operational Guideline
[3]Indicates the statistical significance of the proposed trend (trends are generally considered statistically significant where $p<0.05$)

5.3.2.29 BRIGHTON

The drinking water issues evaluation for the Brighton municipal well system is summarized in Table 5.3-50, which lists the water quality parameters that exceeded the primary benchmark and indicates whether or not they were considered issues and the rationale for the conclusion. Two parameters exceeded the secondary benchmark (method detection limit) and showed a statistically significant upward trend: aluminum and chloride. The trend analysis for these parameters is summarized in Table 5.3-51. One issue related to natural sources was identified but no drinking water issues from anthropogenic sources were identified.

Table 5.3-50: Brighton Water Quality Standards Exceedances

Parameter	Water Type[1]	Years on Record	Exceedances		Standard		Drinking Water Issue (Natural)	Drinking Water Issue (Anthro-pogenic)	Rationale
			%	#	Value	Type[2]			
Schedule 1									
Total Coliforms	Raw	2000-2008 2006-2008	18	3 (Range: <1 – >400)	0 cfu/100mL	MAC	NO	NO	• No exceedances since well system upgrade in 2005
E. coli	Raw	2000-2008 2006-2008	18	3 (Range: <1 – 238)	0 cfu/100mL	MAC	NO	NO	• No exceedances since well system upgrade in 2005
Schedule 2									
Uranium	Treated	2001-2008	8	1	0.02 mg/L	MAC	NO	NO	• Considered anomalous
Table 4									
Hardness	Treated	2002-2003	100	2	80-100 mg/L $CaCO_3$	OG	YES	NO	• Natural Conditions

[1]Indicates if the data on record is for raw (untreated) or treated water, or water from the distribution system
[2]Standard types: MAC=Maximum Acceptable Concentration; AO=Aesthetic Objective; OG=Operational Guideline

Table 5.3-51: Brighton Water Quality Trend Analysis

Parameter	Water Type[1]	Samples on Record	Trend		Extrapolation		Standard		Drinking Water Issue (Natural)	Drinking Water Issue (Anthro-pogenic)	Rationale
			Direction	p[3]	25 Years	50 Years	Value	Type[2]			
Aluminum	Unknown	23	▲	0.050	0.026	0.046	0.1 mg/L	OG	NO	NO	• Trend does not exceed standards within 50 years
Chloride	Unknown	23	▲	0.0128	124	208	250 mg/L	AO	NO	NO	• Trend does not exceed standards within 50 years

[1]Indicates if the data on record is for raw (untreated) or treated water, or water from the distribution system
[2]Standard types: MAC=Maximum Acceptable Concentration; AO=Aesthetic Objective; OG=Operational Guideline
[3]Indicates the statistical significance of the proposed trend (trends are generally considered statistically significant where $p<0.05$)

5.3.2.30 COLBORNE

The drinking water issues evaluation for the Colborne municipal well system is summarized in Table 5.3-52, which lists the water quality parameters that exceeded the primary benchmark and indicates whether or not they were considered issues and the rationale for the conclusion. The only parameter that exceeded the secondary benchmark (method detection limit) and showed a statistically significant upward trend was nitrate. The trend analysis for nitrate is summarized in Table 5.3-53. One issue related to natural sources was identified but no drinking water issues from anthropogenic sources were identified.

Table 5.3-52: Colborne Water Quality Standards Exceedances

Parameter	Water Type[1]	Years on Record	Exceedances		Standard		Drinking Water Issue (Natural)	Drinking Water Issue (Anthropogenic)	Rationale
			%	#	Value	Type[2]			
Schedule 1									
Total Coliforms	Raw	2003-2008	2	8	0 cfu/100mL	MAC	NO	NO	• Rare exceedances • Maximum noted concentration was 1 cfu/100 mL
Table 4									
Hardness	Treated	2000-2003	100	7	80-100 mg/L $CaCO_3$	OG	YES	NO	• Natural Conditions
Iron	Treated	2000-2008	11	1	0.3 mg/L	AO	NO	NO	• Considered anomalous

[1]Indicates if the data on record is for raw (untreated) or treated water, or water from the distribution system
[2]Standard types: MAC=Maximum Acceptable Concentration; AO=Aesthetic Objective; OG=Operational Guideline

Table 5.3-53: Colborne Water Quality Trend Analysis

Parameter	Water Type[1]	Samples on Record	Trend		Extrapolation		Standard		Drinking Water Issue (Natural)	Drinking Water Issue (Anthropogenic)	Rationale
			Direction	p[3]	25 Years	50 Years	Value	Type[2]			
Nitrate	Treated	17	↑	0.017	1.9 mg/L	2.9 mg/L	10 mg/L	MAC	NO	NO	• Trend does not exceed standards within 50 years

[1]Indicates if the data on record is for raw (untreated) or treated water, or water from the distribution system
[2]Standard types: MAC=Maximum Acceptable Concentration; AO=Aesthetic Objective; OG=Operational Guideline
[3]Indicates the statistical significance of the proposed trend (trends are generally considered statistically significant where $p<0.05$)

5.3.2.31 GRAFTON

The drinking water issues evaluation for the Grafton municipal well system is summarized in Table 5.3-54, which lists the water quality parameters that exceeded the primary benchmark and indicates whether or not they were considered issues and the rationale for the conclusion. Two parameters exceeded the secondary benchmark (method detection limit) and showed a statistically significant upward trend: aluminum and sodium. The trend analysis for these parameters is summarized in Table 5.3-55. Two issues related to natural sources were identified but no drinking water issues from anthropogenic sources were identified.

Table 5.3-54: Grafton Water Quality Standards Exceedances

Parameter	Water Type[1]	Years on Record	Exceedances		Standard		Drinking Water Issue (Natural)	Drinking Water Issue (Anthro-pogenic)	Rationale
			%	#	Value	Type[2]			
Schedule 1									
Total Coliforms	Raw	2000-2007	13	31	0 cfu/100mL	MAC	NO	NO	• Occasional exceedances • Exceedances all occurred prior to 2006
Table 4									
Hardness	Raw	2000	100	6	80-100 mg/L	OG	YES	NO	• Natural conditions
Iron	Raw	2001, 2003	28	9	0.3 mg/L	AO	YES	NO	• High background conditions
Organic Nitrogen	Raw	2000	25	1	0.15 mg/L	OG	NO	NO	• Considered anomalous • Limited sample size
Turbidity	Raw	2001-2003	2	1	5 NTU	AO	NO	NO	• Considered anomalous

[1]Indicates if the data on record is for raw (untreated) or treated water, or water from the distribution system
[2]Standard types: MAC=Maximum Acceptable Concentration; AO=Aesthetic Objective; OG=Operational Guideline

Table 5.3-55: Grafton Water Quality Trend Analysis

Parameter	Water Type[1]	Samples on Record	Trend		Extrapolation		Standard		Drinking Water Issue (Natural)	Drinking Water Issue (Anthro-pogenic)	Rationale
			Direction	p[3]	25 Years	50 Years	Value	Type[2]			
Aluminum	Treated	9	↑	0.014	0.010	0.016	0.1 mg/L	OG	NO	NO	• Trend does not exceed standards within 50 years
Sodium	Raw	10	↑	0.0099	55	93	200 mg/L	AO	NO	NO	• Trend does not exceed standards within 50 years

[1]Indicates if the data on record is for raw (untreated) or treated water, or water from the distribution system
[2]Standard types: MAC=Maximum Acceptable Concentration; AO=Aesthetic Objective; OG=Operational Guideline
[3]Indicates the statistical significance of the proposed trend (trends are generally considered statistically significant where $p<0.05$)

5.3.3 SUMMARY OF DRINKING WATER ISSUES

A total of 17 issues from natural sources were identified at the municipal wells in the Trent source protection areas. One drinking water issues resulting from anthropogenic sources (partially or wholly) was noted and is listed below:

- E. coli at the Stirling municipal well system.

The issues from both natural and anthropogenic sources identified in the Trent source protection areas are summarized in Table 5.3-56.

Only drinking water issues determined to be caused partly or wholly by anthropogenic (human) activities are investigated further through a source tracking evaluation.

5.3.4 ISSUE CONTRIBUTING AREAS

For drinking water issues that are at least partially caused by anthropogenic (human) activities, the issue contributing area must be delineated. The *Technical Rules* defines this as the area where activities and conditions may contribute to the parameters or pathogens that are drinking water issues. The issue contributing area for Stirling issues is discussed below.

5.3.4.1 E. COLI AT THE STIRLING MUNICIPAL WELL SYSTEM

E. coli is a drinking water issue for the Stirling municipal well system. The issue contributing area for this issue was delineated as the WHPA-A and WHPA-B as well as the WHPA-E (see Map 5-28f). Since a significant amount of pathogen decay or inactivation is associated with a time horizon greater than 2 years in a subsurface environment, the WHPA-C and WHPA-D are excluded from delineation (as per the *Technical Rules*: the identification of activities that may generate pathogen to subsurface environment is limited to a 2-year time of travel zone). The WHPA-E is included in the delineation because Stirling has a GUDI system. Since there are a large number of pathogen-generating activities identified within the WHPA-E, the WHPA-F is not included in the issue contributing area. Activities in the issue contributing area that could potentially generate E. coli are identified as significant threats (see Section 5.4).

Table 5.3-56: Summary Natural and Anthropogenic Drinking Water Issues*

Drinking Water System	Parameter								Total Drinking Water Issues	
	E. coli	Hardness	Iron	Manganese	Nitrate	Sulphate	Total Coliforms	Uranium	Natural	Anthropogenic
Woods of Manilla										
Sonya										
Mariposa Estates										
King's Bay										
Pleasant Point										
Canadiana Shores										
Janetville										
Woodfield										
Manorview Estates										
Victoria Glen										
Victoria Place										
Birch Point										
Pinewood										
Greenbank										
Port Perry										
Havelock										
Minden			N	N					**2**	
Lutterworth Pines		N		N		N		N	**4**	
Cardiff				N					**1**	
Dyno Estates										
Alpine Village										
Buckhorn Lake Estates										
Norwood							N		**1**	
Stirling	A						N		**1**	**1**
Keene Heights		N	N	N					**3**	
Crystal Springs										
Millbrook			N						**1**	
Brighton		N							**1**	
Colborne		N							**1**	
Grafton		N	N						**2**	
								TOTAL	**17**	**1**

*A = Anthropogenic Source; N = Natural Source

5.3.5 INFORMATION TO SUPPORT CONTINUAL IMPROVEMENT

Updates for new Lutterworth Pines System and new Keene Heights well

Continuous water quality monitoring and corresponding trend analysis is required to ensure that the new Lutterworth Pines drinking water system and the new well (well #1) for the Keene Heights drinking water system do not encounter any emerging issues.

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 existing threats that are present in vulnerable areas. This section refers to the drinking water threats that are located in wellhead protection areas.

The assessment of drinking water threats in the wellhead protection areas in the Trent source protection areas was completed in several separate studies that are documented in the following background reports:

- *Vulnerability, Issues and Threats for Fourteen Groundwater Sourced Municipal Drinking Water Systems in the Trent Conservation Coalition Source Protection Region* (XCG Consultants, July 2010)
- *Vulnerability, Issues and Threats for One Planned Groundwater Sourced Municipal Drinking Water System in the Trent Conservation Coalition Source Protection Region* (XCG Consultants, July 2010)
- *Assessment of Drinking Water Threats – Havelock Water Supply, Township of Havelock-Belmont-Methuen* (GENIVAR Consultants, April 2010)
- *Assessment of Drinking Water Threats – Creighton Heights and Camborne Municipal Wellfields, Township of Hamilton* (GENIVAR Consultants, June 2010)
- *Assessment of Drinking Water Threats – Municipal Residential Groundwater Supplies – The City of Kawartha Lakes (3 Volumes)* (GENIVAR Consultants, August 2010)
- *Assessment of Drinking Water Threats – Municipal Groundwater Supplies – The Regional Municipality of Durham* (GENIVAR Consultants, August 2010)
- *Vulnerability, Issues and Threats for the new Lutterworth Pines Municipal Groundwater Sourced Drinking Water System* (XCG Consultants Ltd., January 2011)
- *Enumeration of Drinking Water Threats for Keene Heights Drinking Water System* (Otonabee Region Conservation Authority, January 2014).
- *Norwood Municipal Wells Updated Modelling, prepared for Township of Asphodel-Norwood (DM Wills Associates Limited, November, 2018)*
- *Enumeration of Drinking Water Threats for Norwood Drinking Water System (Trent Conservation Coalition, November, 2018)*

This section is a summary of the relevant sections of these reports.

5.4.1 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:

- 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 within each vulnerable area that identifies the circumstances under which the identified activities are or would be significant, moderate, or low drinking water threats
- 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.

These requirements are addressed in the following subsections.

5.4.2 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:

- 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.

Each of these three types of activities is identified below.

5.4.2.1 Activities Prescribed to be Drinking Water Threats

The activities prescribed to be drinking water threats are listed in Table 5.4-1. These include 19 water quality threats and 2 water quantity threats. Water quantity threats (19 and 20) were evaluated in the water budget and water quantity stress assessment (see Chapter 3). Water quality threats (1 to 19, and 21) are evaluated in this section.

Table 5.4-1: 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 or biosolids 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 or biosolids
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 waterbody without returning the water taken to the same aquifer or surface waterbody[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

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)

5.4.2.2 Activities Identified by the Source Protection Committee

No local threats related to groundwater systems were identified by the Source Protection Committee.

5.4.2.3 Activities that Contribute to Drinking Water Issues

Activities that contribute to drinking water issues as per Technical Rule 115 are considered drinking water threats. One drinking water issue was identified at municipal wells in the Trent source protection region: E. coli at the Stirling system. The activities that contribute to each of these drinking water issues are discussed below.

The prescribed activities and the related circumstances that would result in activities contributing to drinking water issues are listed in Appendix D. The appendix includes the following table:

- Activities prescribed to be drinking water threats that are potential sources of E. coli.

5.3.5.1.1 E. coli at the Stirling Municipal Well System

The issue contributing area for this issue includes the wellhead protection areas A, B, and E delineated for the Stirling system (shown on Map 5-28f). Activities that would contribute to high E. coli levels include municipal sewage lines and pumping stations, septic systems, and agricultural practices.

5.4.2.4 Circumstances under which each activitiy 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. There are different tables for chemical threats and pathogen threats.

The circumstances that would make the activities prescribed to be drinking water threats significant, moderate, or low drinking water threats in the wellhead protection areas in the Trent source protection areas are identified on maps of these areas by reference to the appropriate sections of the *Tables of Drinking Water Threats* (see Section 5.4.2.5).

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.

5.3.5.1.2 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).

Managed lands were identified differently by GENIVAR and XCG. GENIVAR used the “Property Code” attribute from parcel data obtained from the Municipal Property Assessment Corporation to extract parcels that are used as agricultural and non-agricultural managed lands. XCG used provincial land use data (from the Ministry of Natural Resources and Forestry) to identify agricultural and non-agricultural managed lands (except for golf courses, which were extracted from the parcel/assessment data).

For all sites, non-agricultural managed lands associated with urban and settlement areas were identified from the provincial land use and land cover 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 in a vulnerable area, only the portion of the parcel within the vulnerable area was used in the percent managed land calculation. The percent managed lands in wellhead protection areas 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 5-1b through 5-32b (for the WHPA A-D). The percent managed lands in the WHPA-E are shown on Maps 5-2e, 5-5e, 5-8e, 5-18e, 5-19e, 5-24e, 5-28e, and 5-32e.

5.3.5.1.3 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 values of livestock density. 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 identified using different approaches by GENIVAR and XCG. For the GENIVAR sites, orthophotos were used to identify the locations and sizes of barns, and parcel data were used to identify the types of livestock present. This information was used in conjunction with tables provided in a Ministry of the Environment and Climate Change technical bulletin that relate barn size to a number of nutrient units; these were used to estimate the number of nutrient units per acre in the agricultural managed lands related to the barn. For the XCG sites, located in northern areas, agricultural managed lands were identified from provincial land use and land cover data (from the Ministry of Natural Resources).

Livestock density in the northern part of the Trent source protection areas was calculated for each vulnerable area using information from the 2006 agricultural census that 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. This approach was used because the large areal coverage of intake protection zones, significant groundwater recharge areas, and highly vulnerable aquifers 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 change drastically with market conditions.

Using the CCS method, 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 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 were assigned to the vulnerable areas in which they were located. The detailed steps of the methodology are listed below:

1. Identify the number of different types of livestock for each census consolidated subdivision 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 census consolidated subdivision
4. Calculate the livestock density applicable to the agricultural lands within the census consolidated subdivision 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 4 steps were carried out for all the census consolidated subdivisions 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 (i.e., the WHPA-A, WHPA-B, WHPA-C, WHPA-D, SGRA6, and HVA) in the source protection region, and the livestock densities of the agricultural managed lands were assigned to the vulnerable areas.

Livestock density in wellhead protection areas with vulnerability scores greater than or equal to 4.5 (the minimum score required for an activity to be considered a drinking water threat) is shown on Maps 5-1b through 5-32b (for the WHPA A-D). The livestock density in the WHPA-E is shown on Maps 5-2e, 5-5e, 5-8e, 5-18e, 5-19e, 5-24e, 5-28e, and 5-32e.

5.3.5.1.4 Total Impervious Surface Area

Some of the circumstances listed for the application of road salt refer to the total impervious surface area. This is defined by the *Technical Rules* as 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. The percent impervious surface area was calculated based on the 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 wellhead protection areas 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 5-1b through 5-32b (for the WHPA A-D). Total impervious surface area in the WHPA-E is shown on Maps 5-2e, 5-5e, 5-8e, 5-18e, 5-19e, 5-24e, 5-28e, and 5-32e.

5.4.2.5 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 threats in the wellhead protection areas in the Trent source protection areas are shown on Maps 5-1c through 5-32c (for the WHPA A-D) and on Maps 5-2d, 5-5d, 5-8d, 5-18d, 5-19d, 5-24d, 5-25d, 5-28d, and 5-32d (for the WHPA-E). These areas are mapped separately for chemical threats, pathogen threats, and dense non-aqueous phase liquid (DNAPL) threats because the ranges of vulnerability scores that would result in a drinking water threat are different for these types of threats.

5.4.3 LISTING OF CONDITIONS THAT ARE DRINKING WATER THREATS

Conditions that are drinking water threats are documented conditions resulting from past activities (e.g. contaminated sites). The *Technical Rules* identifies the following as conditions:

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 liquids in surface water in a surface water intake protection zone
3. The presence of a contaminant in groundwater in a highly vulnerable aquifer, significant groundwater recharge area, or wellhead protection area, if the contaminant is listed in Table 2 of the Soil, Groundwater and Sediment Standards and is present at a concentration that exceeds the potable groundwater standard set out for the contaminant in that Table
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, Groundwater and Sediment Standards and is present at a concentration that exceeds the surface soil standard for industrial/commercial/institutional property use set out for the contaminant in that Table
5. The presence of a contaminant in sediment, if the contaminant is listed in Table 1 of the Soil, Groundwater and Sediment Standards and is present at a concentration that exceeds the sediment standard set out for the contaminant in that Table.

Conditions that result from past activities (e.g., contaminated sites) 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.

The following information sources were 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.

The only condition identified for a groundwater system was the site of a former bulk fuel storage facility. This condition was identified from the Ministry of the Environment and Climate Change Data Hound database. The site is contaminated with benzene, toluene, ethylbenzene, and xylene in concentrations that exceed Table 4 of the *Soil, Groundwater and Sediment Standards (O. Reg. 153)*. There is no evidence of off-site impact. The condition is considered a low threat. The evaluation of this condition is summarized in Table 5.4-2.

Table 5.4-2: Summary of Groundwater Condition

Applicable Vulnerable Area	Municipality	Evidence of Off-Site Impact	Vulnerability Score	Hazard Score	Risk Score	Threat Level
Norwood	Township of Asphodel-Norwood	No	8	6	48	Low

5.4.4 ENUMERATION OF SIGNIFICANT THREATS

5.4.4.1 Methodology

The significant threats located in wellhead protection areas were identified through a review of available documentation and databases, field reconnaissance surveys, and aerial photos. To confirm the presence of significant threats, letters were sent to landowners of properties identified as potentially significant threats to collect additional information about the potential threat. Follow-up interviews and/or site visits were conducted to collect information regarding specific circumstances.

Some of the documents and databases consulted for the enumeration of significant threats are identified below:

- EcoLog Environmental Risk Information Service (the search included a wide variety of databases). Records were found in the search from the following databases:
    - Abandoned Aggregate Inventory
    - Abandoned Mine Information System
    - Anderson's Waste Disposal Sites
    - Certificates of Approval
    - Chemical Register
    - Coal Gasification Plants
    - Commercial Fuel Oil Tanks
    - Drill Hole Database
    - Environmental Registry
    - ERIS Historical Searches
    - Fuel Storage Tank
    - Mineral Occurrences
    - MOECC - Environmental Registry
    - National Pollutant Release Inventory
    - Occurrence Reporting Information System
    - Ontario Regulation 347 Waste Generators Summary
    - Ontario Regulation 347 Waste Receivers Summary
    - Ontario Spills
    - Pesticide Register
    - Private and Retail Fuel Storage Tanks
    - Retail Fuel Storage Tanks
    - Scott's Manufacturing Directory
    - Waste Disposal Sites
    - Water Well Information System
- Environment Canada's National Pollutant Release Inventory (NPRI) website
- Morrison Environmental Ltd., Trent Conservation Coalition Municipal Groundwater Study
- Draft Watershed Characterization Reports (Trent Conservation Coalition)
- MOECC Data Hound database.

Each activity identified as a potential significant threat was evaluated based on the known information such as land use, vulnerability score, and circumstances that would result in it being classified as a significant threat (identified in the *Tables of Drinking Water Threats*). The results of the database search were overlaid with assessment parcel data in a geographic information system to identify the total number of activities and parcels that contained significant drinking water threats. 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.

5.4.4.2 Results

5.3.5.1.5 Activities that are Significant Drinking Water Threats

A total of 1,034 activities on 612 parcels were identified in wellhead protection areas in the Trent source protection areas that are considered to be significant drinking water threats. The most common significant threats are the following:

- Below grade home heating oil tanks
- Private sewage systems
- Application of agricultural source material
- Application of commercial fertilizer to land
- Land use as pasture, outdoor confinement, or farm animal yard.

The enumeration of significant threats for the wellhead protection areas in the Trent source protection areas is summarized in Table 5.4-3.

5.3.5.1.6 Significant Drinking Water Threats in Other Source Protection Regions

There were 24 significant threats (in 14 parcels) identified in the portion of the Woods of Manilla Wellhead Protection Area that is located in the South Georgian Bay Lake Simcoe Source Protection Region. These threats are not considered in this Assessment Report; they have been enumerated in the South Georgian Bay Lake Simcoe Source Protection Region Assessment Report.

5.4.5 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 an Updated Assessment Report. An alternative is to use a more general policy to address transportation corridors in the Source Protection Plan.

Potential Addition of Conditions

A Phase 1 Environmental Site Assessment has been conducted at the former Millbrook Correctional Centre property. Portions of this property are located within wellhead protection areas A and B with a vulnerability score of 10. The Phase 1 report provides a historical overview of past activities on the site and identifies a potential for contamination and recommended that a Phase 2 Environmental Site Assessment be conducted. A Phase 2 study, if conducted, will include soil and groundwater sampling for contaminants/parameters noted to be associated with past activities on the site, and can be used to determine if a condition exists at this site with or without any off-site impacts.

Table 5.4-3: Summary of Significant Threats for Groundwater Systems in the Trent Source Protection Areas (Listed by System)

No.	Drinking Water Threats	Minden	Lutterworth Pines	Cardiff	Dyno Estates	Alpine Village	Buckhorn Lake Estates	Norwood	Blackstock	Greenbank	Port Perry	Havelock	Grafton	Colborne	Brighton	Crystal Springs	Keene Heights	Millbrook	Stirling	Fraserville	Birch Point	Canadiana Shores	Janetville	Kings Bay	Manorview	Mariposa Estates	Victoria Glen	Pleasant Point	Pinewood	Sonya	Victoria Place	Woodfield	Woods of Manilla	**TOTAL**
No.	Prescribed Drinking Water Threats																																	
1	The establishment, operation or maintenance of a waste disposal site within the meaning of Part V of the *Environmental Protection Act*	1						1				1																						**3**
2	The establishment, operation or maintenance of a system that collects, stores, transmits, treats or disposes of sewage	1	13	2	7	52	21	10	7	16	3	14	1	2	4	4	18	1		3	41	29	15	2	34	21		20	17	15	29	15	5	**422**
3	The application of agricultural source material to land					3		2	1	5		1			2	2			39	1			1	2		10	3		1		1	1	1	**76**
4	The storage of agricultural source material							2		1						1			7				1	2								1		**15**
5	The management of agricultural source material																																	**0**
6	The application of non-agricultural source material or biosolids to land																																	**0**
7	The handling and storage of non-agricultural source material or biosolids																																	**0**
8	The application of commercial fertilizer to land								7	5													1							8				**21**
9	The handling and storage of commercial fertilizer																							2										**2**
10	The application of pesticide to land					2			1	5		2			2	3			1				1	4	1	2	3		1		1	1	1	**31**
11	The handling and storage of pesticide							1																2										**3**
12	The application of road salt																																	**0**
13	The handling and storage of road salt																																	**0**
14	The storage of snow																																	**0**
15	The handling and storage of fuel	5	1	1	7	33		8	7	14	2	14				3	2	11	25		32	27		21	29	19		19		14	12	14		**320**
16	The handling and storage of a dense non-aqueous phase liquid							2				9																				1		**12**
17	The handling and storage of an organic solvent	1																																**1**
18	The management of runoff that contains chemicals used in the de-icing of aircraft																																	**0**
21	The use of land as livestock grazing or pasturing land, an outdoor confinement area, or a farm-animal yard							2		1				1		2			34	1			1	2			1				1	1		**47**
	Total No. Significant Prescribed Drinking Water Threats	8	8	14	3	14	90	21	28	23	47	5	41	1	3	8	15	20	12	106	5	73	56	20	37	64	52	7	39	19	37	44	34	7
	Total No. Parcels Affected by Significant Prescribed Drinking Water Threats	6	6	13	2	7	54	21	22	8	21	3	28	1	2	6	7	18	12	64	4	41	29	15	23	35	31	3	20	20	15	30	16	6
Local Drinking Water Threats																																		
None																																		
TOTAL (All Significant Drinking Water Threats)																																		
	Total No. Significant Drinking Water Threats	8	8	14	3	14	90	21	28	23	47	5	41	1	3	8	15	20	12	106	5	73	56	20	37	64	52	7	39	19	37	44	34	7
	Total No. Parcels Affected by Significant Drinking Water Threats	6	6	13	2	7	54	21	22	8	21	3	28	1	2	6	7	18	12	64	4	41	29	15	23	35	31	3	20	20	15	30	16	6

Note: the total number of affected parcels may be less than the total number of drinking water threats because more than one threat may occur on some parcels

CHAPTER 6: LANDSCAPE-SCALE GROUNDWATER ANALYSES

6.1 GROUNDWATER VULNERABILITY & 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 documented in the following 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 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 Section 5.2).

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) that 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 (±100 m) and elevation (±7.5 m) 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 (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 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 the provincial guidance (Module 7) (Ministry of the Environment and Climate Change, 2006). 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.

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 source protection region 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 were mapped separately for each of the Trent source protection areas; these are shown on Maps 6-3a to 6-6a.

6.1.6 INFORMATION TO SUPPORT CONTINUAL IMPROVEMENT

Long-term improvements

The broad regional level assessments presented in this section could be improved with additional borehole or well data, as they become available.

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 (SGRA) are locations where these conditions favour groundwater recharge. The delineation of significant groundwater recharge areas for the entire Trent Conservation Coalition Source Protection Region was completed by the Conservation Authorities Moraine Coalition and is documented in the following report:

- *Trent Source Water Protection Study Recharge Study: Final Report (CAMC, November 2009).*

A more refined delineation of significant groundwater recharge areas was completed for the three subwatersheds that were assigned a moderate groundwater stress level in the Tier 1 water quantity stress assessment. These refined delineations are documented in the following memo:

- *Significant Groundwater Recharge Areas for Tier 2 Studies in the Trent Conservation Coalition Area: Memo (XCG Consultants, October 2010).*

This section is a summary of the above documents.

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 throughout the Source Protection Region were delineated using the second 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, which are described in the following three sections. Updates to the delineation within subwatersheds that were assigned a moderate stress level in the Tier 1 water quantity stress assessment are discussed in Section 6.2.6.

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 **Error! Not a valid bookmark self-reference.**.

Table 6.2-1: 30-Year Climate Normals (1971-2000)

Station	Area	Precipitation	Temperature (C)
Cobourg STP	South	871.1	7.1
Peterborough	Central	840.3	5.9
Minden Forestry	North	1044.7	5.2

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 Kassenaar, J.D.C. and Wexler, E.J. (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.

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

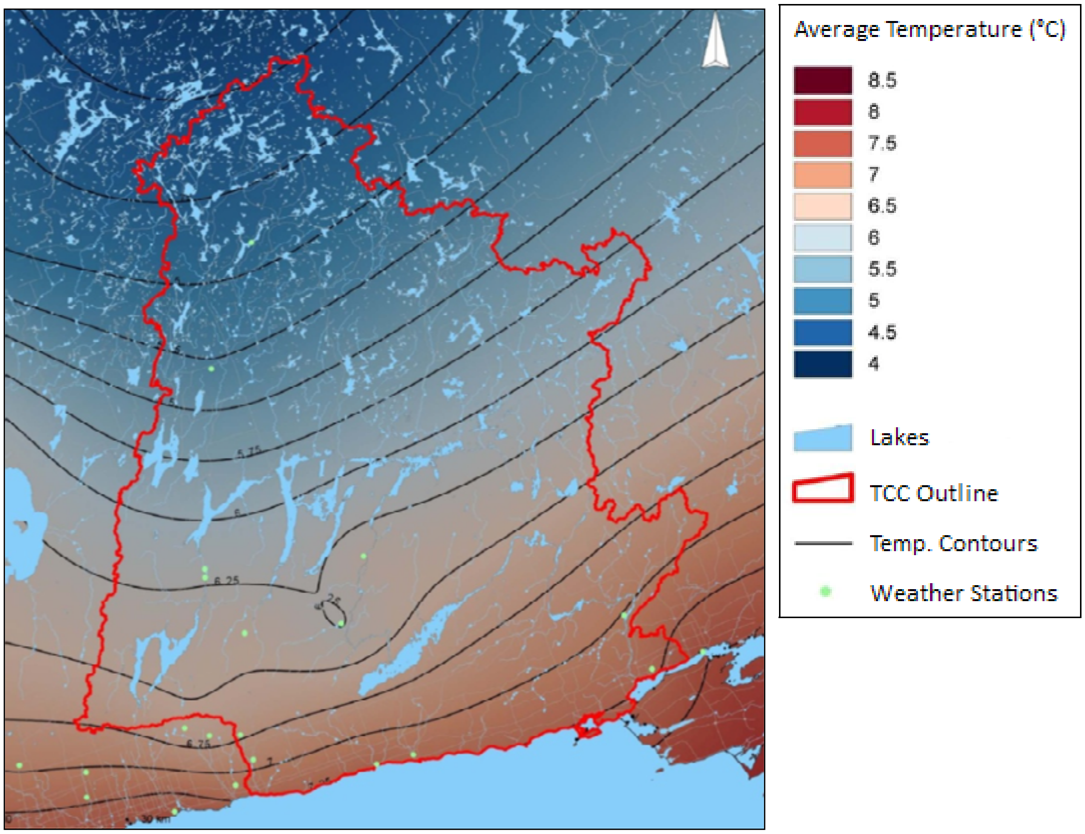

Figure 6.2-1: Temperature Normals (1971-2000)

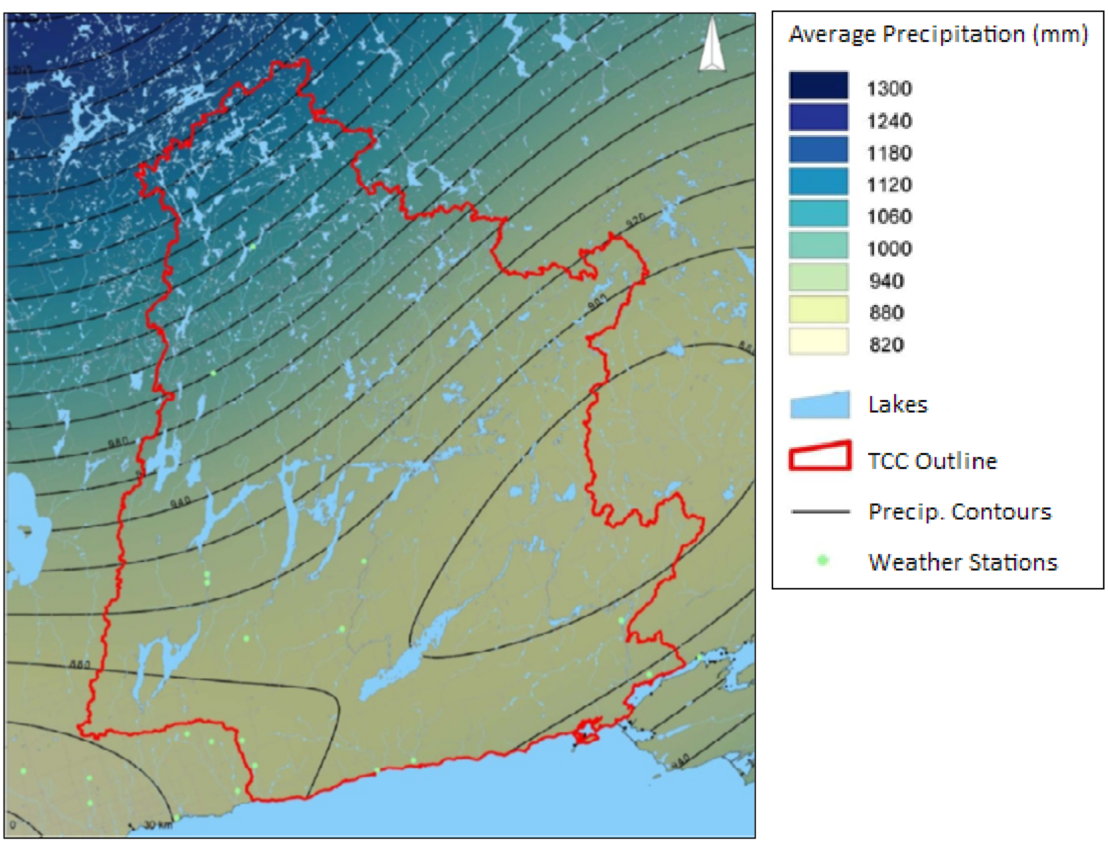

Figure 6.2-2: Precipitation Normals (1971-2000)

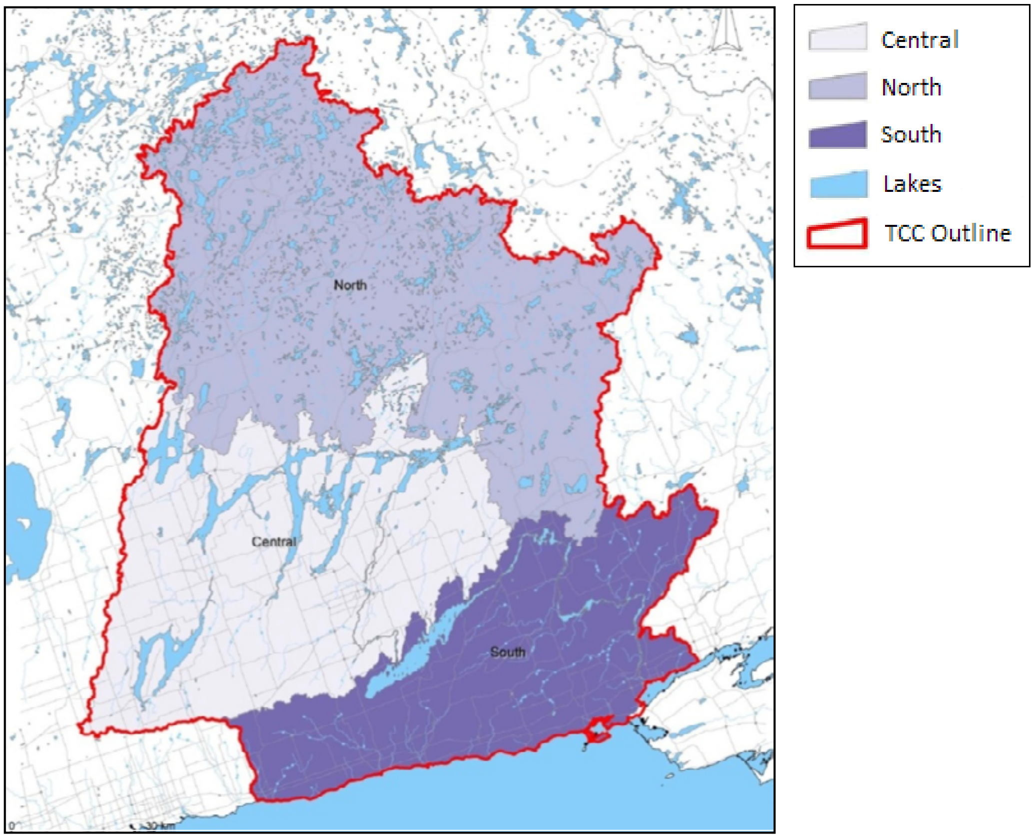

Figure 6.2-3: Climate Zones

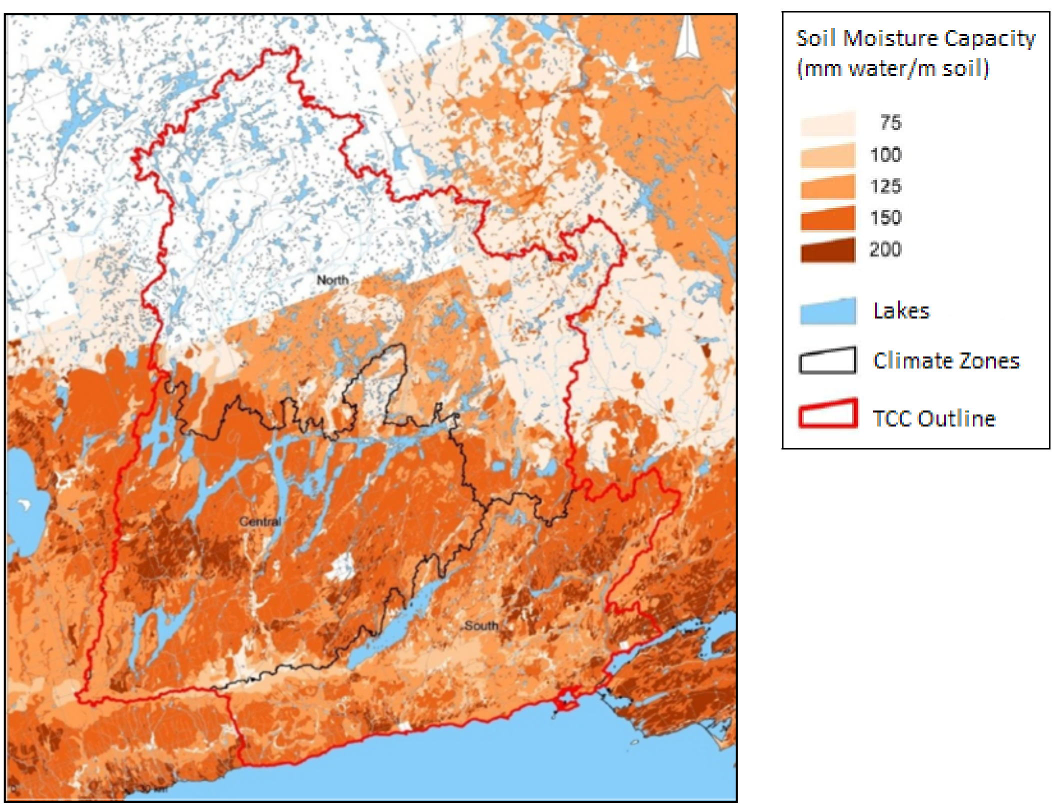

Figure 6.2-4: Soil Moisture Capacities

6.2.4 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 - AET) (mm/yr)
South (Cobourg STP)	871.1	518.2	353.7
Central (Peterborough A)	840.3	560.9	279.5
North (Minden Forestry)	1044.7	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), which 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 is 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 GROUNDWATER 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 and 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 (mm/year)
South (Cobourg STP)	353.7	194.5
Central (Peterborough A)	279.5	153.7
North (Minden Forestry)	485.6	213.7

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 (these are 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.

6.2.5.1.1 Removal of Areas with Shallow Groundwater

Areas with shallow groundwater, which are typically found in low lying valleys, are unlikely to contribute any significant groundwater recharge. Any recharge occurring within 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.

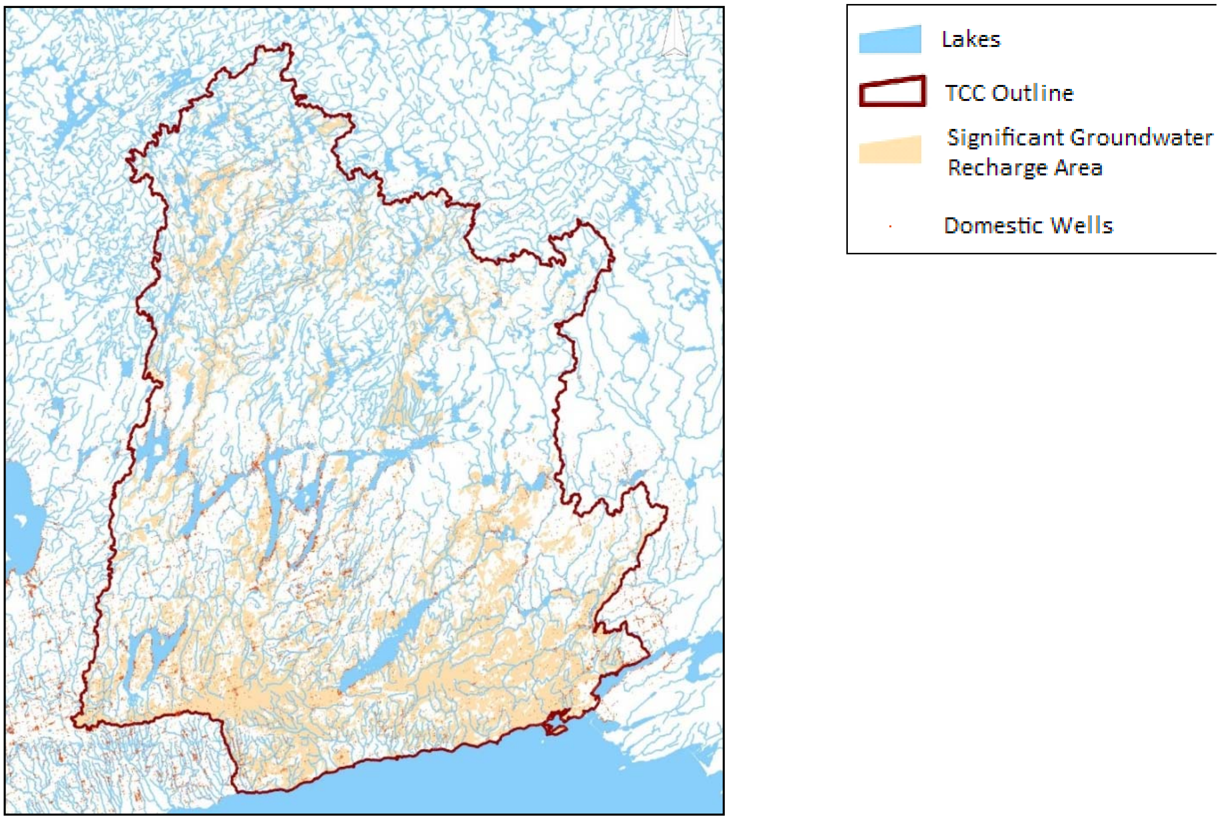

Figure 6.2-5: SGRA Delineation (annual recharge volume > 55% water budget surplus)

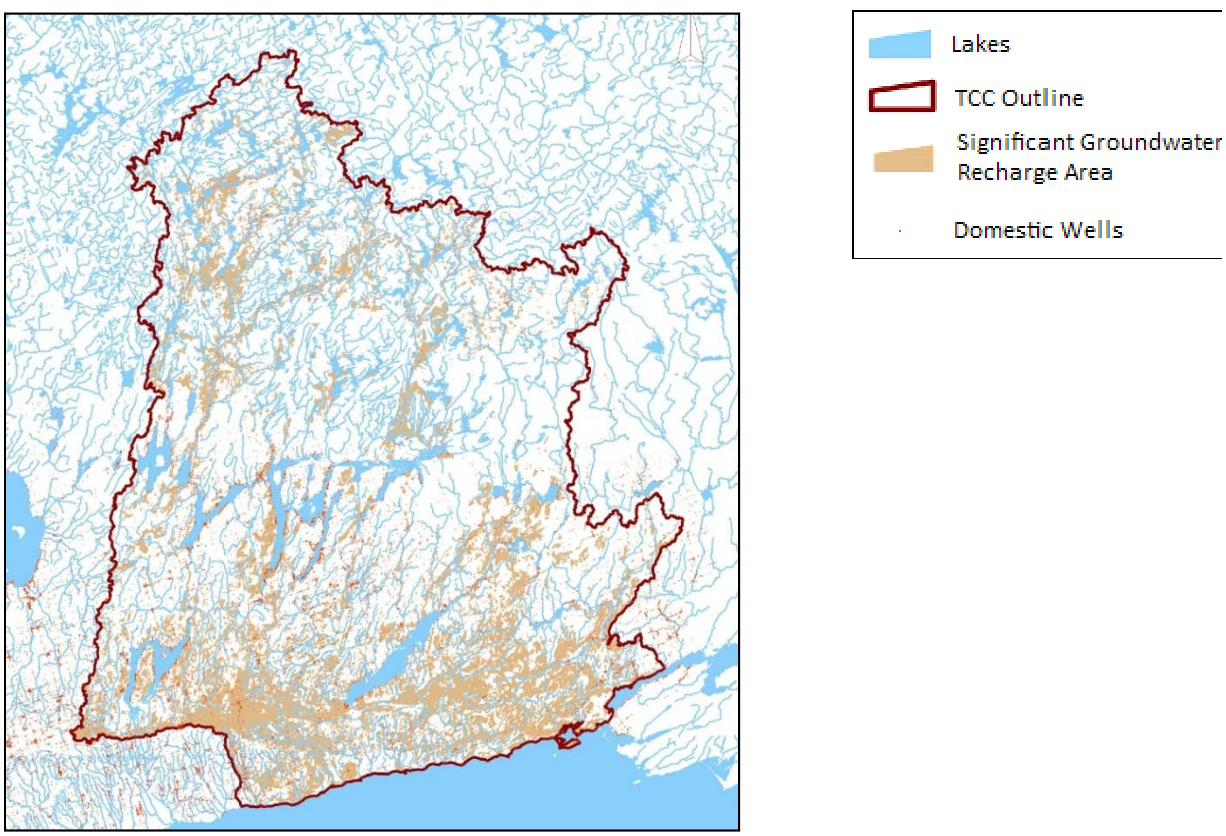

Figure 6.2-6: SGRA Delineation (annual recharge volume > 55% & shallow groundwater areas removed)

6.2.5.2 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 6-7.

6.2.6 UPDATED DELINEATION WITHIN TIER 2 SUBWATERSHEDS

The Tier 2 water budget involved the development of groundwater flow models for the subwatersheds that were assigned a moderate stress level in the Tier 1 water quantity stress assessment (i.e. Havelock, Colborne, and Brighton subwatersheds). The models represent hydrogeologic conditions at a finer scale than the approach used in the regional assessment. To take advantage of this improved information, the significant groundwater recharge areas were updated for the three subwatersheds using the models. This was achieved using the following methodology:

1. Cell-based average annual recharge rates were overlaid on the subwatershed.
2. An average recharge value was determined for the subwatershed.
3. A threshold recharge value (i.e. 1.15 times the average recharge rate) was identified for the subwatershed.
4. All model cells within the subwatershed that had a recharge value greater than or equal to the threshold determined in step 3 were identified as “updated” significant groundwater recharge areas.

The updated delineation of significant groundwater recharge areas in the Havelock, Colborne, and Brighton subwatersheds are shown on Maps 6-12a and 6-13a.

6.2.7 ASSIGNMENT OF VULNERABILITY SCORES

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 Tier 1 SGRA with assigned vulnerability scores were mapped separately for each of the Trent source protection areas. These are shown on Maps 6-8a to 6-11a. (These maps also identify the areas and circumstances where activities are or would be drinking water threats.) The Tier-2 SGRAs with assigned vulnerability scores were mapped for the Crowe-4 (Havelock), Lake Ontario-1 (Colborne), and Lake Ontario-3 (Brighton) subwatersheds and are shown on maps 6-12a and 6-13 (Brighton and Colborne are shown on the same map).

6.2.8 UNCERTAINTY ANALYSIS

The uncertainty of the delineation and vulnerability assessment of significant groundwater recharge areas was 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 identical 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)

6.2.9 INFORMATION TO SUPPORT CONTINUAL IMPROVEMENT

Long-term improvements

The significant groundwater recharge areas delineated in this report are based on broad regional level studies. Additional borehole or well data should be collected over time and used to enhance the findings of future groundwater recharge area assessments.

6.2.10 REFERENCES

British Columbia Ministry of Agriculture, Food, and Fisheries. (2001). *Water Conservation Factsheet: Soil Water Storage Capacity and Available Soil Moisture*. Retrieved September 30, 2009 from http://www.agf.gov.bc.ca/resmgmt/publist/600Series/619000-1.pdf.

CAMC-YPDT. (2009). *Trent Source Water Protection: Recharge Study (CAMC-YPDT Report #01-2009).* Conservation Authorities Moraine Coalition (CAMC) & York-Peel-Durham-Toronto (YPDT) Groundwater Management Study.

Gerber, R.E. (1994). *Recharge Analysis for the Central Portion of the Oak Ridges Moraine.* M.Sc. Thesis. Toronto: University of Toronto.

Kassenaar, J.D.C. , & Wexler, E.J. (2006). *Groundwater Modelling of the Oak Ridges Moraine Area (CAMC-YPDT Technical Report #01-06)*.

Thornthwaite, C.W. and 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 scores of highly vulnerable aquifers and significant groundwater recharge areas cannot exceed 6.0. This means that no significant threats can occur in these vulnerable areas. The requirements for the threats assessment for the Highly Vulnerable Aquifer 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 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 highly vulnerable aquifers or 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

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 drinking water threats are documented conditions resulting from past activities. The *Technical Rules* identifies the following as conditions:

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 liquids in surface water in a surface water intake protection zone;
3. The presence of a contaminant in groundwater in a highly vulnerable aquifer, significant groundwater recharge area, or a wellhead protection area, if the contaminant is listed in Table 2 of the Soil, Groundwater, and Sediment Standards and is present at a concentration that exceeds the potable groundwater standard set out for the contaminant in that Table;
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, Groundwater, and Sediment Standards and is present at a concentration that exceeds the surface soil standard for industrial/commercial/institutional property use set out for the contaminant in that Table; and

5. The presence of a contaminant in sediment, if the contaminant is listed in Table 1 of the Soil, Groundwater, and Sediment Standards and is present at a concentration that exceeds the sediment standard set out for the contaminant in that Table.

The assessment of conditions in highly vulnerable aquifers and significant groundwater recharge areas was limited to records in the Brownfields Environmental Site 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. A single condition (without any off-site impact) was noted within this vulnerable area. Since this condition would only result in a negligible threat, details of this condition are not listed.

6.3.3 CIRCUMSTANCES UNDER WHICH ACTIVITIES ARE OR WOULD BE MODERATE OR LOW DRINKING WATER THREATS

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 Sections 4.4.2.4 and 5.4.2.4). Percent managed lands, livestock density, and percent impervious surface area in highly vulnerable aquifers and significant groundwater recharge areas were mapped separately for each of the four Trent source protection areas. Map numbers are given in the table below.

Table 6.3-2: Vulnerable Area and Associated Source Protection Area Map Number

Vulnerable Area	Map Numbers		
	Percent Managed Lands	Livestock Density	Total Impervious Surface Area
Highly Vulnerable Aquifers	6-3b to 6-6b	6-3c to 6-6c	6-3d to 6-6d
Significant Groundwater Recharge Areas	6-8b to 6-11b	6-8c to 6-11c	6-8d to 6-11d
Significant Groundwater Recharge Areas updated with Tier-2 water budget data	6-12b to 6-13b	6-12c to 6-13c	6-12d to 6-13d

6.3.4 MAPPING OF AREAS AND CIRCUMSTANCES WHERE ACTIVITIES ARE OR WOULD BE A MODERATE OR LOW DRINKING WATER THREAT

The areas that are or would be moderate or low chemical, pathogen, and DNAPL threats in highly vulnerable aquifers are shown separately for each of the Trent source protection areas on Maps 6-3a to 6-6a. The areas that are or would be moderate or low chemical and DNAPL threats in significant groundwater recharge areas are shown on Maps 6-8a to 6-11a. The areas that are or would be moderate or low chemical and DNAPL threats in significant groundwater recharge areas updated using Tier-2 water budget data are shown on Maps 6-12a to 6-13a. 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.

CHAPTER 7: GREAT LAKES CONSIDERATIONS

The four source protection areas that are the subject of this report – Crowe Valley, Kawartha-Haliburton, Lower Trent, and Otonabee-Peterborough – drain into Lake Ontario via the Trent River, the Bay of Quinte, and some direct drainage into Lake Ontario. This chapter addresses the requirements of the *Clean Water Act, 2006* 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 must consider 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* must be included in the Assessment Report.

During the development of the work plan and preparation of the draft 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
- Implementation Manager, Bay of Quinte Remedial Action Plan
- Lake Ontario Lakewide Management Plan (LAMP) Coordinator, Environment Canada
- Remedial Action Plan (RAP) 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., Ministry of the Environment and Climate Change 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 this Assessment Report. The following sections describe the prescribed documents and indicate how they were considered during the preparation of this Assessment Report.

7.2 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 Trent Conservation Coalition Source Protection Region 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 entire Trent River watershed is located within the Bay of Quinte Area of Concern.

BAY OF QUINTE REMEDIAL ACTION PLAN

The Bay of Quinte Remedial Action Plan was initiated to deal with pollution problems in the Bay of Quinte Area of Concern. These problems included a loss of diversity of plant and animal life and their habitats (especially wetlands), human health risks, and a "*mix of toxic contaminants, bacterial, and nutrient overloads [that] led to great imbalances in the aquatic ecosystem*" (Bay of Quinte Remedial Action Plan, n.d.). In 1986, a federal, provincial, and local cleanup partnership was created to draft the Bay of Quinte Remedial Action Plan.

The Bay of Quinte Remedial Action Plan endeavors to address specific impaired beneficial uses of the bay that include: restrictions on drinking water consumption, fish consumption, and dredging activities (due to contaminated sediment); drinking water taste and odour problems; loss of fish and wildlife habitat; degraded aesthetics, benthos, plankton, and fish and wildlife populations; eutrophication or undesirable algae; and beach closures (International Joint Commission, 2006). The restoration effort follows a multi-year work plan that identifies cleanup actions intended to correct these impaired beneficial uses and ultimately result in the delisting of the Bay of Quinte as an Area of Concern.

The cleanup actions in the latest work plan include: protection of significant natural areas in partnership with municipalities and landowners; protection of fish habitats through the development of a Bay of Quinte fish habitat management plan; monitoring of wildlife to track trends in environmental conditions through a volunteer community wildlife watchers program; reduction of urban pollution to the Bay through the implementation of municipal pollution prevention and control planning studies; and a review of the progress made to date on lowering toxic inputs to the Bay (Bay of Quinte Remedial Action Plan, n.d.). Some of these cleanup actions will serve to improve the quality of source water for the Bayside municipal surface water intake, located in the Bay of Quinte.

The Bay of Quinte Remedial Action Plan was an important consideration in the development of this Assessment Report. The document was considered in the following ways:

1. During the preparation of technical studies that are components of this Assessment Report, data and reports made available through the Bay of Quinte Remedial Action Plan were reviewed, including the following:
    a. An inventory of potential sources of contamination in the Bay of Quinte (Lower Trent Conservation, 2004)
    b. Water quality reports on algal toxins and taste and odour compounds (e.g., Taste, Odour, and Toxins in the Bay of Quinte (Watson et al., 2009))
    c. Modeling Phosphorus Management in the Bay of Quinte, Lake Ontario in the Past, 1972 to 2001, and in the Future (Minns, C.K. & Moore, J.E., 2004)

   d. *City of Trenton Pollution Planning Control Study* (XCG Consultants, 1997 & 1998).

2. Bay of Quinte Remedial Action Plan staff were consulted regarding the shared concern of drinking water taste and odour, which is both an impaired beneficial use in the Bay of Quinte Remedial Action Plan and a potential drinking water issue.

3. Cyanobacterial toxins (harmful algal blooms) are identified as an emerging threat in the Project Quinte Annual Report 2007 (Bay of Quinte Restoration Council, 2009). *Microcystin* is a cyanotoxin (produced by cyanobacteria) that is one of the parameters that can be considered for identification of drinking water issues under the *Clean Water Act*. Phosphorus is the limiting nutrient for all algae in the Bay of Quinte including harmful algae (e.g., *Microcystis* species). Scientists from Environment Canada and the Department of Fisheries and Oceans are currently investigating the sources of phosphorus to determine whether they are anthropogenic (watershed-based) or natural (recycled from the decaying algae).

4. Source protection staff have attended meetings and made presentations to the Bay of Quinte Remedial Action Plan Restoration Council to provide updates and solicit input in preparing the Terms of Reference and Assessment Report.

5. The presence of dioxins and furans in the sediments in the mouth of the Trent River was initially identified through annual monitoring programs that were conducted under Project Quinte, a collaborative research program led by Fisheries and Oceans Canada. Reports that were prepared to assess the findings (e.g., *Lower Trent River: Preliminary Quantitative Human Health Risk Assessment* (Dillon Consulting Ltd., 2006); *Ecological Risk Assessment for the Trent River Mouth Sediment Depositional Areas* (Dillon Consulting Ltd., 2007)) were considered during the identification of conditions for this Assessment Report.

7.3 CANADA-ONTARIO AGREEMENT RESPECTING THE GREAT LAKES BASIN ECOSYSTEM

The *Canada-Ontario Agreement Respecting the Great Lakes Basin Ecosystem* is an agreement between the governments 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, 2004**b**). 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.

7.4 GREAT LAKES CHARTER

The *Great Lakes Charter* is a series of agreements among 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.

7.5 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.

7.6 LAKE ONTARIO WORKING GROUP

The source protection regions and areas draining into Lake Ontario (Niagara, Halton-Hamilton, CTC (**C**redit Valley, **T**oronto and Region, and **C**entral Lake Ontario), 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 within 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 and 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 daily precipitation extremes are 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 has generally 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 increases moisture availability in the air for 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 ^{o}C) is expected to increase across Canada and the frequency of extreme cold days is 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 because of climate change. From 1948 to 2006, annual average temperatures across Ontario have increased between 0 and 1.4 ^{o}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 analyse 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 and 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 in 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). Some projections, however, 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 from south to north, 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 extreme 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).

8.2 POTENTIAL IMPACTS ON WATER RESOURCES

Climate change has the potential to impact water resources on a national scale. Increasing temperatures increase the amount of evapotranspiration that occurs, which in turn decreases soil moisture. Climate models indicate that North America may experience changes in annual runoff, with increases in the eastern regions, little change in the mid-west and south, and substantial decreases 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 (Chiotti & Lavender, 2008).

8.3 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 streamflow records less reliable for making projections about future conditions. The findings 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 within the next 25 years are summarized in Table 8-2.

Table 8-1: 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 and Lavender, 2008

8.4 INFORMATION TO SUPPORT CONTINUAL IMPROVEMENT

Continual improvement 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.

Table 8-2: Potential Impacts of Climate Change on Contents of the Trent River 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 & 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 & geologic characteristics; Surface Water Vulnerabilities are based on intake characteristics and corresponding terrain characteristics such as topography, drainage, soil characteristics, geology, and land use.

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CHAPTER 9: CROSS-BOUNDARY CONSIDERATIONS

The findings of this Assessment Report will affect source protection planning in neighbouring source protection areas and regions. Similarly, the Assessment Reports for neighbouring source protection areas and regions will affect source protection planning in the Trent source protection areas. The Source Protection Committee will need to work with the committees for neighbouring source protection areas and 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.

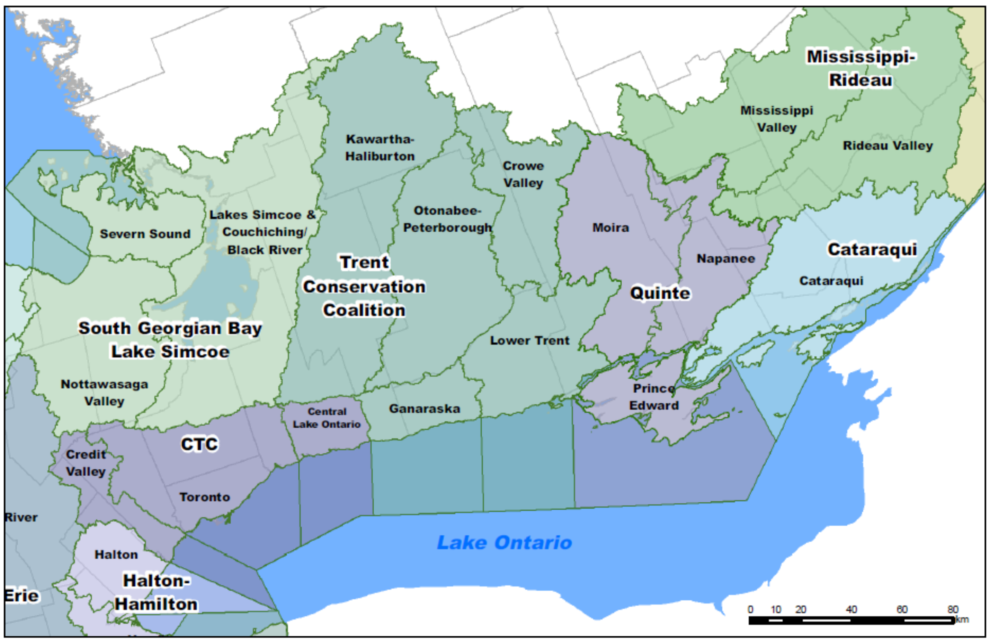

Figure 9.1: Neighbouring Source Protection Areas and Regions

9.1 GANARASKA REGION SOURCE PROTECTION AREA

The Ganaraska Region Source Protection Area is a part of the Trent Conservation Coalition Source Protection Region but is addressed in a separate Assessment Report. Matters that affect the Ganaraska Region Source Protection Area and the ways that they have been addressed are listed below:

- Intake Protection Zone 3 for the Hastings surface water intake (located in the Otonabee-Peterborough and Lower Trent Source Protection Areas) extends into the Ganaraska Region Source Protection Area. Maps for this zone are included in both Assessment Reports (Maps 4-9d to 4-9f in this Assessment Report).
- Significant groundwater recharge areas and highly vulnerable areas were delineated for the entire Trent Conservation Coalition Source Protection Region. Some of these areas cross the boundary between the

Ganaraska Region Source Protection Area and the Trent source protection areas. The same summary of the delineation processes has been included in both Assessment Reports.

- 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 this 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 TORONTO REGION SOURCE PROTECTION AREA

The sub-watersheds confirmed to be moderately stressed from the CTC Tier-2 Water Budget and Water Quantity Stress Assessment Studies are identified in the Table 9.2 below.

Table 9.2: Moderately stressed sub-watersheds from CTC Tier-2 Water Budget Studies

Watershed	Sub-Watershed	Tier 2 Stress Level	Municipal DWS
Rouge River	Little Rouge River(RO02)	Moderate	Stouffville (PW1, PW2, PW3, PW5)
Duffins Creek	Stouffville/Reesor Creek (DU06)	Moderate	Stouffville (PW6) Uxville(MW1, MW2)

Subsequently, the Tier-3 Water Budget and Water Quantity Risk Assessment Studies completed in 2014 for the Stouffville (York Region) and Uxville (Durham Region) municipal wells (see Table 9.2) delineated water quantity vulnerable areas called WHPA-Q1 and WHPA-Q2; where,

WHPA-Q1: The combined area that is the cone of influence (or “drawdown” cones) of the municipal well and the whole of the cones of influence of all other (municipal and non-municipal) wells that intersect that area. Due to intersections of the modelled “drawdown” cones of many nearby municipal systems, the water quantity based vulnerable area WHPA-Q1 was geographically very extensive.

WHPA-Q2: WHPA-Q1 PLUS any area where a future reduction in recharge would significantly impact that area. Since future proposed land use change has no “measureable” impact on the municipal wells, WHPA-Q2 was therefore made coincident with WHPA-Q1 (i.e. WHPA-Q1/Q2; see Figure 9.2 below).

The combination of WHPA-Q1 and WHPA-Q2 are called a “Local Area”. Activities considered drinking water quantity threats (i.e. activities contributing to consumptive water takings and activities which reduces recharge) within the local area are classified as low, moderate, or significant depending on the risk level assigned to the Local Area. If the risk level is significant, then all current and future water quantity threat activities are classified as significant drinking water threats. If the risk level is moderate, the current water quantity threat activities are classified as moderate drinking water threats, while the future such activities would be classified as significant drinking water threats.

In summary, the Tier-3 York/Durham Water Budget and Water Quantity Risk Assessment provided the following results:

“Exposure” level under scenario G (Table 4 – Exposure Scenarios; Technical Rules, 2009) is high due to impacts to “other users”: 20% decrease in base flows to cold water streams in the Yonge Street Aquifer area, greater than 1m incremental drawdown in other permitted wells and under provincially significant wetlands.

“Tolerance” levels of Stouffville and Uxville drinking water systems are assessed to be high.

“Uncertainty” level of analysis was assessed to be low.

Therefore as per Technical Rule 98(2) and 100(1), a “moderate” risk level is assigned to the Local Area WHPA-Q1/Q2).

Since York/Durham Tier 3 Local Area (WHPA-Q1/Q2) was assigned a moderate risk level, all existing consumptive water takings and recharge reductions within this local area are classed as moderate threats and all future consumptive water takings (those requiring PTTW) and future recharge reductions are classed as significant threats (Ref # 4 & 8, Table 5: Water Quantity Drinking Water Threats; Technical Rules, 2009).

A small portion of the Local Area in the Region of Durham (within the municipalities of Uxbridge & Scugog) extends into Kawartha-Haliburton Source Protection Area, part of the Trent Conservation Coalition SPR.

Policies are required to ensure that moderate threats in the local area do not become significant and to prevent future significant threats (i.e. increase to an existing taking or a new taking or reduction in recharge).

TCC are technically required to implement policies with respect to York/Durham Tier 3 Local Area coming under the jurisdiction of Kawartha-Haliburton SPA after MOECC approves TRSPA’s Updated Assessment Report. MOECC approved TRSPA’s Updated Assessment Report on July 24, 2015. Therefore it is recommended that:

1. TCC SPC be requested to develop water quantity policies aimed at future consumptive takings and/or future reductions in recharge activities for the Local Area (WHPA-Q1/Q2) falling within Kawartha-Haliburton SPA.
2. Carry out public consultation in relation to the updates to the Trent Assessment Report and Trent Source Protection Plan.

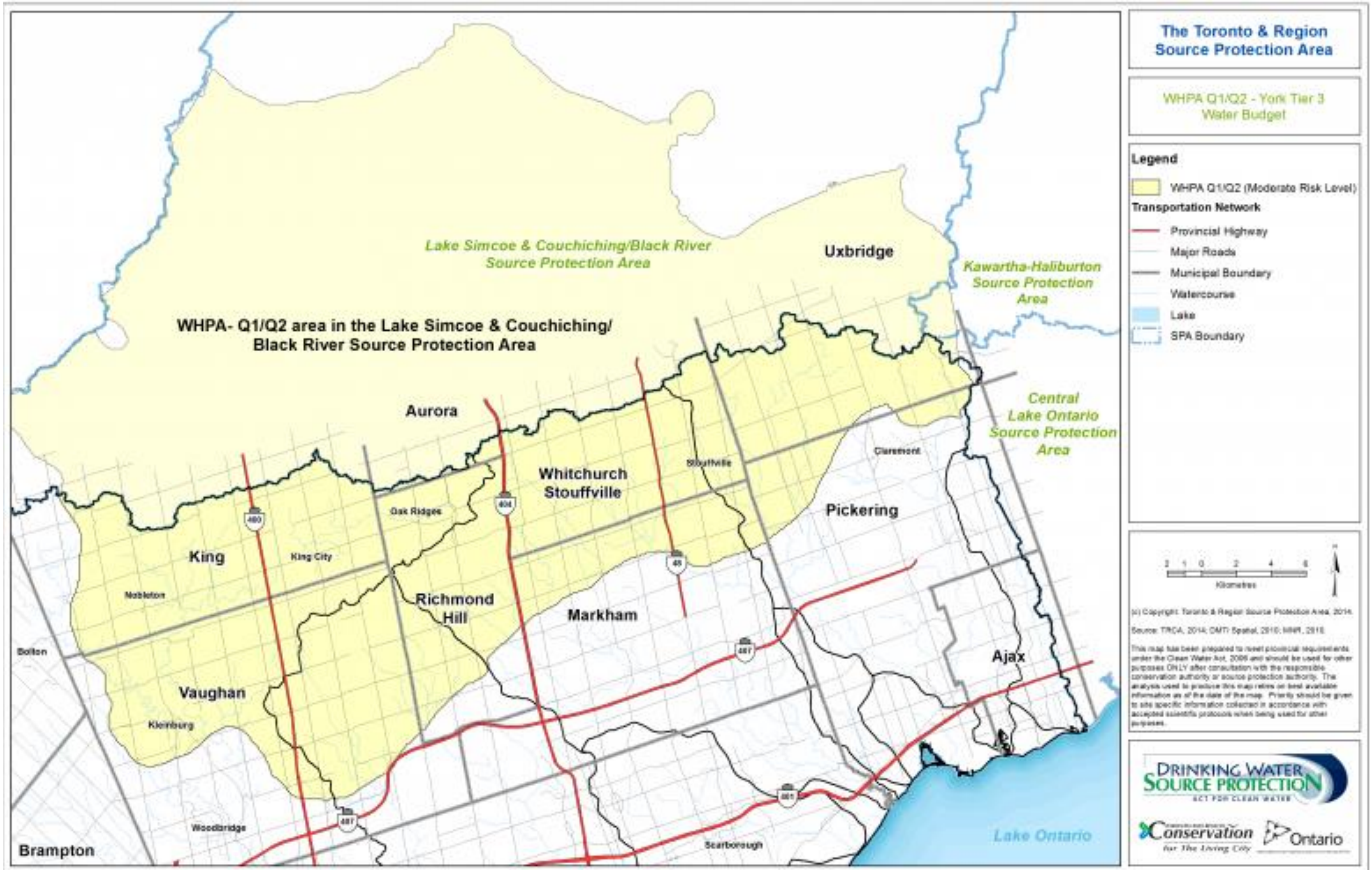

Figure 9.2: WHPA Q1 & Q2 Boundaries in Credit Valley, Toronto and Region, and Central Lake (CTC) and Lake Simcoe & Couchiching / Black River Source Protection Regions. Note the small area to the East which enters Kawartha-Haliburton Source Protection Area.

9.3 OTHER SOURCE PROTECTION REGIONS

The Trent source protection areas are bordered to the east by the Quinte Source Protection Area and to the west by the South Georgian Bay-Lake Simcoe Source Protection Region (Lake Simcoe & Couchiching/Black River Source Protection Area) and the CTC Source Protection Region (Credit Valley, Toronto and Region, and Central Lake Ontario). The matters that affect other source protection regions are listed in Table 9.3a to 9.3d.

Where vulnerable areas cross source protection region boundaries, information was shared among the affected source protection regions to compare knowledge and coordinate approaches. In these cases, consultation among the Source Protection Committees for the related source protection regions will be required to ensure that a common approach is taken at the source protection planning stage.

Table 9.3a: Cross-Boundary Considerations (Quinte Source Protection Area)

Shared Concern	Description of the Matter	Steps Taken to Date / Notes
Bayside IPZ	Intake Protection Zones 1, 2, and 3 for the Bayside intake in the Bay of Quinte (in the Trent Conservation Coalition Source Protection Region) extend into the Quinte Source Protection Area (in the Municipality of Prince Edward County). One significant threat was identified in the portion of the Intake Protection Zone located in the Quinte Source Protection Area.	• Trent Conservation Coalition Source Protection Region and Quinte Source Protection Area held several joint technical meetings to discuss approaches for vulnerability, issues, and threats assessments. • Results for the Bayside vulnerability and threats assessment were shared with the Quinte Source Protection Area, • The significant threat for Bayside in the Quinte Source Protection Area has been accounted for in the Quinte Assessment Report, • The Intake Protection Zones for Bayside (including the portion in the Quinte Source Protection Area) are shown on Maps 4-11a and 4-11d.
Belleville IPZ	Intake Protection Zone 3 for the Belleville intake in the Bay of Quinte (in the Quinte Source Protection Area) extends into the Trent Conservation Coalition Source Protection Region (Lower Trent Source Protection Area). The Trent River watershed flows into the Bay of Quinte, where the Belleville intake is located.	• Ongoing communications occurred between technical staff and consultants for the two source protection regions to ensure consistent approaches for the Bay. • Vulnerability mapping was shared to facilitate edge-mapping. • The Intake Protection Zones for the Belleville system (including the portion in the Lower Trent Source Protection Area) are shown on Figure 9.3-1. • The circumstances that would make the activities prescribed to be drinking water threats significant, moderate, or low drinking water threats in the Belleville IPZ-3 are identified in Table 9.3-1 (by reference to the applicable Provincial Tables of Circumstances). • No significant threats were identified in IPZ-3.
Trenton Water Treatment Plant	The Trenton Water Treatment Plant (located in the Trent Conservation Coalition Source Protection Region) provides drinking water via a pipeline under the Bay of Quinte to a portion of the Municipality of Prince Edward County (Carrying Place to Consecon) located in the Quinte Source Protection Area.	• No concerns have been brought forward to date. • Communication and consultation may be required if any issues arise from this arrangement.
Stirling Wellhead Protection Area	Preliminary modeling results indicated that the Stirling Wellhead Protection Area (Trent Conservation Coalition Source Protection Region) extended marginally into the Quinte Source Protection Area.	• The updated Wellhead Protection Area for Stirling does not extend into the Quinte Source Protection Area. • No further action required.

Table 9.3b: Cross-Boundary Considerations (South Georgian Bay – Lake Simcoe Source Protection Region)

Shared Concern	Description of the Matter	Steps Taken to Date / Notes
Woodville WHPA	Preliminary results indicated that the Wellhead Protection Area for the Woodville wells in the South Georgian Bay - Lake Simcoe Source Protection Region (Lake Simcoe and Couchiching/Black River Source Protection Area) extend into the Trent Conservation Coalition Source Protection Region (Kawartha-Haliburton Source Protection Area). The wells are located in South Georgian Bay - Lake Simcoe Source Protection Region.	• The updated Wellhead Protection Area indicates that WHPA-D for Woodville extends into the Trent Conservation Coalition Source Protection Region (no Significant Threats were identified in this area). • The technical studies for Woodville were completed by the City of Kawartha Lakes in consultation with both source protection regions. Both regions have access to the findings. • The portion of the Woodville Wellhead Protection Area located in the Kawartha-Haliburton Source Protection Area is shown on Figure 9.3-2 • The circumstances that would make the activities prescribed to be drinking water threats significant, moderate, or low drinking water threats in the Woodville WHPA-D are identified in Table 9.3-2 (by reference to the applicable Provincial Tables of Circumstances). • No significant threats were identified in the portion of the WHPA that extends into Kawartha-Haliburton Source Protection Area.
Cannington WHPA	Preliminary results indicated that the Wellhead Protection Area for the Cannington wells in the South Georgian Bay - Lake Simcoe Source Protection Region (Lake Simcoe and Couchiching/Black River Source Protection Area) may extend into the Trent Conservation Coalition Source Protection Region (Kawartha-Haliburton Source Protection Area). The wells are located in South Georgian Bay - Lake Simcoe Source Protection Region.	• The updated Wellhead Protection Area for Cannington does not extend into the Kawartha-Haliburton Source Protection Area. • No further action required.
Woods of Manilla WHPA	The Woods of Manilla wells are located in both the South Georgian Bay - Lake Simcoe Source Protection Region (Lake Simcoe and Couchiching/Black River Source Protection Area) and the Trent Conservation Coalition Source Protection Region (Kawartha-Haliburton Source Protection Area). The main production well appears to be in the Trent Conservation Coalition Source Protection Region. The Wellhead Protection Area for the system extends into both regions.	• The technical studies for the Woods of Manilla were completed by the City of Kawartha Lakes in consultation with both source protection regions. One well is located in South Georgian Bay - Lake Simcoe Source Protection Region and the other in Trent Conservation Coalition Source Protection Region (Kawartha-Haliburton Source Protection Area). Both regions have access to the findings. • The Wellhead Protection Area for the Woods of Manilla system (including the portion located in the South Georgian Bay – Lake Simcoe Source Protection Region) is shown on Map 5-13a. • The areas where threats are or would be significant, moderate, or low chemical, DNAPL and pathogen threats are shown on Map 5-13c. • The enumeration of significant threats for the portion of the WHPA in the Kawartha-Haliburton Source Protection Area is provided in Chapter 5 of this Assessment Report.
Greenbank WHPA	The Greenbank Wellhead Protection Area D (Trent Conservation Coalition Source Protection Region) extends marginally into the Georgian Bay - Lake Simcoe Source Protection Region (Lake Simcoe and Couchiching/Black River Source Protection Area). The wells are located in the Trent Conservation Coalition Source Protection Region (Kawartha-Haliburton Source Protection Area). There are no significant threats in the portion of the Wellhead Protection Area located in the Trent Conservation Coalition Source Protection Region.	• The technical studies for Greenbank were completed by the Regional Municipality of Durham in consultation with both source protection regions. Both regions have access to the findings. • The Wellhead Protection Area for Greenbank (including the portion located in the Georgian Bay – Lake Simcoe Source Protection Region) is shown on Map 5-15a. • The areas where threats are or would be significant, moderate, or low chemical, DNAPL and pathogen threats are shown on Map 5-15c. • The enumeration of significant threats for the portion of the WHPA in the Kawartha-Haliburton Source Protection Area is provided in Chapter 5 of this Assessment Report.
Trent-Severn Waterway	The Trent-Severn Waterway periodically directs water from Balsam Lake (in the Kawartha-Haliburton Source Protection Authority) into the Lake Simcoe watershed.	• Minor concern. No action is required.

Table 9.3c: Cross-Boundary Considerations (South Georgian Bay – Lake Simcoe Source Protection Region)

Shared Concern	Description of the Matter	Steps Taken to Date / Notes
SGRA Edge Matching	Significant Groundwater Recharge Areas are being identified as part of the Assessment Reports in each source protection region. Methodologies for mapping Significant Recharge Areas will need to be reviewed to ensure compatible, comparable products for all three neighbouring source protection regions (most specifically with the Central Lake Ontario, Lake Simcoe and Couchiching/Black River Source Protection Area, and Quinte Source Protection Areas). Vulnerability assessments and issues-based evaluations within SGRAs will also need to align.	• The Significant Groundwater Recharge Area report and mapping for the Trent Conservation Coalition Source Protection Region were provided to South Georgian Bay - Lake Simcoe and CTC Source Protection Regions, as well as, Quinte Source Protection Area. • Edge matching summary is provided in Section 9.4.
HVA Edge Matching	Highly Vulnerable Aquifers are being identified as part of the Assessment Reports in each source protection region. Methodologies for mapping Highly Vulnerable Aquifers will need to be reviewed to ensure that the products are similar for all three neighbouring source protection regions. Vulnerability assessments and issues-based evaluations within the HVAs will also need to align.	• Groundwater Vulnerability and Highly Vulnerable Aquifers reports and mapping for the Trent Conservation Coalition Source Protection Region were provided to the South Georgian Bay - Lake Simcoe and CTC Source Protection Regions, as well as, and Quinte Source Protection Area. • Edge matching summary is provided in Section 9.4.
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 source protection region.	• Water Budget reports (Conceptual and Tier 1) for the Trent Conservation Coalition Source Protection Region were provided to South Georgian Bay - Lake Simcoe and CTC Source Protection Regions, as well as Quinte Source Protection Area.

Table 9.3d: Cross-Boundary Considerations (Miscellaneous Considerations)

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 Source Protection Regions		
Peer Review of Groundwater Vulnerability Studies	Peer Review of Groundwater Vulnerability Studies for municipal systems should be coordinated among the three source protection regions in Durham Region to ensure a consistent review and consistent products for the Municipality.	• Discussion took place among 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 Areas/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 Trent Conservation Coalition Source Protection Region (all 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. • No Intake Protection Zone 3 identified to date affects the Trent source protection areas. • Intake Protection Zone 3 will be included in an updated Assessment Report, if required.
Bay of Quinte Area of Concern (Quinte Source Protection Area and Cataraqui Source Protection Area)		
Bay of Quinte Area of Concern	The Cataraqui, Quinte, and Trent Conservation Coalition Source Protection Areas and Regions are partially located within the Bay of Quinte Area of Concern. There are surface water intakes in the Bay of Quinte (Bayside is in the Lower Trent Source Protection Area). Drinking water source protection research and planning may assist the communities around the Bay to achieve the objectives of the Remedial Action Plan for the Area of Concern. The committees should consult with one another on issues that relate to the Remedial Action Plan.	• Ongoing communication has occurred between the source protection region/area staff and Bay of Quinte Remedial Action Plan staff.

Table 9.3-1: Circumstances that would result in a drinking water threat in the Belleville IPZ-3

Type of Threat	Provincial Table of Circumstances		
	Significant Threats	Moderate Threats	Low Threats
Chemical Threats	None	Table 27 (CIPZWE7.2M)	Table 35 (CIPZWE7.2L)
Pathogen Threats	None	Table 53 (PIPZWE7.2M)	Table 62 (PIPZWE7.2L)

Table 9.3-2: Circumstances that would result in a drinking water threat in the Woodville WHPA-D

Type of Threat	Provincial Table of Circumstances		
	Significant Threats	Moderate Threats	Low Threats
Chemical Threats	None	Table 05 (CW6M)	Table 08 (CW6L)
Pathogen Threats	None	None	Table 16 (PW6L)
DNAPL Threats	None	Table 10 (DW6M)	Table 11 (DW6L)

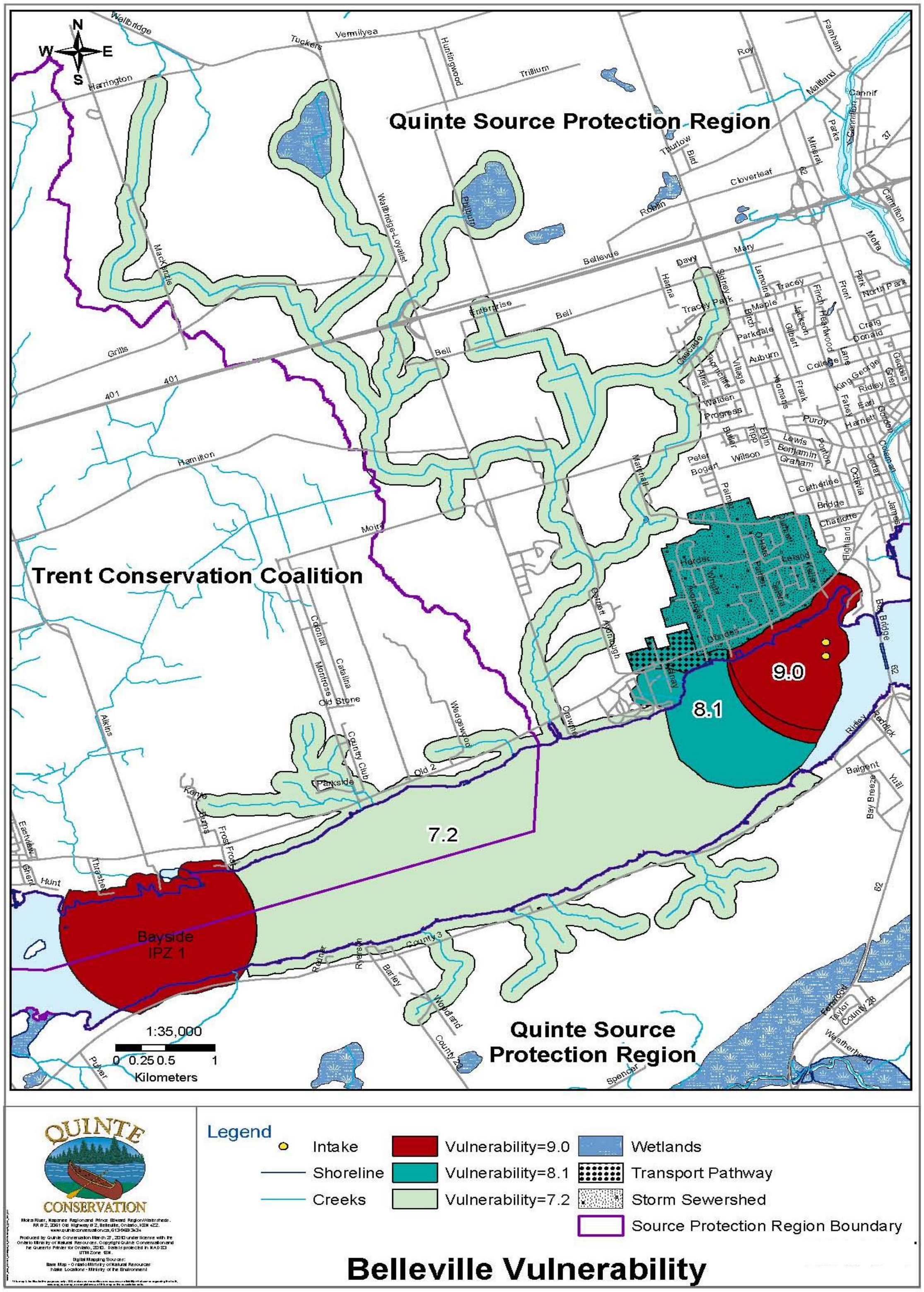

Figure 9.3-1: Portion of Belleville Intake Protection Zone in the Trent Conservation Coalition Source Protection Region

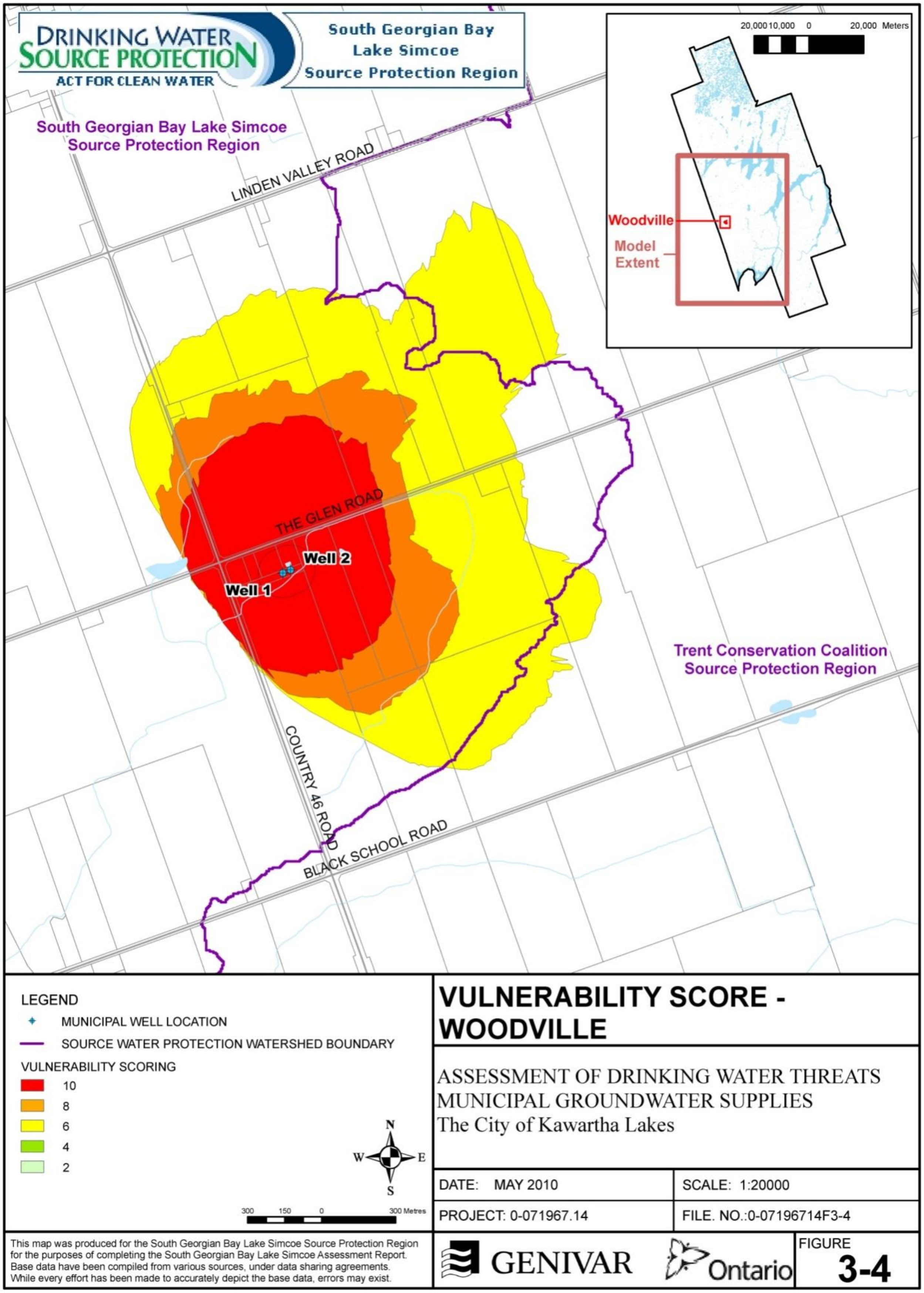

Figure 9.3-2: Portion of Woodville Wellhead Protection Area in the Trent Conservation Coalition Source Protection Region

9.4 EDGE MATCHING WITH ADJACENT SOURCE PROTECTION AREAS

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, the Trent Conservation Coalition Source Protection Region, as well as the three other Source Protection Regions / Area with which it shares a border, adopted different methodologies to delineate highly vulnerable aquifers and significant groundwater recharge areas.

As discussed earlier, the Trent Conservation Coalition Source Protection Region is bordered to the east by the Quinte Source Protection Area. To the west, the Region is bordered by the South Georgian Bay-Lake Simcoe Source Protection Region (Lake Simcoe & Couchiching/Black River Source Protection Areas) and the Credit Valley-Toronto & 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 9-4 below. A summary of the edge-matching review for the contact boundaries between the Kawartha-Haliburton, Lower Trent, and Crowe Valley Source Protection Areas with neighbouring source protection areas outside of the Region is given below. The review of edge-matching for the contact boundary between the Ganaraska Region and Central Lake Ontario Source Protection Areas is discussed in the Ganaraska Assessment Report.

Table 9-4: 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	Quinte	NA (stand-alone Source Protection Area)
Crowe Valley	Quinte	NA (stand-alone Source Protection Area)

9.4.1 LAKE SIMCOE AND COUCHICHING/BLACK RIVER SOURCE PROTECTION AREA

9.4.1.1 BOUNDARY WITH KAWARTHA-HALIBURTON SOURCE PROTECTION AREA

The mapped HVA and SGRA along the contact are reasonably consistent and continuous despite the different methodologies adopted by the two source protection regions. In addition to several minor discrepancies, only twelve (12) significant zones/locations along the contact were identified where the HVA feature was seen to change abruptly across the contact. The distribution of SGRA features across the contact was identified to be quite similar and only a single significant zone along the contact was identified, where the SGRA is seen to change abruptly across the contact.

It was concluded by the consultants that it may be more reasonable to address the consistency along these contact boundaries through requirements for on-site work in conjunction with planning applications rather than to attempt to create a more consistent mapping at a regional scale that will retain a relatively high degree of uncertainty on a local scale.

9.4.2 CENTRAL LAKE ONTARIO SOURCE PROTECTION AREA

9.4.2.1 BOUNDARY WITH KAWARTHA-HALIBURTON SOURCE PROTECTION AREA

The mapped HVA appears to change abruptly for a distance of approximately 10 km along the northern boundary of the Town of Oshawa. There are also three zones along the contact where the vulnerability to the north appears to be moderate to low (within the Kawartha-Haliburton Source Protection Area) and the vulnerability to the south appear to be high (within the Central Lake Ontario Source Protection Area). The distribution of SGRA is identified consistently along the majority of this contact. Two significant zones were identified where the SGRA is seen to change abruptly at the contact.

It was concluded by the consultants that it may be more reasonable to address the consistency along these contact boundaries through requirements for on-site work in conjunction with planning applications rather than to attempt to create more consistent mapping at a regional scale mapping that will retain a relatively high degree of uncertainty on a local scale.

9.4.3 QUINTE SOURCE PROTECTION AREA

9.4.3.1 BOUNDARY WITH LOWER TRENT SOURCE PROTECTION AREA

The HVA mapping shows significant differences across the regional boundary, particularly in the vicinity of the Oak Lake area. These significant differences can be attributed to differences in assessment methodologies adopted by, and assumptions made by the two source protection region/areas.

There is a significant density of SGRA polygons in the vicinity of Oak Lake in both regions' mapping. Though these SGRA polygons do not match perfectly across the regional boundary in the strictest sense, overall, there is a general consistency across the regional boundary.

9.4.3.2 CROWE VALLEY SOURCE PROTECTION AREA

The HVA mapping across the contact boundary between Crowe Valley Source Protection Area within the TCC SPR and Quinte SPA is consistent with few exceptions (i.e. very small areas (less than 2 km^2)).

The SGRA mapping across the contact boundary between Crowe Valley SPA within TCC SPR and Quinte SPA corresponds with each other (i.e. no SGRA polygons are located in this contact region).

9.5 REFERENCES

Technical Memorandum E – Durham Region Significant Groundwater Recharge Area Edge Matching Review dated (GENIVAR, Jan 14, 2011)

Technical Memorandum A – SGBLS/TCC Edge Matching Review (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 Kawartha-Haliburton, Otonabee-Peterborough, Crowe Valley, and Lower Trent Source Protection Areas. There are 46 existing municipal drinking water systems in the Trent source protection areas. Of these systems, 15 draw their water from surface water sources and 31 draw their water from groundwater sources. There is also one planned groundwater system.

The surface water systems are on inland lakes and rivers and generally serve the larger communities including Peterborough, Trenton, and Lindsay. The entire Trent River system is included in the intake protection zones because water flows from the uppermost part of the watershed in Algonquin Park to the Bay of Quinte (where the Bayside intake is located). The intake protection zone continues downstream of the Bayside intake to the Quinte Source Protection Region boundary because municipalities in this neighbouring source protection region also use the Bay of Quinte as a source of drinking water.

Nine of the groundwater systems (Canadiana Shores, Pleasant Point, Manorview, Buckhorn Lake Estates, Cardiff, Havelock, Stirling, Crystal Springs, and Fraserville) in the four Trent source protection areas are considered GUDI (groundwater under the direct influence of surface water). These systems required additional mapping beyond traditional wellhead protection areas to include WHPA-E, which was mapped for each of these areas to capture areas of potential contamination from surface water sources.

The following drinking water quality issue was identified in the Trent source protection areas (per Technical Rule 115):

- *E. coli* at the Stirling well system (Lower Trent Source Protection Area).

In total, 1,597 drinking water threats were identified on 980 parcels. Approximately 70% of the parcels affected are residential, 20% are agricultural, 6.5% are municipal (mostly road salt), and 3.5% are industrial.

The water budget analyses completed (Conceptual Water Budget, Tier 1 Water Budget and Stress Assessment, and Tier 2 Stress Assessments for Lindsay, Havelock, Colborne, and Brighton) indicate a low stress level. As such, no water quantity risk assessment is required and there are no water quantity threats.

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. Data gaps are listed in Table 10-1.

Table 10-1: Data Gaps

Data Gap	Description	Applicable Technical Rule	Work Required	Estimated Completion Date
Determination if *Microcystin*-LR is an issue (and if so, whether or not the source is anthropogenic or natural)	*Microcystin* is identified as a potential issue; there has been one exceedance in a limited data set. It is unknown whether the source is natural or anthropogenic. There is a knowledge gap regarding the specific environmental conditions that promote the growth of harmful algae.	114	Additional sampling to determine if *Microcystin* is an issue. If it is identified as an issue, additional research on the source of phosphorus contributing to the growth of blue-green algae that releases *Microcystin*-LR (e.g., watershed point and non-point sources or recycling within the Bay) is needed. Research is also required to identify environmental conditions that promote the growth of harmful algae.	Unknown

10.3 PREPARATION OF SOURCE PROTECTION PLAN

The Assessment Report findings will be used to develop policies for the Source Protection Plan that will serve to protect the sources of drinking water for the municipal systems in the Trent source protection areas and adjacent source protection regions. Policies will be 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 be held on the draft and proposed Source Protection Plan.

GLOSSARY

LIST OF ACRONYMS

ACRONYM	EXPLANATION
AVI	Aquifer Vulnerability Index
CAMC-YPDT	Conservation Authorities Moraine Coalition & York - Peel - Durham - Toronto (a group working together on groundwater initiatives within the Oak Ridges Moraine study area)
CSP	Corrugated steel pipe
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
SGRA	Significant Groundwater Recharge Area
SPA	Source Protection Area
SWAT	Surface to Well Advection Time
TOT	Time-of-Travel
UZAT	Unsaturated Zone Advection Time
WHPA	Wellhead Protection Area
WWAT	Water table to Well Advection Time

DEFINITION OF TERMS

TERM	DEFINITION
Advection	Transport by horizontal movement, as in the transport of heat and water vapor from one location to another by the horizontal movement of air or water.
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.
Alvar	A biological environment based on a limestone plain with thin or no soil and, as a result, sparse vegetation.
Anaerobic	A life or process that occurs in, or is not destroyed by, the absence of oxygen.
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	The water that flows into a stream through the subsurface.
Bedrock	Solid or fractured rock usually underlying unconsolidated geologic materials; bedrock may be exposed at the land surface.
Biodegradation	The composition of a substance into more elementary compounds by the action of microorganisms such as bacteria.
Biofilm	An aggregate of microorganisms in which cells adhere to each other and/or to a surface.
Biosolids	The byproduct of domestic and commercial sewage and wastewater treatment. Also referred to as sludge.

TERM	DEFINITION
Brownfields	Abandoned, idle, or under-utilized industrial and commercial properties where a previous property use caused environmental contamination. The land may need to be cleaned up before it can be redeveloped.
Calcareous	Soil that is chalky in appearance, containing calcium carbonate or magnesium carbonate.
Canadian Shield	A large geographic area in eastern and central Canada, covering approximately 8 million square kilometers, composed of bare rock dating to the Precambrian era (between 4.5 billion and 540 million years ago). The Canadian Shield is made up of some of the planet's oldest rock, largely granite and gneiss.
Catchments	The entire area from which water drains into a river, lake, or reservoir.
Coagulation	Clumping of particles in water to settle out impurities, often induced by chemicals such as lime, alum, and iron salts.
Conservation Authority 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*.
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	A system, 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, and; (c) A well or intake that serves as the source or entry point of raw water supply for the system.
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 an activity or condition that is prescribed by the *Clean Water Act* as a drinking water threat.

TERM	DEFINITION
Drought	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	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.
Esker	A ridge of glacial sediment deposited by a stream flowing in and under a melting glacier.
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	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.
Fens	Wetlands characterized by surface layers of poorly to moderately decomposed peat, often with well-decomposed peat near the base. The waters and peat in fens are less acidic than in bogs.
Geographic Information System (GIS)	A computer based system that has the capability to input, store, retrieve, manipulate, analyze, and output geographically referenced data.
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.

TERM	DEFINITION
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.
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	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 hydrologic processes.
Hydrograph	A graph that shows water level as a function of time.
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.
Impervious	Surfaces that resist or prevent the infiltration of water.
Infiltration	The process by which water on the ground surface enters the soil.
Intake Protection Zone (IPZ)	An area adjacent 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.
Krigging	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.
Lithology	The compositional and textural characteristics of a subsurface layer.

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	Land 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 unconsolidated glacial debris (soil and rock) which was deposited as a result of glaciation.
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.
Numerical Groundwater Model	A computer-based mathematical representation of water movement in an aquifer, calibrated to groundwater and stream level observations, used to predict flow direction and time of travel.
Overburden Wells	Groundwater wells tapping water from the unconsolidated geologic material above the bedrock.
Paleozoic	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.

TERM	DEFINITION
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 Director under the *Ontario Water Resources Act,* unless they meet the criteria for certain exempted water takings.
Physiography	A science that deals with the origins and development of landforms.
Porosity	A measure of the void spaces in a material (such as soils, sediments, or rocks) and is defined as the fraction of the volume of voids over the total volume.
Precambrian	A long-established, informal name for the 4 billion years of Earth's history before hard-bodied organisms arose at the beginning of the Cambrian Period (which began about 500 million years ago).
Quaternary Period	The most recent geological period of time in Earth's history, spanning the last two million years and extending up to the present day.
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. The Act 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 Areas (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 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.

TERM	DEFINITION
Stormwater	Stormwater is water that flows across the land during an intense precipitation event and is routed into drainage systems and ultimately into rivers, streams, lakes and wetlands.
Streamflow	The surface water flow 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 (e.g., rivers, lakes, reservoirs, ponds, streams, impoundments, etc.)
Surface Water Intake	A structure that draws water from a surface water body (lake, river or stream) for a water supply system.
Tables of Drinking Water Threats	The Ministry of the Environment and Climate Change publication "Tables of Drinking Water Threats: *Clean Water Act, 2006*" dated November 16, 2009, as amended from time to time, accessible via trentsourceprotection.on.ca.
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 the components of the water cycle.
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	Physical features, especially the relief and contours of the land surface.
Transport Pathways	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.

TERM	DEFINITION
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	Areas containing one or more wells that produce usable amounts of water.
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).