DRINKING WATER
SOURCE PROTECTION
ACT FOR CLEAN WATER

Thames-Sydenham and Region Source Protection Committee

Upper Thames River Source Protection Area

Assessment Report

August 12, 2011
Amendments initiated under
s.36 of the CWA - July 2023

ST. CLAIR CONSERVATION
LOWER THAMES VALLEY CONSERVATION AUTHORITY
UPPER THAMES RIVER CONSERVATION AUTHORITY
Ontario
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Thames-Sydenham and Region Upper Thames Assessment Report

Updated July 2023

Assessment Reports for Lower Thames Valley, St. Clair Region and Upper Thames River Source Protection Areas

Thames-Sydenham and Region Source Protection Committee

Table of Contents

Appendices

Appendix 11 – Glossary of Terms and Acronyms
Appendix 12 – References
Appendix 13 – Uncertainty Analysis
Appendix 14 – MECP communications

List of Figures

List of Maps

List of Tables

Introduction and Background

Following the tragedy in Walkerton (May, 2000) when the town's drinking water became contaminated with a specific strain of *Escherichia coli (E. coli)* and *Campylobacter* bacteria, Justice O'Connor presided over the Walkerton Inquiry. Justice O'Connor made 121 recommendations in a two-part report which recommended a multi-barrier approach to protecting Ontario's drinking water. Many of Justice O'Connor's recommendations were implemented with the introduction of the Safe Drinking Water Act, 2002 (*SDWA*). The *SDWA* dealt with the treatment, distribution and testing of drinking water as well as the training of operators and notification protocols. The Clean Water Act, 2006 (*CWA*) addressed Justice O'Connor's recommendations pertaining to the watershed-based protection of drinking water sources referred to as Drinking Water Source Protection.

The Clean Water Act, 2006 required the establishment of Source Protection Committees to oversee the process locally. The Source Protection Committee developed and consulted on a work plan document called the Terms of Reference and submitted it to the Minister of the Environment for Approval. Based on the approved Terms of Reference the Source Protection Committee completed an Assessment Report and Source Protection Plan. The Assessment Report is a science-based document that forms the basis of the Source Protection Plan. The Plan contains policies to reduce the risk associated with threats to the drinking water sources identified in the Assessment Report.

The Clean Water Act, 2006 requires that Assessment Reports be completed for each Source Protection Area within a Source Protection Region (*SPR*). The Assessment Reports contain detailed information that identifies *vulnerable* areas associated with drinking water systems, assesses the level of vulnerability, identifies *issues* related to the drinking water sources, identifies activities within those vulnerable areas which pose threats to the systems, and assesses the risk due to threats. The three Source Protection Areas of the Thames-Sydenham and Region *SPR* are shown in the Map 1-1. An Assessment Report is prepared for each Source Protection Area.

1.1 Document Overview

This Assessment Report is modular in nature. It is comprised of several Sections and Appendices. The Sections are, in effect, a summary of various technical studies which are described later in this section. Each of the Sections is summarized in Section Summaries contained in Appendix 2. Material pertinent to a specific drinking water system is summarized in System Summaries included in Appendix 3. Maps form a large part of the content of the Assessment Report, and are contained in Appendix 1. Tabloid sized (11"x17") maps are included in this report, and may be printed on letter sized paper and remain mostly legible. The entire document is available on DVD complete with the appendices to the Assessment Report and the Source Protection Plan.

Each Section of the Assessment Report is outlined below:

Introduction and Background (Section 1)

The first section provides an overview of the process and background behind the Assessment Report. It refers to mapping products related to the extent of the Source Protection Region and Source Protection Areas as well as the municipal partners involved in developing the Source Protection Plan.

Watershed Characterization (Section 2)

The Watershed Characterization Reports for the region were completed in 2008. A three volume report was produced for the Thames Watershed and Region which included the Upper Thames River Source Protection Area and the Lower Thames Valley Source Protection Area. A summary of the report was developed which included all of the mapping products used in the Watershed Characterization Report. The summary of the Thames Watershed and Region Watershed Characterization Report is included in Appendix 5. The summary and the full Watershed Characterization Reports are available in portable document format (Adobe PDF) on the Source Protection Plan DVD.

Water Budget and Water Quantity Stress Assessment (Section 3)

A Conceptual Water Budget was developed for the Thames-Sydenham and Region. This report is included as Appendix 6 of this Assessment Report. The Conceptual Water Budget compiles water quantity information from the region, such as precipitation and water takings, for use in the Tier 1 Water Budget. In the Tier 1 Water Budget, a preliminary stress assessment indicating the potential for water quantity stress in subwatersheds of the region is undertaken. The potential for stress determines whether additional work is required to refine the water budget in that *subwatershed*. If the potential stress could affect a drinking water system included in the Terms of Reference for the region (generally municipal drinking water systems), the additional refinement is completed through a Tier 2, and potentially a Tier 3 Water Budget. If, however, the potential stress does not have an impact on the water systems in the area, the work should be undertaken through different programs. The Thames-Sydenham and Region Tier 1 Water Budget has identified a potential for stress which would affect municipal drinking water systems in the Upper Thames River Source Protection Area. In the Tier 2 Water Budget, the analysis was further refined to confirm the potential for stress on drinking water systems. Further, a Tier 3 local area risk assessment and water budget was completed to assess the water quantity risks at each drinking water system exhibiting a potential for stress in the Tier 2 assessment.

Vulnerability Assessment (Section 4)

The Vulnerability Assessment section is a summary of the identification of the *vulnerable areas*, the assessment of vulnerability within those areas, and the *uncertainty* in that assessment as required by the Clean Water Act. The work related to this section was undertaken through a number of technical studies which were generally completed on the geographic scale of the upper tier municipalities (counties). This section summarizes the work completed on a Source Protection Area basis for each type of vulnerable area. The work is also summarized for each drinking water system in the System Summaries included in Appendix 3. A peer review of the vulnerability assessment work was undertaken.

Issues Evaluation (Section 5)

The Issues Evaluation Section describes the methods applied and the findings of the drinking water quality *issues* evaluation process across the Source Protection Area. The detailed methodology for the *issues* evaluation process is included in Appendix 8. A table of *issues* identified is included in the Issues Evaluation section as well as a description of the impact of identifying an *issue*.

Conditions Assessment (Section 6)

The Conditions Assessment section of the Assessment Report includes a description of the work undertaken to assess the potential *conditions* (drinking water threats due to past activities) which have been identified to date. This is an ongoing process.

Threats and Risk Assessment (Section 7)

The Threats and Risk Assessment section of this Assessment Report includes a list of the types of *threats* which are or would be a risk to drinking water systems in the region and the number of locations where significant threats are believed to exist. It is not the intent of this report to identify individuals who are believed to be engaged in those activities nor is it intended to identify specific properties where those activities exist. Policies developed in the Source Protection Plan will be focused on general types of activities which 'are or would be' *threats* to drinking water. This section also outlines the additional work required to investigate activities believed to be threats.

Great Lakes (Section 8)

The Great Lakes section includes the required references to other work undertaken in the region related to Great Lakes water quality and how the Assessment Report supports and complements that work and vice-versa. It identifies additional work required in this area once all the Assessment Reports for Source Protection Areas that drain into the Great Lakes are completed.

Data Gaps and Next Steps (Section 9)

Data gaps and next steps are listed in this section. Data gaps such as infrequent groundwater sampling or inaccurate tile drainage network information were identified through the technical studies and have been included in this Assessment Report so that they may be considered in the future. Several of the gaps identified in the Proposed Assessment Report are now filled, thus allowing for the materials to be available to the Source Protection Committee for the development of the *Source Protection Plan*. The remaining few gaps in the Upper Thames River Source Protection Area Assessment Report are noted in Section 9.

1.2 Clean Water Act Rules and Regulations

The Clean Water Act, 2006 established the requirements to develop a Source Protection Plan and set up the framework to develop that plan. In order to define the work and enable aspects of the work to be completed, regulations and *rules* were required. The development of these *rules* and regulations was led by the Drinking Water Source Protection Branch of the Ministry of the Environment, Conservation and Parks. These regulations were developed through consultation with stakeholders including the Source Protection Committee chairs and committees and the staff of the Conservation Authorities working with the Source Protection Committees. Many consultation sessions were held with sector representatives of those who may be impacted by the *rules* and regulations.

1.2.1 Regulations

A regulation established Source Protection Areas and Regions (O. Reg. 284/07). This regulation established the Thames-Sydenham and Region Source Protection Region and the three Source Protection Areas described in the sections to follow. This Source Protection Region recognized in regulation a partnership established by the Conservation Authorities to prepare for the work which the Clean Water Act requires.

A regulation was introduced to establish Source Protection Committees (O. Reg. 288/07). The regulation described the make-up of the committees and also the process for establishing the committees. The regulation required that the Source Protection Authorities in the region form the committee while the chair is appointed by the Minister of the Environment.

A General Regulation (O. Reg. 287/07) provides requirements for the Terms of Reference, Assessment Reports and Source Protection Plans. The General Regulation also establishes the 21 activities which can be considered drinking water *threats*. The requirements of the Act, Regulation and *rules* are summarized in the Assessment Report Checklist which is included in Appendix 7. The checklist indicates where the requirements have been satisfied in this Assessment Report.

1.2.2 Technical Rules

In order to fully define the contents of, and methodologies used in developing Assessment Reports, the Ministry of the Environment, Conservation and Parks (MECP) released *Technical Rules*: *Assessment Report* (December 12, 2008). The Director (MECP) amended those *rules* in November 2009, and again in March 2017).

The *Technical Rules 2013: Assessment Report* replaced interim guidance which was developed by MECP to guide much of the technical work initiated in 2006 and 2007. The guidance was developed in a modular manner with each module describing a specific component of the work. Much of the technical work followed those guidance modules which provided the basis for the organization of many of the technical studies. The guidance modules were detailed and descriptive. The organization of this report is partially reflective of those modules.

The Assessement Report aligns with 2017 Technical Rules.

1.2.3 Local Guidance Documents

The *rules* and regulations leave room for local discretion by the Source Protection Committee and system operating authorities. In many cases, local guidance documents were required to provide consistent guidance across the region. This local guidance developed by the Thames-Sydenham and Region in consultation with municipality staff and consultants includes:

- Issues Evaluation Methodology
- Threats and Risk Assessment
- Transport Pathways Consideration

1.2.4 Tables of Drinking Water Threats

Along with the *Technical Rules (2013): Assessment Report*, the province released 'Tables of Drinking Water Threats', which list the vulnerability and establish the circumstances under which threats can be considered significant, moderate or low risk. The tables provided describe the activities related to chemical and pathogen threats separately. The MECP threats tables, as they are commonly called, describe specific circumstances which affect the risk level of the activity. Circumstances include such factors as the volume of contaminant, the method of release into the environment, the type of contaminant, and the area in which the activity is undertaken. The tables are organized by Prescribed Drinking Water Threats (activities) established in the General Regulation (O. Reg. 287/07). The tables of drinking water threats (2013) are posted on the MECP website at https://www.ontario.ca/environment-and-energy/tables-drinking-water-threats

The circumstances, along with the vulnerability assessment of the vulnerable areas, determine the level of risk associated with an activity in a particular location. The MECP tables of circumstances are available at http://ontario.ca/environment-and-energy/provincial-tables-circumstances

1.2.5 Mapping Symbology

Along with the *Technical Rules 2013: Assessment Report*, the province also released and updated guidance on Assessment Report mapping standards, called the Mapping Symbology for the Clean Water Act (November 2009). This guidance facilitates consistency in mapping products produced in the 19 Source Protection Regions in the province. This guidance has been used to develop the various mapping products included in this Assessment Report and the supporting studies, with a few minor exceptions which enabled a more reader-friendly product to be generated.

1.2.6 Source Protection Plan

Following the completion of the Assessment Report, a Source Protection Plan must be developed by the Source Protection Committee by August 2012. The focus of the Source

Protection Plan is to reduce or manage risks to drinking water sources. The Source Protection Plan contains policies focused on activities which are identified as threats. The Regulation 287/07 ("General Regulation") was amended in July 2010 to include the requirements of a Source Protection Plan. These policies may include:

- education and outreach programs (leading to voluntary risk reduction)
- incentive programs (leading to voluntary risk reduction)
- land-use planning approaches (e.g., official plans, zoning bylaws, site plan controls, development permits)
- new or amended provincial instruments (e.g., Certificates of Approval)
- risk management plans
- prohibition
- restricted land uses.

The more restrictive policies listed above would only be applied to significant drinking water threats. Similarly, the policies related to significant threats are mandatory and must be implemented, whereas the policies related to moderate and low risk drinking water threats are optional and leave some discretion to Source Protection Committee and possibly the implementer. The Source Protection Plan may also include various policies related to monitoring of the policies implemented, to ensure that the required outcome is achieved.

1.3 Source Protection Committee

In the Thames-Sydenham and Region, the Conservation Authorities are required to form a Source Protection Committee (SPC) for the region as part of their responsibilities as Source Protection Authorities. They are also required to provide support to that committee. In order to carry out their responsibilities, each Conservation Authority meets individually as a Source Protection Authority. While many of their responsibilities can be undertaken individually, Conservation Authorities (and Source Protection Authorities, as appropriate) established various committees to undertake those items which required collective involvement.

A Management Committee was established to undertake the day-to-day administration related to the program. The Management Committee includes the General Managers of the three Conservation Authorities who meet regularly with the Source Protection Project Manager. The Management Committee, among other things, ensures that the Source Protection Committee has the resources to undertake their responsibilities as funded by the MECP.

A striking committee was formed to provide appointment recommendations to the Source Protection Authorities.

The Clean Water Act identifies the general make-up of the Source Protection Committee as having one third of its members representing each of the municipalities, sectors and other stakeholders. The Conservation Authorities in the region further refined the make-up of each third. A discussion paper was developed and distributed to the municipalities in the region for their input. Discussions with First Nations encouraged their participation on the Source Protection Committee. Those discussions led to the appointment of the three First Nations members on the Source Protection Committee. These members were appointed by the London District Chief's Council to represent the eight First Nations in the region.

The make-up and representation of the Source Protection Committee are summarized in Table 1-1.

Table 0-1 SPC members and representation

Chair		Robert Bedggood
Municipalities	Chatham-Kent	Sheldon Parsons
	Lambton	Darrell Randell
	London	Patrick Donnelly
	Middlesex	James Maudsley
	Elgin	Brent Clutterbuck
	Oxford	Pat Sobeski
	Perth, Stratford, St. Marys, Huron	Joe Salter
Sectors	Agriculture	John Van Dorp Patrick Feryn Don McCabe
	Industry/Commercial	Dean Edwardson Earl Morwood
	Aggregate and Quarries	Paul Hymus
	Oil and Gas	Hugh Moran
Other		George Marr Doug McGee Joseph Kerr Carl Kennes Valerie M'Garry John Trudgen Charles Sharina
First Nations		Kennon Johnson Augustus Tobias Darlene Whitecalf
Liaisons	Medical Officers of Health	Jim Reffle
	Province	Teresa McLellan
	Source Protection Authority	Murray Blackie

Once established, the Source Protection Committee was required to establish rules of order and operating procedures. The Source Protection Committee's rules of order are posted on the region's web site at the address included in the footer of this report. In order to guide them through the Source Protection planning process, the Source Protection Committee developed a Mission Statement and Guiding Principles. The Source Protection Committee's guiding principles and mission statement are summarized as follows:

Table 0-2 SPC Mission Statement and Guiding Principles

Mission Statement Protect sources of drinking water by developing a plan based on science and local cooperation.	
Guiding Principles We value: • Fair and reasonable solutions • Consensus within our diverse area group	 • Clarity of information • Open communication • Respecting diversity of opinion

More detail on the committee's Mission Statement and Guiding Principles is posted on the region's web site, listed in the footer of this page.

The Source Protection Committee meets regularly to review and assess work conducted for the Assessment Report, to consider amendments to the Terms of Reference, and to discuss source protection planning for the region. The meetings are open to the public. The meeting agenda and minutes are available at the region’s web site.

The Source Protection Committee has initiated the source protection planning process, by developing threats policy discussion papers based on information from the Assessment Report, drafting policies to address significant drinking water threats, and by consulting with various sectors including persons affected. Work on the source protection plans will continue into 2012, as described in Section 1.2.6.

1.4 Role of the Conservation Authorities

The Conservation Authorities provide the resources to the SPC to complete their work. This includes the provision of technical and administrative staff such as hydrogeology, engineering, geographic information system and communications specialists. This team is led by the Source

Protection Project Manager, Chris Tasker, and technical leads at each of the Source Protection Authorities.

1.5 Terms of Reference

The first major task of the Source Protection Committee was to develop a work plan to guide the source protection planning process for the following five years. The work plan – called the Terms of Reference, was developed with input from municipalities and stakeholders.

The Terms of Reference outlines who does what, when it will happen and how much it will cost. It guides the Source Protection Committee through the completion of the Assessment Report and the Source Protection Plan.

Two municipal working groups, for surface water and groundwater related studies, were established to help complete the work plan for the Terms of Reference. The groups were chaired by SPC members and comprised of municipal staff and water treatment plant operators, who provided technical input.

Public Open Houses on the Terms of Reference were held in September of 2008 at Ridgetown, St. Marys and Wyoming. A follow-up Public Meeting was held in London. In addition, comments were received through the posting of the Terms of Reference on the region's web site. The SPC submitted the proposed Terms of Reference to the Source Protection Authorities on December 18, 2008. Comments were received by the *SPA*s and submitted to the Minister of the Environment for approval. The Terms of Reference for the Upper Thames River Source Protection Area was approved by the Minister of the Environment and the notice of approval posted on the *Environmental Registry* on April 20, 2009. This approval sets the due date of the Assessment Report one year from the posting of the approval of the Terms of Reference, to be April 20, 2010. However due to an adjustment in work plans to fill several gaps and to allow for adequate consultation on the Assessment Report, an extension in submission of the *UTRSPA* Proposed Assessment Report was requested of the MECP. This request for a new due date of October 29, 2010 was granted by the Director, Source Protection Programs Branch, MECP. Further technical work was conducted (see Section 1.10.2), and the Director required that updates and amendments be made to the Proposed Report. This resulted in the current Amended Proposed Assessment Report, dated in August, 2011. It has since been updated to the current Updated Assessment Report due to be submitted for approval in early 2015.

1.6 Thames-Sydenham and Region Source Protection Region

The Thames-Sydenham and Region (*TSR*) Source Protection Region (*SPR*) is located in southwestern Ontario bounded by Lake Erie in the south and by Lake Huron to the north of the western end of the region. It is surrounded by the Lake Erie Source Protection Region to the east and the Essex Region Source Protection Area to the west of its southern end. To the north and west of the northern part of the region is the Ausable-Bayfield Maitland Valley Source Protection Region. The region is shown in Map 1-1.

The Thames-Sydenham and Region (*TSR*) is comprised of three Source Protection Areas. The Upper Thames River Source Protection Area (*UTRSPA*) is to the north and east of the region. The Lower Thames Valley Source Protection Area (*LTVSPA*) is to the south and west of the Upper Thames River Source Protection Area while the St. Clair Region Source Protection Area (*SCRSPA*) is north of the Lower Thames Valley Source Protection Area. The three Source Protection Areas are also shown in Map 1-1.

1.6.1 Upper Thames River Source Protection Area

The Upper Thames River Source Protection Area includes parts of the municipalities listed in Table 1-3 below.

Table 0-3 Municipalities in the UTRSPA

Township of Blandford-Blenheim	County of Oxford
Township of East Zorra-Tavistock	Township of Perth East
County of Elgin	Township of Perth South
Municipality of Huron East	County of Perth
County of Huron	Municipality of South Huron
Town of Ingersoll	Township of South-West Oxford
City of London	Town of St. Marys
Municipality of Lucan-Biddulph	City of Stratford
Township of Malahide	Municipality of Strathroy-Caradoc
Municipality of Middlesex Centre	Municipality of Thames Centre
County of Middlesex	Municipality of West Perth
Municipality of North Perth	City of Woodstock
Township of Norwich	Township of Zorra

There are no First Nations in the *UTRSPA*.

In the Upper Thames River Source Protection Area, the municipalities receive most of their drinking water from 21 municipal groundwater well supply systems located within the source protection area. The exceptions are the City of London, Delaware and Ballymote which primarily rely on Lake Huron and Lake Erie surface water intakes located outside the source protection region (SPR). The communities of Mt. Brydges and Kilworth/Komoka also receive their drinking water from a Lake Huron intake located outside of the SPR. Private wells supply water to the remainder of the residents in the region. Map 1-3 shows the location of the well supply systems and surface water intakes that serve the Upper Thames River Source Protection Area.

The largest settlement in the area is the City of London, while other significant settlements include the City of Stratford, Town of St. Marys, Ingersoll, Woodstock and Dorchester. Settlement areas are shown in Map 1-4. The approximate population of these settlement areas is indicated by the relative size of the symbol indicating the location of the settlement. These populations have been included based on available information or estimated based on the number of parcels in the settlement area.

More details on the area, its water systems and the population of the area are included in Section 2 - Watershed Characterization.

1.7 Technical Studies

The Assessment Report is a summary and compilation of a number of technical studies including:

- Watershed Characterization
- Conceptual Water Budget
- Various levels of Water Budgets (Tier 1, 2 or 3)
- Municipal Technical Studies

The Municipal Technical Studies were completed through partnerships between the municipalities and the Conservation Authorities. Leads for each study were established. The studies were led by the Conservation Authorities (CAs) or by a municipality. Most of the municipal technical studies (such as the vulnerability assessment, issues evaluation and threats assessment studies) were organized based on the geographic extent of the upper tier municipalities (counties). Drinking water system operating authorities or municipal staff participated in the studies through steering committees for those projects which were not led by the municipalities directly. The watershed characterization and the water budget studies were led by the CAs and completed by CA staff.

Vulnerability Assessment technical reports were peer reviewed by a four member peer review committee comprised of hydrodynamic and groundwater modelling experts with experience in vulnerability assessment studies. This peer review is described in more detail in Section 4.0

Vulnerability Assessment. The water budget work was also subject to a peer review process. The Ministry of Natural Resources and Forestry (MNRF) also participated in the peer review as well as people who have been involved in water budget work of the neighbouring Source Protection Areas. Many of these studies are still ongoing; however components from the studies have been compiled into these Assessment Reports.

1.8 Consultation

Regulations require consultation on the Assessment Reports. This consultation, much like that of the Terms of Reference, requires a public meeting and posting of the Assessment Report. Two posting periods are required: one posted by the Source Protection Committee for consultation on the draft proposed Assessment Report; and the second posted by the Source Protection Authority for comments on the proposed Assessment Report. The proposed Assessment Report is then submitted to the Ministry of the Environment, Conservation and Parks, along with comments received in the final posting period. The Director may then approve the Assessment Report or require amendments to the report which has been referred to as the amended proposed Assessment Report. Once approved any revisions are included in an updated Assessment Report. If the Director requires amendments, then the Director would require that those affected by the amendments are consulted with.

The Source Protection Committee identified the need to undertake a more detailed and locally focused consultation on the contents of the Assessment Report. A multi-phase consultation plan was developed and is included in Appendix 4 (and on the web site). The plan identifies four consultation phases. The first two phases of consultation provide a more local focus on the vulnerable areas associated with the municipal water supplies. The first phase includes the (peer reviewed) vulnerability assessment of the areas while the second phase adds discussion on the threats and issues identified in the vulnerable areas. Both phases include individual correspondence with property owners in the proposed vulnerable areas as well as advertisements in local newspapers. Maps of the areas and fact sheets were distributed with invitations to attend the local meetings. These materials were also made available on the region's web site.

The third phase of consultation is the required public meeting and posting of the draft proposed Assessment Report, and then the proposed Assessment Report for comment. This phase is more regional in scope involving open houses in each of the Source Protection Areas. The fourth phase of consultation involves posting of the amendments to the proposed Assessment Report for comment, and public meetings. Advertisements were placed in local newspapers.

The draft proposed Assessment Report must be published on the Internet for a 35 day comment period, and copies made available to stakeholders including the public. A copy of the notice of the posting of the draft proposed Assessment Report must be published in newspapers and distributed to the municipal clerks in which any part of the *SPA* is located, First Nation band chiefs if any part of a band reserve is included in the *SPA*, landowners engaging in an activity known by the SPC that is or would be a significant threat, other SPCs listed in the Terms of Reference, persons or bodies related to Great Lakes Water Quality Agreements, Remedial Action Plans and Lakewide Management Plans for their comments. At least 21 days after publishing the draft proposed report on the Internet, the required public meeting must take place.

The proposed Assessment Report must be published on the Internet for a 30 day comment period, and copies of the report submitted to municipal clerks and band chiefs (if any part of a band reserve is in the *SPA*). There are no First Nation reserves in the *UTRSPA*. Similarly, the Amended Proposed Assessment Report is published on the Internet for a 30 day comment period and copies sent to municipal clerks.

Any future updates to the Assessment Reports will go through an Early Engagement with MECP, Pre-consultation and Public Consultation.

Table 0-4 Summary of planned UTRSPA Assessment Report Consultation

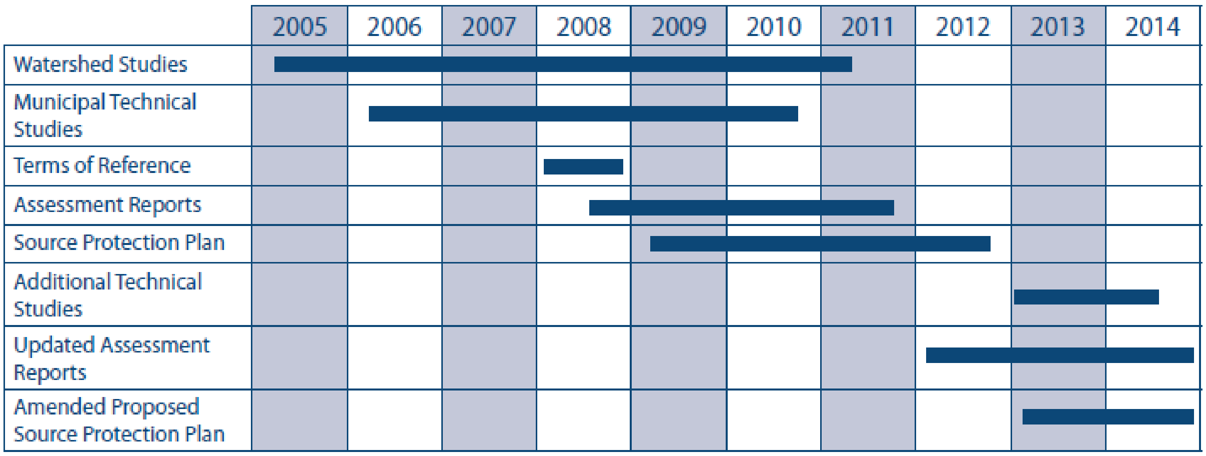
Please refer to Assessment Report Consultation in Appendix 4 for details on Assessment Report

1.9 Schedule

The due date of the Assessment Report was set with the posting of the approval of the Terms of Reference for the Source Protection Area. The Clean Water Act identifies that Assessment Reports are to be submitted within one year of the posting of the approval of the Terms of Reference. As described earlier, the due date to submit the proposed *UTRSPA* Assessment Report was extended to October 29, 2010. This allowed for some aspects of the work to be completed as per the amended provincial guidance.

Upon submission of the proposed Assessment Report and based on further technical work conducted (see Section 1.10.2), the Director (Source Protection Programs Branch, MECP) required that updates and amendments be made to the Proposed Report. This resulted in the current Amended Proposed Assessment Report, due August 8, 2011. This Assessment Report fills several data gaps identified in the Proposed Assessment Report. The following schedule describes at high level the work to complete the Assessment Report and Source Protection Plan and update the Assessment Report and amended the Source Protection Plan before the approval of the first Source Protection Plan for the Thames-Sydenham and Region.

Figure 0-1 Source Protection planning schedule overview



1.10 Local Acceptance, Approvals and Next Steps

The Assessment Report consultation plan illustrates a number of review and acceptance stages in the development of the Assessment Reports for the Source Protection Areas. This ultimately culminates in the approval of the Assessment Reports by the Director of Source Protection Programs Branch of the Ministry of the Environment, Conservation and Parks.

Local acceptance of the Assessment Reports is also included in the consultation process. Prior to inclusion in the Assessment Report the components have been reviewed and accepted by the Source Protection Committee. This review included:

- involvement of municipal operators in the technical studies;
- peer review of the work;
- presentations to the Source Protection Committee by those undertaking the work;
- review of the products from the technical studies which are to be included in the Assessment Report;

- review of summary level information included in the Assessment Report in the form of section summaries and system summaries;
- consideration of municipal and other stakeholder comments on the draft proposed, and proposed Assessment Report; and
- ultimately, the acceptance of the Assessment Report by the SPC.

Municipal and other local involvement in the development of the Assessment Report has been included in many ways. Municipalities have been involved in many of the technical studies throughout the region, especially those which are focused on the sources of drinking water for their municipal systems. Operating Authority staff participated in technical steering committees on these projects. Where appropriate, operating Authority staff kept their commissions or councils up to date on the completion of the technical work. Updates on the progress of Source Protection Planning have been distributed to municipalities throughout the work stages of the Assessment Report. Municipal comments were also requested on the Watershed Characterization Reports and the Conceptual Water Budget. Representatives on the Source Protection Committee have been instrumental in keeping their representation updated on the Source Protection Planning process including organizing and attending meetings with stakeholders.

During the first two phases of the consultation, municipal staff and councils were circulated invitations to the open houses and offers were made of presentations to municipal councils. Municipal Planners were invited to attend a municipal planners forum where the materials included in the Assessment Reports were discussed.

The third phase of consultation is comprised of two steps: consulting on the draft proposed Assessment Report, and then on the proposed Assessment Report. In the third phase of consultation, the notice of publishing of the draft proposed Assessment Report must be sent to municipal clerks of municipalities in which any part of the *SPA* is located, and First Nation band chiefs if any part of a band reserve is included in the *SPA*. There are no First Nation reserves in the *UTRSPA*. The draft proposed Assessment Report was distributed on Compact Disk (CD) to the municipalities for their comments. Through ongoing involvement in the Assessment Report development process as discussed above, the municipal input has been incorporated into the Assessment Report. Municipalities and other stakeholders had 35 days from the time the notice was posted to review and provide comments on the draft proposed Assessment Report. These comments were considered by the Source Protection Committee in finalizing the proposed Assessment Report.

The proposed Assessment Report was posted on the Internet for a 30 day comment period. This posting asked for comments to be submitted to the Source Protection Authority. Further, a copy of the proposed Assessment Report was submitted to the municipal clerks.

The proposed report was amended as required by the Director, due to additional technical work carried out, as described in Section 1.10.2. The Amended Proposed Assessment Report was also posted on the Internet for a 30 day comment period. The current report is an Updated Assessment Report which fills in many of the data gaps identified in previous Assessment Reports. Local consultation with those affected by the updates has to be conducted as well as a posting and open house in conjunction with the consultation on the amended proposed Source Protection Plan.

In submitting the Assessment Report to the Ministry of the Environment, Conservation and Parks, the Source Protection Authority is to include any outstanding comments including any municipal or First Nations concerns over the Assessment Reports. The Director can approve the Assessment Report as submitted or require further amendments to the Assessment Report.

1.10.1 Engaging First Nations

The *TSR* source protection region includes eight First Nations, seven of which have reserves as shown on Map 1-1. Caldwell First Nation is also established in the area between Leamington and Rondeau Bay; however they currently do not have a reserve. There are no First Nations in the *UTRSPA*. Table 1-5 lists the First Nation communities in the *TSR SPR*.

Table 0-5 First Nations of the TSR SPR

Bkejwanong First Nation (Walpole Island)
Caldwell First Nation
Chippewas of Aamjiwnaang (Sarnia)
Chippewas of Kettle and Stony Point First Nation
Chippewas of the Thames First Nation*
Delaware Nation Council*
Munsee-Delaware Nation*
Oneida Nation of the Thames*

Note: There are no First Nations in the UTRSPA
*These First Nations are located on or near the Thames River, downstream of the UTRSPA

Four of the eight First Nations in the region have reserves on or near the Thames River in the *LTVSPA*, directly downstream of the *UTRSPA*. These four First Nations, the Delaware Nation Council, Chippewas of the Thames, Munsee-Delaware Nation and Oneida Nation of the Thames, rely on groundwater sources of drinking water. Some of these groundwater wells are classified as groundwater under the influence of surface water, or *GUDI* wells (Oakridge Environmental Ltd. July 2007, Oakridge Environmental Ltd. June 2007 and First Nations Engineering, May 2009). These wells are influenced by the upstream Thames River, in both water quality and quantity.

While the First Nations have been encouraged to participate in the development of the Assessment Reports in the Thames-Sydenham and Region in a number of ways, initially that participation was rather limited and very informal in nature. First Nations forums were set up in 2008-2009 across the region.

First Nations participate on the Source Protection Committee with the appointment of three First Nations members. Previously various staff of the Southern First Nations Secretariat and councillors from the First Nations have participated in various ways including informal participation in tours and meetings of the Source Protection Committee, forums and workshops held at various stages in the Source Protection Planning process. A First Nations liaison hired by the Conservation Authorities has been instrumental in the involvement of First Nation communities in many aspects of Source Protection Planning.

The Chippewa of Kettle & Stoney Point First Nation (in St. Clair Region Source Protection Area) passed a band council resolution requesting the Minister to include their intake in the Terms of Reference for the region and allow them to undertake the technical work to include Intake Protection Zones for their intake. Other First Nations in the Lower Thames Valley Source Protection Area participated in a study to assess a potential WHPA-E associated with their GUDI wells. The First Nations working Group also explored potential policies which could be put in place on reserve to afford their groundwater a similar level of protection to municipal systems under the Source Protection Plan although they did not formally request to have their systems added to the Terms of Reference for the region.

1.10.2 Updates to the Assessment Report

Several of the gaps identified in the Proposed Assessment Report are now filled. This updated Assessment Report includes the completion of the Tier 3 Water Budget and Water Quantity

Risk Assessment, as well as Issues Contributing Area delineation. The SGRA and related risk assessment information has also been updated. The *Source Protection Plan* is also amended and consultation on the Plan is occurring with this Assessment Report. Section 9 indicates the remaining few gaps in the Upper Thames River Source Protection Area Assessment Report.

The Assessment Report can be updated if the Source Protection Committee becomes aware of the need to update the report. Changes in understanding or factors such as land use which may have an impact on the Assessment Report may be brought to the attention of the Source Protection Committee. As a result of this new information or understanding, the Source Protection Committee may update the Assessment Report in the future. The Source Protection Committee will also need to consider amendments to the Assessment Report when the Source Protection Plan is reviewed. The period for review of the Source Protection Plan will be established by the Minister in the approval of the Source Protection Plan.

Any updates to the Assessment Report would require consultation of those affected by the amendments.

2.0 Watershed Characterization

Justice O'Connor recommended that watershed-based *Source Protection Plans* be developed. The recommendations were part of the inquiry which investigated the May 2000 bacterial contamination of the Town of Walkerton's water supply. Compiling a summary of information pertinent to drinking water sources is one of the first steps in developing a *Source Protection Plan*.

Under the Clean Water Act (2006), the Assessment Report must identify all subwatersheds in the source protection area and characterize the water quality and quantity across the watershed. The Regulations and *rules* under the Clean Water Act (2006) require that the physical and human geography also be characterized. This information is contained in a watershed characterization report.

2.1 Watershed Characterization Report

The Watershed Characterization Report for the Thames Watershed and Region, completed in 2008, is based on information available at the time. Updated characterization information is included in other sections of the Assessment Report. Some of the water budget related mapping products are available in the Conceptual Water Budget, which is included as an appendix to the Assessment Report.

The Watershed Characterization Report summarizes information on the physical, social and economic characteristics of the Thames Watershed & Region. It reviews surface water and groundwater quality, and summarizes known issues and concerns pertaining to drinking water sources. A series of maps help to illustrate the information presented in the report. Each of the components of the watershed characterization report is described in the sections that follow.

The summary of the Watershed Characterization Report for the Thames Watershed and Region is included in Appendix 5 in the Lower Thames Valley and Upper Thames River Source Protection Area Assessment Reports; complete with all maps. The entire Watershed Characterization Report is available on compact disk (CD).

2.2 Data Sources

A wide range of data sources have been used as resources to prepare the Watershed Characterization Report and the accompanying maps. Data used to characterize the Thames watershed is provided in Table 2-1 below.

Table 2-1 Watershed Characterization Report Data Sources

Component	Data Source
Bedrock Geology	Waterloo Hydrogeologic. 2005. Six Conservation Authorities FEFLOW Groundwater Model: Conceptual Model Report.
Surficial Geology	Waterloo Hydrogeologic. 2005. Southwestern Region Edge-Matching Study. Surficial Geology of Southern Ontario. Ontario Geological Survey Miscellaneous Release –Data 128.
Physiography	Chapman, L.J. and D.F. Putnam. 1984. The Physiography of Southern Ontario, 3rd edition.
Soils Information	Ontario Ministry of Agriculture and Food and Agriculture Canada, Soils Ontario Version 1.0. Ontario Soils Surveys
Groundwater Hydrogeology	Waterloo Hydrogeologic. 2005. Six Conservation Authorities FEFLOW Groundwater Model: Conceptual Model Report. Waterloo Hydrogeologic. 2005. Southwestern Region Edge-Matching Study. Municipal Groundwater Studies. MECP.
Surface Water Hydrology	Ontario Ministry of the Environment and Ontario Ministry of Natural Resources. 1975. Thames River Basin Water Management Study. Stream Gauge Data. Ontario Ministry of Agriculture and Food and Agriculture. Municipal Drain Classification (Fisheries and Oceans Canada project) data. UTRCA. 1991. Dam Inventory and Reservoir Assessment.
Naturally Vegetated Areas	Ministry of Natural Resources Aerial Mapping 2001 and 2003.
Aquatic Ecology	Species at Risk Recovery Plan. Fisheries and Oceans Canada. Ontario Ministry of Natural Resources. Royal Ontario Museum. Ontario Ministry of the Environment. COA and COA partners - Thames River Habitat Assessment and Monitoring Program. Aquatic Species at Risk in the Thames River Watershed, Ontario. Cudmore, B., C. A. MacKinnon and S. E. Madzia. Dec. 2004. Canadian Manuscript Report of Fisheries and Aquatic Sciences. 2707. Thames River Recovery Team. 2004. Recovery strategy for the Thames River Aquatic Ecosystem: 2005-2010. December 2004 Draft. 145 pp. Natural Heritage Information Centre. COSEWIC assessment and status report on the Rainbow mussel *Villosa iris* in Canada. COSEWIC. 2006. Committee on the Status of Endangered Wildlife in Canada. Ottawa. Vii + 38 pp. (www.sararegistry.gc.ca/status/status_e.cfm). Spiny Softshell and Queen Snake Research and Recovery Along the Thames River Watershed. Gillingwater, S.D. 2009. Report submitted to the Ontario Ministry of Natural Resources. National Recovery Strategy for the Queen Snake (*Regina septemvittata*) in Canada. Gillingwater, S.D. 2008. Prepared for the Queen Snake Recovery

Table 2-1 Watershed Characterization Report Data Sources

Component	Data Source
	Team. Draft. 38 pp. Rare Reptile Research of the Thames River Watershed. Gillingwater, S.D. and T.J. Piraino. 2002. Report submitted to the Ontario Ministry of Natural Resources, Aylmer District. Freshwater mussel communities of the Thames River, Ontario: 2004-2005. Morris, T.J. and A. Edwards. 2007. Can. Manuscr. Rpt. Fish. Aquat. Sci. 2810: v + 30 pp. Queen Snakes (*Regina eptemvittata*) and Spiny Softshell Turtles (*Apalone spinifera spinifera*) Along the Upper Thames River Watershed. Piraino, T.J. and S.D. Gillingwater. 2004. Report submitted to the Upper Thames River Conservation Authority.
Human Characterization	Statistics Canada. Censuses of Population, 1901-2001 and 1996-2006. Indian and Northern Affairs Canada website: http://ainc-inac.gc.ca Ontario Ministry of Finance Ontario Population Projections, 2006-2031. Municipality Official Plans. Ministry of Environment. June 1991. Waste Disposal Site Inventory. Census Canada. Ontario Ministry of Agriculture and Food and Agriculture.
Drinking Water Sources	Ministry of Environment Permit To Take Water (PTTW) database. Municipal Groundwater Studies. MECP.
Water Quality	Provincial Water Quality Monitoring Network. Provincial Groundwater Monitoring Network. Drinking Water Surveillance Program. Drinking Water Information System. Annual Drinking Water System Reports. Ministry of Environment Inspection reports. Water treatment plant laboratory data. Ambient Groundwater Chemistry Study of the Thames River and St. Clair Region Watersheds. Waterloo Hydrologic Incorporated, 2008.

2.3 Components of the Watershed Characterization Report

2.3.1 Watersheds and Subwatersheds

The source protection area (*SPA*) watershed boundary within the source protection region (SPR), as well as the subwatersheds within the *SPA*, are identified and described. The Thames watershed and region is comprised of the Lower Thames Valley Source Protection Area (*LTVSPA*) and the Upper Thames River Source Protection Area (*UTRSPA*). Map 1-1 in Appendix 1 illustrates the Thames-Sydenham and Region boundary and the Source Protetcion Area watershed boundaries within the Region.

The Upper Thames River Source Protection Area includes all areas draining into the Thames River above the community of Delaware. This area covers large parts of Oxford, Perth and Middlesex Counties, including most of the City of London. Very small portions of Huron and

Elgin Counties also drain into the upper Thames River. The *UTRSPA* covers approximately 3,423 square kilometres with a total watershed population (2001) of about 472,000.

2.3.2 Physical Geography

This component describes the location and types of natural vegetative cover, aquatic habitats, and species habitats within the source protection area that are on the Species at Risk in Ontario List. It also describes the history, structure and composition of the surface, just below the surface, and deep beneath the surface (geology). In addition, this component describes natural landscape features (physiography), soil types, and surface shape and features (topography). Water movement on the surface (surface hydrology), such as rainfall, and water movement below the ground (groundwater hydrogeology), and climate, including air temperature and flooding are also included. A few details are given below but do not provide a complete picture of the characterization. For accurate descriptions, refer to the Thames Watershed and Region Watershed Characterization Report (2008).

Geology, Physiography and Soil Types

Bedrock is the rock formation deep under the ground, over which lies the overburden formation. The bedrock geology formations in Upper Thames River Source Protection Area are mainly the Dundee formation (fossiliferous limestone) and Detroit River Group (orthoquartzitic sandstone). The surficial geology is influenced by the type and nature of overburden. In the *UTRSPA*, the primary material of diamicton/till dominates, with silt plain north of St. Marys, and gravel near Komoka. Till is a mixture of clay, silt, sand and pebbles. The *UTRSPA* is mainly till plains without drumlins (streamlined landforms), with the exceptions of Oxford County which is a till plain with drumlins, and a sand plain north of London surrounded by spillways. As described below, till moraines are also important features of the *UTRSPA*. In the *UTRSPA*, 'silt & clay loam' type of soil is predominant (39%), with 'silt & clay' (26%) and 'loams' (15%) following. Maps 4, 5, 6 and 7 in Appendix 5 show the Thames watershed bedrock geology, overburden thickness, surficial geology and physiography respectively.

Topography, Hydrology and Hydrogeology

In the Upper Thames River Source Protection Area, the bedrock topography is higher than in other parts of the SPR, with the highest elevations occurring in northeastern parts of Perth County. Moraines are ridges of material that are generally topographic highs. Till moraines are seen across Komoka to Ingersoll and Woodstock, and in Perth County north of St. Marys, while a kame moraine is south of St. Marys. The Thames rises at three distinct points in the *UTRSPA*, near Mitchell (North Thames), Hickson (Middle Thames) and Tavistock (South Thames). The riverbeds are rocky and the valley slopes are steep, in contrast with the lower Thames River in the *LTVSPA* where the plains are flat. In the upper portion of the Thames River, the flow is 40% surface runoff and 60% 'base flow'. Base flow includes contributions from groundwater, tile drains, flow augmentation from reservoirs and treated sewage effluent discharge.

An aquifer is a water-bearing layer under the surface, which can be tapped by drilling groundwater wells. The Watershed Characterization Report Summary, included as Appendix 5 of this Assessment Report, includes a brief summary of the prevalent aquifers in the Upper Thames *SPA* while more detail is contained in the Watershed Characterization Report - Thames Watershed and Region (Thames-Sydenham and Region, December 2008). The Conceptual Water Budget (Appendix 6) includes a conceptualization of the aquifers and aquitards which continues to be improved through subsequent Water Budget work. Municipal groundwater systems in the Upper Thames *SPA* draw most of their drinking water from the bedrock aquifers with the exceptions of some Oxford and Middlesex systems which rely on water table aquifers. The aquifers tapped by each system are described in each system summary (Appendix 3). Similarly, private wells draw from both the water table and bedrock aquifers. In Perth County, wells draw predominantly from bedrock aquifers, while in Oxford and Middlesex, wells draw from both sources.

As with surface water, aquifers flow from an area of higher elevation (potential head) to an area of lower elevation. Maps 12 and 13 from the Watershed Characterization Report Summary (Appendix 5), illustrate the bedrock potentiometric surface elevation and the water table elevation across the region. The general flow direction in the Upper Thames *SPA* can be seen by referring to these maps. Groundwater flows generally from the higher areas in the northern end of the watershed towards the south and west parts of the region. Locally the aquifers, especially the water table aquifer, will flow towards lower hydrologic features such as streams. A more dramatic gradient is shown west of St. Marys where bedrock potentiometric surface drops off towards a karst area west of the watershed. Local aquifer flow directions can be seen by referring to the individual system *WHPA* maps 4-1-1 to 4-1-23 and considering that water flows from the outer edge of the *WHPA* towards the well as influenced by the local groundwater gradient and, to some degree, by the pumping of the wells.

Hydrology and climatic conditions are monitored locally by a combination of Environment Canada and Conservation Authority monitoring stations, including at London, Woodstock and Stratford in the Upper Thames River Source Protection Area. From plotting 10 year running averages over the data years of 1950 to 2005, an increasing level of precipitation in the 1970s and 1980s is seen with decreases recently. An increase in the linear trend line is seen at London, Woodstock and Stratford.

Natural Vegetative Cover

Wetlands are about 57 sq. km and make up less than 2% of the total *UTRSPA* watershed area of 3,447 sq. km, as shown in Map 23a of Appendix 5. Overall, wetland cover averages 1.7% with a high of 9.7%. The subwatersheds with the highest wetland cover are Black Creek (north of Stratford), Dorchester (east of London) and Komoka (west of London). All of these areas contain large wetland complexes. The vast majority of the remaining wetlands in the Upper Thames River Conservation Authority (UTRCA) are classified as deciduous swamps or mixed deciduous-coniferous swamps that are dominated by trees and shrubs such as silver maple, ash, willow, dogwood and cedar. Many swamps contain small pockets of marsh vegetation where emergent plants such as cattails, rushes and sedges dominate, but there are no large marsh sites. Bogs and fens are also very rare. There are a couple of kettle bogs in the London area. In the Upper Thames River watershed there are 31 provincially significant and 35 locally significant wetlands.

In the *UTRSPA* watershed, woodland/forest cover varies between 5 and 21% within the subwatersheds (with an average of 12%, or about 413 sq. km), as shown in Map 25a of Appendix 5. The subwatershed with the highest amount of woodland/forest cover is Dorchester, owing to the presence of the large Dorchester Swamp and North Dorchester Swamp complexes. The largest woodland/forest tract is Ellice Swamp (1,014 ha), located north of Stratford. The lowest amount of woodland/forest cover (4.9%) is in the North Mitchell watershed which is the headwaters of the North Branch of the Thames in Perth County.

The area of land adjacent to streams is often called the riparian zone or buffer zone. In the *UTRSPA*, the riparian areas ranged from a low of 6.1% to a high of 31.8% with an overall average of 21.14%. The lowest riparian woodland/forest cover occurs in the headwaters area of the North Branch of the Thames River in rural Perth County (North Mitchell and Whirl Creek subwatersheds). The highest cover is in the Dorchester watershed east of London and the River Bend and Oxbow Creek watersheds west of London.

Specific areas are protected from developmental changes that could alter their natural character. This protection is designated through federal, provincial and local initiatives. Depending on the degree of protection, "protected areas" are not likely to change over time and will encounter minimal human disturbance. There are several significant protected areas in the

UTRSPA watershed. The Ellice Swamp covers approximately 856 hectares and is the largest woodlot in Perth County. Golspie Swamp covers 295 hectares and represents the third largest forested area remaining in Oxford County. The Dorchester Swamp is a 548-hectare site that is recognized as a Class 1 Significant Wetland, a Carolinian Canada Site and an Area of Natural and Scientific Interest (ANSI). The Sifton Bog in the City of London is a Class 2 provincially significant wetland and the most southerly large acidic bog in Canada. Also in London, Westminster Ponds/Pond Mills Conservation Area covers approximately 300 hectares with six major ponds over an area 3 kilometres long and 1.5 kilometres wide.

Aquatic Ecology and Habitats

In the Thames Watershed & Region, the wide variety of habitats, favourable climate, nutrient-rich waters, and connection with the Great Lakes result in a particularly diverse aquatic community. The Thames River and its tributaries support one of the most diverse fish communities in Canada. Records exist for approximately 94 fish species in the Thames River subwatershed, which represents more than half of all of Ontario's 165 species. Table A5-1 (Appendix 5 Addendum) lists the fish species recorded in the Thames River subwatershed. Table A5-2 (Appendix 5 Addendum) lists the mussel species found in the Thames River.

Aquatic invertebrates, especially the benthic macroinvertebrates (BMI) that inhabit watercourse substrates, are abundant in all Thames reaches and tributaries. BMI communities consist of insect larvae, aquatic worms, crustaceans, and many other species. Most have fairly well known tolerances to pollution and disturbance. Table A5-3 (Appendix 5 Addendum) lists the benthic species commonly found in the Thames River and tributaries.

Introduced fish species found in the Thames such as the common carp and round goby are considered invasive species. In the Great Lakes, native freshwater mussel populations have been decimated by zebra mussels (from certain water bodies in Asia).

Map 20 of Appendix 5 illustrates the UTRCA Watershed Watercourse Classification to differentiate between municipal drains, natural watercourses (non-municipal drains) and some tiled (closed surface) watercourses. There are approximately 47% open municipal drains, 28% natural or non-municipal drains, and 25% tiled watercourses in the UTRCA watershed. The natural or non-municipal drains represent more than 25% of the length of watercourses in the UTRCA watershed. However, based on a review of Map 20 of Appendix 5, the majority of the natural watercourses are the main rivers including the Thames River, the north, middle and south branches of the Thames and the lower sections of some of the larger tributaries such as the Avon River. Approximately 24% of watercourses in this watershed provide suitable water quality and habitat conditions for sensitive species. Of those watercourses approximately 6% are municipal drains and 18% are natural watercourses.

Table 2-2 shows the habitat and temperature assessment information for the *UTRSPA*. Some watercourses can be classified as both warmwater and coldwater, or as both permanent and intermittent flow. Sometimes thermal assessments were not possible, for example, during dry weather when there is no flow in certain watercourses. Approximately 10% of watercourses in *UTRSPA* are permanent cold/cool water streams with less than half considered to be natural. Approximately 61% are permanent warm water while about 30% are intermittent watercourses. Of the 61% that are warm water, there is an almost equal division between natural watercourses (31%) and municipal drains (30%). Of the roughly 30% of watercourses that are intermittent systems, or dry for most of the year, only 2% are considered natural while 28% are municipal drains.

Table 2-2 Habitat and Temperature Assessments in the UTRSPA

Municipality	Permanent Flow	Intermittent Flow	Coldwater	Warmwater
Biddulph	13	3	3	13
Blandford-Blenheim	7	27	0	31
Central Huron	2	0	2	0
East Zorra-Tavistock	44	50	18	78
Ingersoll	2	0	2	0
London	69	93	7	155
Middlesex Centre	71	111	6	176
Mitchell	6	0	0	6
North Dorchester	1	0	1	0
North Perth	0	8	0	8
Norwich	17	1	5	13
Perth East	82	79	18	143
Perth South	126	28	11	143
Sebringville	2	0	0	2
South Huron	16	3	0	19
South-West Oxford	25	18	9	34
St. Marys	13	1	0	14
Stratford	22	3	0	25
Strathroy-Caradoc	4	2	2	4
Thames Centre	84	120	20	184
West Perth	99	85	3	181
Zorra	115	145	43	217
Total	**820**	**777**	**150**	**1,446**

Much of the headwaters, particularly intermittent drains, have remnant pools that provide refuge areas for a variety of the more tolerant or hardy aquatic species. However changes such as the removal of cobble from the channels and the lack of pool riffles result in aquatic communities limited to hardy warmwater species.

In a few isolated headwater locations in the Thames, conditions allow more sensitive coldwater communities to persist. Sensitive BMI species, such as stoneflies and some caddisflies, are indicators of a high quality aquatic habitat or ecosystem. Coldwater fish species, such as trout and sculpin, that require well-oxygenated cool or cold flows year-round, can be found in these headwater streams. Moving downstream from the headwaters to medium-sized Thames tributaries, overall aquatic habitat generally improves as the stream size increases. In these streams, a diverse aquatic community is generally present, often including many mid-tolerant and the occasional sensitive BMI. In addition, most streams support a diverse fish community that may include top-level predators and Species at Risk (SAR). A few streams that have significant groundwater inputs support native brook trout or introduced brown trout populations.

Farther downstream, the larger tributaries and the three main Thames branches generally support aquatic communities of increased complexity and stability. Much of the north Thames, portions of the middle and south Thames, and a few larger tributaries support very diverse and productive aquatic communities. The communities of BMI are largely comprised of mid-tolerant and a few sensitive species. Top-level predators and species that require relatively clear flows and clean substrates to survive are well represented within the fish community. These river and stream reaches also provide habitat for a large proportion of the surviving fish, reptile and freshwater mussel SAR found in the Thames. From London downstream to the Delaware area, the flow and habitat conditions for the river are much like the upper branches but at a larger scale.

Impact of Human Activities on Aquatic Ecology and Habitats

The Watershed Characterization Report also discusses the impacts human activities have had on aquatic ecology and habitats. The Thames River is situated in a highly developed part of southern Ontario. The aquatic community faces many pressures from urban and rural land uses and human activities. Most of the watercourses have been greatly altered by human influences. On larger watercourses, many of the influences accrue from urban development, including channel alteration, bank hardening, storm water runoff, and sewage effluent input. Rural influences often involve smaller watercourses where habitat changes and alterations such as drains and channelization are aimed at improving agricultural operations. In general, species that prefer clear, fast flowing water are declining (Cudmore, B., C. A. MacKinnon and S. E. Madzia. Dec. 2004).

In 1986, Holm and Crossman completed a study comparing current (1985) information to historic surveys from the 1920s and 1940s. They identified water quality and fish habitat as conditions that had deteriorated significantly in the Thames River. They noted that turbidity and siltation had increased, and that stream flow rates had changed as a result of habitat disruptions such as impoundments. They also indicated a decline of species with a preference for clear, fast water and an increase in abundance of species more tolerant of turbidity.

Intermittent drain systems provide a significant function to the watershed. They provide fish habitat when wet and, in many cases, significant spawning areas during spring flooding. Some drains have pooled refuge areas (as evident in the Upper Thames watershed) and support habitat generalist species. These drains still support aquatic communities that primarily consist of tolerant BMI and fish species. These are particularly evident where agricultural best management practices (BMPs) have reduced agricultural impacts. In recent years, many of these intermittent watercourses have been converted to closed systems. The trend to close drain systems has altered the hydrograph, hydrologic regime and fluvial dynamics of the receiving watercourses and has led to an increase in erosion in downstream watercourses. Changes such as the removal of cobble from the channels and the lack of pool riffles result in aquatic communities limited to hardy warmwater species.

In a few isolated headwater locations in the Thames, more sensitive coldwater communities persist due to the presence of groundwater discharge, riparian vegetation and shading, headwater wetlands, and usually an undisturbed natural channel (although several drains support coldwater communities). Moving down from the headwaters, most medium-sized streams have natural channels or, if channelized, their stream power is often more in balance with the channel characteristics. Riffle/pool sequences have redeveloped with a firm (cobble/gravel/sand) substrate similar to that found in most natural watercourses. Most have an evident, well-defined flood plain with varying levels of disruption. A few have relatively undisturbed riparian vegetation and others are pastured or are idle pasture. The areas with idle pasture are now undergoing the slow process of natural succession or regeneration. Influences on these streams are silt, nutrient and pollutant inputs, both from neighbouring land use and from upstream sources. However, the improved habitat allows development of a complex and productive aquatic community with flood plain and hyporheic zone interactions. This enhances nutrient utilization and cycling. A diverse aquatic community is generally present. Farther downstream, the larger tributaries and the three main Thames branches generally support aquatic communities of increased complexity and stability. For the most part natural stream morphology and undisturbed flood plain is evident. The less impacted sections include much of the north Thames, portions of the middle and south Thames, and a few larger tributaries which support very diverse and productive aquatic communities. These river and stream reaches also provide habitat for a large proportion of the surviving fish, reptile and freshwater mussel Species at Risk (SAR) found in the Thames. However, many of these larger watercourses are influenced by urban development, including channel alteration, bank hardening, stormwater runoff, and sewage effluent input.

In general, a diverse community of mussels characterizes a healthy aquatic environment. There was once a diverse mussel community in the Thames. Mussel species that have disappeared, or mussel species that are extremely hard to find, indicate that aquatic conditions may be deteriorating. The primary threats to native freshwater mussel populations include turbidity, siltation, habitat loss or degradation, watercourse barriers, invasive species and poor water quality.

Species at Risk

A "species at risk" (SAR) is any naturally-occurring plant or animal in danger of extinction or of disappearing from the province (Source: http://www.mnr.gov.on.ca/en/Business/Species/). Map 29 of Appendix 5 shows the number and locations of SAR in the Thames watershed. Table A5-4 (Appendix 5 Addendum) lists the aquatic SAR (fish, reptile and mussel) in the Thames River subwatershed.

Of the more than 90 species of fish found in the Thames River watershed, there are currently 11 fish listed as Species at Risk (as of May 2010). The gravel chub is the only species considered to be extirpated (wildlife species no longer existing in the wild in Canada, but occurring elsewhere). Only two records exist for the Thames, and Canada, with the last specimen captured in 1958. A slight chance exists that the species may persist, as it is potentially very difficult to capture with the sampling methodology that has been utilized in recent years. The northern madtom is the only species listed as endangered (wildlife species facing imminent extirpation or extinction) by Committee on the Status of Endangered Wildlife in Canada (COSEWIC), although the eastern sand darter is listed as endangered on the provincial SAR list. Federally, the eastern sand darter, spotted gar, and black redhorse are threatened (wildlife species likely to become endangered if limiting factors are not reversed) species. The northern brook lamprey, grass pickerel, silver shiner, pugnose minnow, river redhorse, and spotted sucker are of special concern (wildlife species that may become a threatened or an endangered species because of a combination of biological characteristics and identified threats). Bigmouth buffalo, black buffalo and greenside darter were listed as special concern, but, have been delisted for a variety of reasons.

A few reptile SAR are identified in the Thames River watershed, amongst which the spiny softshell turtle (*Apalone spinifera spinifera*) was designated as threatened in 1989, by COSEWIC. The Thames River holds one of only three large communal nesting sites known in Canada, the other two occurring along the north shore of Lake Erie. The Thames is also one of the few rivers in Ontario from which consistent reports of the queen snake still occur. The queen snake was designated as endangered in 2010 by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC).

There are ten SAR mussels (as of May 2010) in the Thames River: snuffbox, round hickorynut, kidneyshell, salamander mussel, rayed bean, rainbow, mapleleaf, wavyrayed lampmussel, fawnsfoot and round pigtoe. The snuffbox and round hickorynut are believed to be extirpated from the Thames River. Almost all of the mussels are listed as endangered by COSEWIC. The mapleleaf is threatened and the wavyrayed lampmussel has just recently changed from endangered to special concern. Provincially, under the Endangered Species Act for Ontario 2007, the mussels have a status of endangered, except for the rainbow and mapleleaf that are listed as threatened.

2.3.3 Human Geography

The current population and estimated growth rate in each municipality are presented. The Upper Thames River Source Protection Area (*UTRSPA*) includes most of the municipality of City of London, and large parts of Elgin County, Middlesex County, Perth County and Oxford County. It also contains small parts of Huron County and Elgin County. The area covers approximately 3,423 square kilometres with a total watershed population (2001) of about 472,000. There are no First Nations in the *UTRSPA*, however there are First Nations in the other two SPAs of the source protection region.

Types of settlements (urban and rural centres) and land use (such as agricultural, residential and industrial) across the watershed are discussed. Map 1-4 of Appendix 1 shows the Areas of Settlement (as per the Places to Grow Act, 2005) in the Upper Thames River Source Protection

Area. The largest urban centre within the Upper Thames River Source Protection Area is the City of London, with an approximate population of 336,539 in 2001. Table 2-3 shows the population by municipality, for the years 2006, 2001 and 1996. Map 2-1 in Appendix 1 shows the population density across the Upper Thames River watershed. Growth rate projections for municipalities in the *UTRSPA* are discussed in the Watershed Characterization Report.

Table 2-3 Population Density of Municipalities in the Upper Thames River SPA Watershed

Census Division	2006 Population	2001 Population	1996 Population	1996 to 2001 Population Change	2001 to 2006 Population Change
Middlesex (incl. City of London)	422,333	403,165	389,616	3.50%	4.70%
Elgin	85,351	81,553	79,159	3.00%	4.70%
Huron	59,325	59,701	60,220	-0.9%	-0.6%
Perth	74,344	73,675	72,106	2.2%	0.9%
Oxford	102,756	99,270	97,142	2.2%	3.5%

Map 30 of Appendix 5 shows the generalized land cover in the Thames Watershed & Region. Agriculture is the dominant land use, but a wide variety of industrial, commercial and institutional land uses also provide employment for people.

General locations of federal lands in the Upper Thames River Source Protection Area are shown in Map 2-2 of Appendix 1. The Map 2-2 was generated using data available at the Treasury Board of Canada Secretariat website (http://www.tbs-sct.gc.ca/dfrp-rbif/home-accueil.asp?Language=EN), map navigator page.

Interaction between Physical and Human Geography

The watershed characterization report discusses the interaction between human and physical geography.

The original amount of wetland cover in the *UTRSPA* watershed is unknown. The total area of wetland cover (evaluated wetlands) is now less than 2% of the conservation authority's watershed area.

The smaller watercourses (first to third order streams) have, on average, 20% woodland riparian cover. The larger watercourses (fourth order and higher) have approximately 28% riparian cover. This difference is to be expected as many of the first and second order streams are farm drains that are often without any buffer at all.

Hardwood forests covered the majority of the upper Thames River watershed prior to European settlement with smaller pockets of grassland and savanna habitat. Species diversity was very high in this region due to the long growing season, rich soils and productive waterways. However, these same factors also made the area attractive for farming and urban development. Today, the woodland/forest cover in the *UTRSPA* is highly fragmented, existing as small woodlots separated by agricultural fields, urban development and other land uses. Over 70% of the woodlots in the Upper Thames watershed are less than 10 hectares. Due to the practice of clearing the acreage closest to the concession road for farming, many woodlots represent the ‘back 40’ of farms and are distributed in a linear fashion parallel to the roads.

Over the past century, several diseases and pests introduced by man have had a significant impact on the local tree species. The American Chestnut was destroyed by chestnut blight, caused by an Asian bark fungus accidentally introduced to America on imported Asiatic chestnut trees. The Blight was probably imported into North America from Asia in the early 1900s. Similarly, the American Elm has been seriously affected by an introduced fungal disease, Dutch Elm Disease, with heavy mortality. The disease was accidentally introduced into North America in 1931, in shipments of logs from the Netherlands destined for use as veneer. More recently, the Emerald Ash Borer, which is native to China and eastern Asia, has left a path of destruction in Essex County in southwestern Ontario (as well as southeastern Michigan, northern Ohio and Indiana). It has been found in Chatham-Kent and Elgin County. Its significance for woodlands in the region is not yet known but ash trees form an important part of the local tree cover in many woodlots.

Oxford County is characterized by significant reserves of mineral aggregates from both naturally occurring sand and gravel deposits and bedrock-derived crushed stone. The presence of substantial, high-quality deposits has led to the establishment of significant quarrying and sand and gravel extraction industries in the county. Much of the activity is located in Zorra Township. Several sections of Middlesex County contain abundant Quaternary deposits of sand and gravel. Portions of the City of London, including the Byron area and land surrounding Fanshawe Conservation Area, contain valuable deposits in close proximity to a large market with high demands for aggregate resources. In the Komoka area of Middlesex Centre Township, most of the aggregate resources have been extracted, although some pits are still active. In Perth County, excessive overburden limits the accessibility of limestone deposits that underlay most of the county, with St. Marys being the notable exception. Here, extensive quarrying activity since the 1880s has produced a significant percentage of limestone used for the production of cement products in the Great Lakes region.

In the *UTRSPA* watershed, there are 11 active landfills, most of which are in Perth County. The active landfills are small and for local communities. In the *UTRSPA* watershed, there are brownfield areas in all of the major urban centres. Brownfields are generally abandoned or underused commercial or industrial areas thought to be contaminated by past activties but which have a potential for redevelopment. Municipalities have either developed or are developing policies and incentives to encourage brownfield re-development. In the smaller urban settings, brownfields are limited in size and location. The Brownfield and Community Improvement Plans (*CIP*) vary from municipality to municipality. In the City of London, the *CIP* for brownfields cover lands within the Urban Growth Boundary identified on the Land Use Map (Schedule “A”) of the Official Plan, allowing those lands possible remediation.

Southwestern Ontario has a long history related to the oil and gas industry. Map 31 of Appendix 5 shows the concentration of oil and gas wells across the area. Middlesex, Oxford and Perth Counties are underlain by Paleozoic sedimentary rocks that have the potential for occurrence of oil and gas resources. However, very few commercial discoveries of hydrocarbons have been made other than the Innerkip gas pool in the northwestern corner of the *UTRSPA* watershed. Natural gas has been produced from the Innerkip gas pool since 1961. Only non-commercial shows of oil or natural gas have been encountered in the rest of the watershed. Relatively few wells have been drilled over 100 m to explore for hydrocarbons in the area and there is potential for additional undiscovered pools.

Due to a number of factors, including moderate temperatures, adequate rainfall, adequate growing season and good soil, the major land use in the region is agricultural and, more specifically, cash crop land. As shown on Map 33 of Appendix 5, most of the soils in the region are Class 1, 2 or 3 soils that are suitable for the sustained production of common field crops. Over the last 40 years, a significant trend in the agriculture industry has been the conversion from a mixed land use of both livestock pasture and crop cultivation, to either of these. In the 20-year period from 1986 to 2006, the number of farm operations has decreased and the farm operation size has increased dramatically due to a number of factors. Farmland makes up over 80% of the land use in the region. Farming dates back more than 1,000 years in the Thames watershed, when the Woodland peoples grew corn on fertile flood plain lands. These areas were considered to be highly suitable for agriculture as well as trade, transportation and later, industry. In the *UTRSPA*, agriculture is the predominant land use in 26 of the 28 subwatershed units, and Oxford County is a highly productive area with several livestock and cash crop operations.

Navigation by vessels is limited to the Thames River below London. The Thames River, although not navigable for large craft, still provides a picturesque locale for recreational boating, canoeing, rowing, and kayaking. Canoeing can be done in much of the upper Thames and small boats can be used on the impoundments behind some of the dams on the river. Fishing takes place in these waters and many of the other creeks and streams in the region. The Wildwood, Pittock and Fanshawe dams provide flood control. Map 22 of Appendix 5 shows the dams and control structures in the Thames watershed. These structures may affect water quality and restrict fish migration. Along the shoreline of the Thames River are pockets of cottages as well as low density residential and estate residential development with direct access to both public and private roads. Permanent dwellings in these locations are attractive because of their scenic vistas, recreational amenities and relatively easy commute to urban centres.

There are 17 private and municipal/conservation authority campgrounds in the *UTRSPA*. There are more than 30 public and private golf courses located throughout the *UTRSPA* including several that incorporate lands (flood plains) adjacent to local watercourses.

As mentioned earlier, there are several significant protected areas in the *UTRSPA* watershed. Ellice Swamp in Perth County, Golspie Swamp in Oxford County, Dorchester Swamp in Dorchester and Middlesex County, Sifton Bog in the City of London, and the Westminster Ponds/Pond Mills Conservation Area in the City of London are some of the protected areas in the *UTRSPA*. These areas are protected from developmental changes that could alter their natural characteristics.

2.3.4 Water Quality

This component describes the water quality across the *SPA*. The selection of indicator substances (parameters) is discussed. The watershed inland surface water, the ambient groundwater, municipal well raw (untreated) water, and the municipal surface water intake raw water quality data is reviewed and assessed using certain standards or guidelines. Where possible, trend lines are shown and statistical analyses performed.

Both drinking water quality standards and aquatic protection guidelines are used to assess water quality. The comparison is only intended to provide a means of quality assessment by using an established value and is not intended to judge conformance of raw (untreated) water to the standards or guidelines. The operation of a water treatment plant, including treated and distributed water quality, is governed separately under the Safe Drinking Water Act.

Inland Surface Water Quality Monitoring

To evaluate inland surface water quality, data from 24 surface water quality monitoring stations across the Upper Thames River Source Protection Area were reviewed for certain parameters. These stations are monitored under the Provincial Water Quality Monitoring Network (PWQMN) program. At all stations in the UTRCA subwatersheds, the current 75th percentile phosphorus levels are above the Interim Provincial Water Quality Objective (IPWQO) of 0.03 mg/L. Most sites are less than 0.15 mg/L but two stations, Thames Woodstock and Thames Byron, are over 0.2 mg/L. The historic phosphorus values are generally between two and eight times the IPWQO. Seven of 30 UTRCA stations have current 75th percentile nitrate values that are higher than the Ontario treated drinking water standard (ODWS) of 10 mg/L. To evaluate water quality for aquatic life, a nitrate level of 2.93 mg/L has been used for comparison. Only two UTRCA stations have current 75th percentile nitrate values that are less than 2.93 mg/L. Historically, the levels at all UTRCA stations were above 2.93 mg/L with the exception of Dorchester Swamp Creek which has been consistently below 2.93 mg/L.

The current 75th percentile chloride concentrations at all UTRCA sites are below the ODWS of 250 mg/L. Historically, most UTRCA sites have concentrations that are below 100 mg/L. However, the chloride concentrations at the Avon River have shown a significant increase since 1990-1994 from approximately 100 mg/L to over 200 mg/L. The Environment Canada aquatic health guideline for chloride is 210 mg/L. The current 75th percentile chloride concentration at the Avon River station in the UTRCA watershed is close to this and 25% of the samples are above 210 mg/L. All other UTRCA stations have chloride concentrations below 210 mg/L.

A review of data for *Escherichia coli (E. coli)*, a bacterial indicator, shows that the indicator is consistently above the recreational use guideline of 100 counts per 100 mL at most of the monitoring stations. The recreational use guideline for *E. coli* is intended for application by the local Medical Officer of Health, to decide the suitability of the use of swimming and bathing beaches. Copper and zinc levels are lower than their respective guidelines at all stations. At the UTRCA stations in 1980-84, all stations had samples above the lead ODWS of 10 µg/L and the percentage of samples above the ODWS ranged from 21% to 51%. By 2000-04, five of the six stations with historic data had all sample results below the ODWS and the other station only had 2% of the samples above the ODWS.

Groundwater Quality Monitoring

To evaluate the groundwater quality, data from 23 groundwater monitoring wells across the Upper Thames River Source Protection Area were reviewed. The monitoring is part of the Provincial Groundwater Monitoring Network (PGMN) program. Based on the PGMN monitoring, the UTRCA overburden and bedrock wells are dominated by calcium-magnesium-bicarbonate water. The carbonate, magnesium (and sulphate) ions in the groundwater primarily originate from the carbonate rock at depth (bedrock: dolostones, limestones and evaporites) and the carbonate material incorporated in overburden sediments.

Fluoride levels were above the ODWS of 1.5 mg/L in seven UTRCA monitoring wells. Fluoride can occur naturally in groundwater at levels that are above the drinking water standard. Two monitoring wells had nitrate + nitrite or nitrate results above the ODWS of 10 mg/L, one monitoring well had arsenic above the ODWS of 0.025 mg/L, and one monitoring well had cadmium above the ODWS of 0.005 mg/L. In the UTRCA, 13 monitoring wells had iron above the Ontario Drinking Water aesthetic objective (AO) of 0.3 mg/L and six monitoring wells had manganese above 0.05 mg/L. Iron and manganese in groundwater are usually due to the natural weathering of rocks and minerals. In the UTRCA watershed, dissolved solids (five monitoring wells), dissolved organic carbon (three monitoring wells) and chloride (one monitoring well) were found above the AOs. Sodium values above 20 mg/L can be of concern for individuals that are on a sodium restricted diet and the local Medical Officer of Health is notified. Sodium above 20 mg/L (but below the ODWS of 200 mg/L) was found in nine UTRCA monitoring wells. There were 19 UTRCA monitoring wells that had hardness levels that were not within the Ontario Drinking Water Operational Guideline (OG) range of 80 to 100 mg/L. In addition to hardness, four UTRCA monitoring wells had high aluminum and one UTRCA monitoring well had high pH.

Municipal Groundwater System Water Quality

In the Upper Thames River Source Protection Area, there are 22 municipal groundwater and no surface water drinking water systems. Data used to evaluate water quality of raw water to the drinking water systems were: Drinking Water Surveillance Program (*DWSP*), Drinking Water Information System (*DWIS*), Annual Drinking Water System Reports, Ministry of Environment, Conservation and Parks Inspection reports and minimal water treatment plant laboratory data. Similar to the findings of the groundwater monitoring data review, fluoride in raw (untreated) municipal well water is generally higher than the treated drinking water standard. Bacterial indicator total coliform is present in untreated water of most municipal wells, but *E. coli* was present in untreated water of only five systems. Raw (untreated) water quality is compared

against treated drinking water standards and this comparison does not reflect the treated drinking water quality. The treated drinking water standards include those from the Reg. 169/03, and Table 4 parameters from the Technical Support Document for the Ontario Drinking Water Standards, Objectives and Guidelines (MECP 2006).
nitrates occur above the Reg. 169/03 treated drinking water standard of 10 mg/L in the Thornton wellfield of the Woodstock wells. Fluoride occurs above the Reg. 169/03 treated drinking water standard of 1.5 mg/L in most wells, and is known to be naturally occurring in the groundwater.

In Middlesex County and City of London (now decommissioned) back up wells, sodium was below the Table 4 treated drinking water standard of 200 mg/L but above the 20 mg/L Health Unit notification level. One instance of fluoride above Reg. 169/03 treated drinking water standard of 1.5 mg/L occurred in the Thorndale system in 2004. In Oxford County, the Embro, Thamesford, Woodstock and Ingersoll systems had wells that had sodium levels below the Table 4 drinking water standard of 200 mg/L but over the Health Unit notification level of 20 mg/L. The Ingersoll, Lakeside and Thamesford systems had wells that had instances of fluoride above the Reg. 169/03 treated drinking water standard.

In Perth County, St. Marys and City of Stratford systems, the Sebringville, St. Pauls and Stratford well systems, sodium levels above the 20 mg/L Health Unit notification level are observed but the sodium levels are below the Table 4 drinking water standard of 200 mg/L. The Mitchell, Sebringville, St. Pauls and Stratford well systems had instances of fluoride levels above the Reg. 169/03 treated drinking water standard. In the Sebringville and Stratford systems, fluoride levels are noticeably high, often above 2.0 mg/L.

In addition, in Middlesex County, iron is above the Table 4 treated drinking water standard in the Kilworth-Komoka (now decommissioned) and Melrose systems, with manganese above Table 4 treated drinking water standard also in the former. Iron and manganese levels above the ODWS are also observed in a few Oxford County wells. In the City of London back up wells (now decommissioned), organic nitrogen and phosphorus also are above Table 4 treated drinking water standard and IPWQO, respectively. Hardness and total dissolved solids are seen in City of London (now decommissioned) and St. Marys wells. In Perth, iron levels above the Table 4 treated drinking water standard are observed.

2.3.5 Water Quantity

In this component, the water use across the Source Protection Area is discussed. Section 34 of the Ontario Water Resources Act (*OWRA*) requires anyone taking more than a total of 50,000 litres of water per day to acquire a Permit To Take Water (*PTTW*). Water taking includes uses which return the water to the source, as well as those which do not. Water taking also includes taking water into storage. In Section 3 - Water Budget and Water Quantity Stress Assessment water use is considered in more detail, including quantifying how much of the water taking is consumptive.

Water takers have a responsibility to ensure that the amount of water they use does not threaten the environment or existing water users. Some water takings are exempt from the requirement to obtain a permit. These include takings by an individual for ordinary household purposes, and water takings for the direct watering of livestock or poultry or for firefighting purposes. The approximate water taking (use) by sector (agricultural, commercial, industrial, municipal, water supply, dewatering, remediation, construction) is presented and described. The water taking for each subwatershed catchment area is also presented. These catchment areas are delineated through the Conceptual Water Budget study, which is described in Section 3 - Water Budget and Water Quantity Stress Assessment.

In the Thames watershed and region, while the agricultural sector has around 33% of the total permits, the percent of total maximum volume permitted is only 5%. This difference probably reflects the seasonal nature of the water taking associated with crop irrigation. Water supply makes up about 24% of the water taking permits, and includes takings by municipalities, campgrounds and communal uses.

2.3.6 Drinking Water Systems

There are 23 municipal drinking water systems which service people living in the Upper Thames River *SPA* of which two are located outside the *SPA*. The drinking water supply systems servicing the Upper Thames River *SPA* are shown in Map 1-3 of Appendix 1. Details are provided in Table 2-4. The 21 municipal drinking water systems located within this *SPA* are included in the Upper Thames River Source Protection Area Terms of Reference document, and therefore in this Assessment Report.

As per Regulation 287/07 (Section 14), an existing or planned major residential system may be exempted from Section 15 (2) (e) (i) of the Clean Water Act (i.e. identifying wellhead protection areas and intake protection zones), if the council of the municipality that owns the system has:

- passed a resolution stating that the municipality intends, within five years after the day the resolution is passed to discontinue the use of the drinking water system, and to make an application under the Safe Drinking Water Act, 2002 (and the Ontario Water Resources Act, if an IPZ or WHPA is delineated) for the revocation of any approval, municipal drinking water licence or drinking water works permit that is applicable to the drinking water system;
- published notice of the resolution referred to in clause (a) in one or more newspapers that, in the opinion of the council of the municipality, are of sufficiently general circulation to bring the notice to the attention of the public in the municipality; and
- sent a copy of the resolution referred to in clause (a) to the source protection committee for the source protection area

In June 2009, the Municipality of Strathroy-Caradoc passed a council resolution in order to exempt the Mt Brydges groundwater drinking water system from consideration in further technical studies towards the Assessment Report. Water is now obtained from the Lake Huron Primary Water Supply.

The Kilworth-Komoka wells were decommissioned in October 2010. The community of Komoka/Kilworth is now supplied by the Lake Huron Primary Water Supply System.

Table 2-4 Municipal Drinking Water Systems Serving the Upper Thames River Source Protection Area								
Drinking Water System (No. of wells)	**System Type***	**Operating Authority**	**Approx Population Served**	**Well Name**	**Well Depth (m)**	**Pumping Rates m³/day**		
						Max. Annual	**Avg. Annual**	**Avg. Month-ly**
Birr (1)	2	American Water Systems	63	Well #1	49	4743	4316	4316
Dorchester (9)	1	Municipality of Thames Centre	5586	Well 2PW-1	18	152624	124982	10415
				Well 3PW-1	10	90684	76351	6363
				Well 3PW-2B	12	115904	100932	8411
				Well 3PW-3	12	104974	86163	7180
				Well 3PW-4A	12	119575	94716	7893
				Well 3PW-7	12	100963	67518	5626
				Well 3PW-5	27	421	335	23
				Well 3PW-6	27	1003	688	48
				Well 3PW-8 (New well)	13.1	NA	71508	5959
Melrose (2)	2	American Water Systems	224	Well 2	25.6	17263	12248	1017
				Well 3	24.7	13882	11931	994
Thorndale (2)	1	Municipality of Thames Centre	675	Well 1	46	23891	20026	1669
				Well 2	45.1	23338	19376	1615
Beachville (1)	2	County of Oxford	180	Well #1	91.5	24156	21092	1758
Embro (2)	1	County of Oxford	828	Well 1	60	46248	38049	3171
				Well 3	60	46693	43282	3607
Hickson (1)	1	County of Oxford	99	Well # 2	53	12087	11111	926
Ingersoll (7)	1	County of Oxford	13,572	Well 2	140.5	549028	478392	39866
				Well 3 (Not presently in use)	117	259407	141017	15998
				Well 5	108.9	559446	493549	42714
				Well 7	122.8	188504	66668	7757
				Well 8	125.3	638316	378813	31568
				Well 10	112.5	1174171	909965	76935
				Well 11 (offline)	115.7	NA	NA	NA
Innerkip (2)	1	County of	935	Well 1	35	46938	41828	3486

Table 2-4 Municipal Drinking Water Systems Serving the Upper Thames River Source Protection Area								
Drinking Water System (No. of wells)	**System Type***	**Operating Authority**	**Approx Population Served**	**Well Name**	**Well Depth (m)**	**Pumping Rates m^3/day**		
						Max. Annual	**Avg. Annual**	**Avg. Month-ly**
		Oxford		Well 2	35	47604	44285	3690
Lakeside (1)	1	County of Oxford	310	Well 2	106	16620	15851	1321
Mt Elgin (2, includes 1 planned well)	1	County of Oxford	369	Well #3	60	36536	34757	2933
				Graydon well (planned)	No Data	No Data	No Data	No data
Tavistock (3)	1	County of Oxford	2658	Well 1	19.5	30873	24059	2005
				Well 2A	48	171953	62004	5167
				Well 3	61.5	447789	350055	34510
Thamesford (3)	1	County of Oxford	2016	Well #1	9.4	203581	105480	8790
				Well #2	14	203581	81069	11260
				Well #3	78	203581	132310	11026
Woodstock (11, includes 1 planned well)	1	County of Oxford	36,600	Well #1 (Thornton)	30	1980288	767680	63973
				Well #2 (Tabor)	20.8	1945843	1382113	115176
				Well #3 (Thornton)	16.1	275460	134961	11247
				Well #4 (Tabor)	23.5	2148179	1627792	135649
				Well #5 (Thornton)	27.1	1666172	444085	37007
				Well #6	48.8	609105	300616	25051
				Well #7 (Offline)	62.5	5492	5492	458
				Well #8 (Thornton)	14.6	776768	542950	45246
				Well #9	63.1	8581	5841	487
				Well #11 (Thornton)	31.9	1089339	791825	65985
				Bond well (planned)	No Data	No Data	No Data	No data
Mitchell (4)	1	West Perth Power Inc.	4000	Well 1 (Standby)	24.4	NA	69350	5779
				Well 2 (Standby)	33.5	NA	69350	5779
				Well 3	60	204458	989915	32493
				Well 4	56	567419	801726	66811

Table 2-4 Municipal Drinking Water Systems Serving the Upper Thames River Source Protection Area								
Drinking Water System (No. of wells)	**System Type***	**Operating Authority**	**Approx Population Served**	**Well Name**	**Well Depth (m)**	**Pumping Rates m^3/day**		
						Max. Annual	**Avg. Annual**	**Avg. Month-ly**
Sebringville (1)	2	Township of Perth South	90	Well 1	54.9	15152	12442	1037
Shakes-peare (2)	2	Township of Perth East (AWS)	220	Well 1	85	1158	851	71
				Well 2	88.4		395	
St. Marys (3)	1	Town of St. Marys	6200	Well 1	45.7	695162	615372	51281
				Well #2A	44.5	238348	214526	17877
				Well l#3	44.5	680292	431474	35956
St. Pauls (1)	2	Township of Perth South	90	Well #1	70.4	8389	8147	679
Stratford (11)	1	City of Stratford	30,460	Well (Chestnut)	150.3	83650	68221	5685
				Well (Dunn)	135.3	1145360	996574	83048
				Well (Lorne)	137.5	198005	116183	9682
				Well (Mornington)	99.4	418440	205663	17139
				Well (O'Loane)	135.3	798890	661318	55110
				Well 1 (Romeo)	122	357747	280073	23339
				Well 2 (Romeo)	121	239425	137050	11421
				Well 3 (Romeo)	107	299028	186700	15558
				Well 4 (Romeo)	103	117393	85855	7155
				Well 6 (Romeo)	139	1289283	1080007	90001
				Well 7 (Romeo)	81	746575	574866	47905
Lake Huron Primary Water Supply System**								
Elgin Area Water Supply System***								

*System Type 1 – Large municipal residential, 2 – small municipal residential
**Serve some area of the UTRSPA but located outside of this SPA and therefore not included in this Assessment Report; see the Ausable Bayfield Source Protection Area Assessment Report for information
*** Serve some area of the UTRSPA but located outside of this SPA and therefore not included in this Assessment Report; see the Kettle Creek Source Protection Area Assessment Report for information

Residents in the northern part of the Thames watershed rely on treated groundwater for their drinking water. These include the communities of Shakespeare, Mitchell, St. Pauls and

Sebringville in Perth County, City of Stratford and Town of St. Marys, and communities of Beachville, Embro, Hickson (King subdivision), Ingersoll, Innerkip, Lakeside, Mt Elgin, Tavistock, Thamesford, Woodstock and Sweaburg in Oxford County.

Some parts of Middlesex County (communites of Birr, Melrose in Middlesex Centre, and Thorndale and Dorchester in Thames Centre) also have municipal systems that use groundwater sources.

Residents in the City of London and some neighbouring Middlesex communities (including Delaware and Ballymote) use treated surface water piped from Lake Huron (Lake Huron Primary Water Supply System) and Lake Erie (Elgin Area Primary Water Supply System). The Fanshawe and Hyde Park well systems served as back up drinking water systems to the City of London until they were decommissioned in 2019. Most of the water for residents in Elgin County is from Lake Erie.

2.4 Data Gaps

The data gaps encountered during the preparation of the watershed characterization report are listed in Table 2-5 below.

Table 2-5 Watershed Characterization Data Gaps relevant to the Upper Thames River Source Protection Area

Subject	Data Gaps
Aquatic Ecology	
Fisheries Evaluation	Cold water refuges in natural water systems, historic evidence of cold water streams has not been investigated, application of indices such as the Index of Biological Integrity (IBI) to existing fish data.
Aquatic Macroinvertebrates - Habitat Conditions & Water Quality	Simpson's Diversity Index should also be considered, Analysis of physiography & land use to identify potential communities and groundwater quality/quantity stressors and impacts.
Reptile - Survival habitat and population dynamics	Extent, abundance and population demographics of prey (needed for some species); lack of species information, habitat identification, seasonal dispersal, population isolation, reproductive success, past distribution.
Species at Risk - Range and numbers of fish species at risk	Sections of the Thames River have little or no sampling, population, abundance, distribution or status unknown for some species.
Human Characterization	
Landfills	Information on active, closed landfills and expansions not provided for the Upper Thames watershed.
Water Quality	
Inland surface water quality - physical, chemical and microbial	Data from 1997 to 2001 from the commonly used provincial water quality monitoring network (PWQMN) dataset does not exist.
Additional sources of information	COA, Health Unit, sediment analysis and Research data have not been reviewed.
Inland and intakes surface	Not enough data on emerging contaminants (fire

Table 2-5 Watershed Characterization Data Gaps relevant to the Upper Thames River Source Protection Area

Subject	Data Gaps
water and groundwater quality – emerging pollutants	retardants, pharmaceuticals, algae toxins, etc.).
Groundwater monitoring well data	Comprehensive data not available.
Long term municipal groundwater well physical and chemical data	Comprehensive, long-term data not available; alternate sources of data used.
Wildlife impact on water quality	Locations of large populations of wildlife and the resulting effect on water quality (pathogen contamination and nutrient loading) require a better understanding.
Water Quantity	
Permit To Take Water Data	Data out of date - Many permits in database have expired dates and it is unclear if they have been renewed.
Water uses	Data Incomplete - Older permits only have maximum water taking per day. Difficult to determine actual usage.

Section 9.0 Data Gaps and Next Steps lists those data gaps considered to be a priority in filling, in order to meet the requirements of the Assessment Report. From the above table, the 'water uses' data gap is brought forward to Section 9.0.

3.0 Water Budget and Water Quantity Stress Assessment

The Clean Water Act is intended to reduce the threats to the quality and quantity of drinking water sources. In order to do this, threats within *vulnerable areas* are identified and assessed to determine the relative *risk* to the drinking water source. The Clean Water Act and its regulations identify 21 activities which can be drinking water *threats*. These activities include two which are related to the quantity of drinking water. One is 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. The other water quantity threat is an *activity* that reduces the recharge of an aquifer. To determine the risks to drinking water quantity from either of these threats, it is necessary to understand the level of *stress* on a drinking water system's source. The Water Budget is the tool used to understand the level of *stress* on a system or within a *watershed*.

Where there is little potential for *stress*, there are no *threats*. On the other hand, where there is a significant potential for *stress*, activities contributing to the *stress* were assessed to determine if they constituted significant threats. This was done through the Tier 3 Water Budget in those areas where the potential stress warranted a detailed local analysis. The Clean Water Act requires that the *Source Protection Committee* develop a *Source Protection Plan* that reduces the *risk* associated with *significant threats* so that they cease being significant and prevents new *significant threats* from being undertaken in these areas.

The Water Budget looks at the balance of water within an area known as a *watershed*. A Water Budget can be assessed at different scales, but generally this is undertaken on a *watershed* or a part of the *watershed* referred to as a *subwatershed*. It considers inputs or supply to the *watershed* or *subwatershed* which include: precipitation (rain and snow), flow into the watershed from up river, flow into the watershed through groundwater and flow imported into the watershed such as that which is piped water from the Great Lakes. The Water Budget balances these inputs with removals from the *watershed*, or *demand*, which include: discharges into the next *watershed* through stream flow or groundwater, use of water which is consumptive in nature (and therefore does not return the water to the same source from which it was removed), evaporation and transpiration (use of the water by plants). The water budget considers a balance between supply and *demand* that includes a *reserve* quantity that is removed from the supply in the stress calculation. The components of the water budget are described in detail in the Conceptual Water Budget (attached as Appendix 6), the Tier 1 Water Budget and summarized in the following sections.

The Water Budget is developed in stages referred to as tiers. As they progress, these tiers involve more detailed analysis, refined data and generally reduced study area. In this manner, only those areas with the potential to be stressed require detailed modelling and analysis; those which appear not to be stressed receive a less detailed screening. Each of these tiers is described in the following sections. *The Upper Thames River Source Protection Area* is included with the other Source Protection Areas in the Thames-Sydenham and Region in the Conceptual Water Budget and the Tier 1 Water Budget. Only areas where there is a moderate or significant *potential for stress* on drinking water systems included in the Terms of Reference (only municipal systems in the *UTRSPA*) proceed to a Tier 2 Water Budget. Only those areas which are confirmed to have a significant or moderate stress level in the tier 2 assessment proceed to a Tier 3 Water Budget. It is only through a Tier 3 Water Budget, or Local Area Assessment, that water quantity threats are assessed. As the potential for *stress* on some drinking water sources was determined to be moderate or significant through the Tier 1 and Tier 2 Water Budgets, Tier 3 Local Area Risk Assessments are required for the Upper Thames River Source Protection Area. A Tier 3 Water Budget and Local Area Risk Assessment (Tier 3 Assessment) was completed for the municipal drinking water systems of:

- City of Woodstock, the Town of Ingersoll, and the Community of Beachville, located within the County of Oxford,
- The Town of St. Mary's,
- The City of Stratford and
- The Village of St. Paul's located within the County of Perth.

3.1 What is a Water Budget?

A water budget quantifies and compares the components of the hydrologic cycle. Much like a bank account, if more water is leaving than is entering, the water in the *watershed* will be depleted over time. If in balance, the water use is sustainable. Each component of the water budget must be quantified so that the *demand* can be compared to the supply. If the *demand* is greater than the supply, the reserves, like the savings in a bank account, will be depleted. Over time this would result in reduced water levels in water bodies and aquifers. Normal and cyclical fluctuations in water levels make it necessary to look at the components of the water budget over long periods of time rather than looking at short-term trends in levels. This is especially true in groundwater systems where changes in water levels are more difficult to monitor and analyze.

3.2 Components of the Water Budget

3.2.1 Precipitation

Precipitation, or rain and snow, is the primary component of the supply component of the water budget. Long-term precipitation was analyzed from various meteorological stations around the region. Map 3-2 illustrates the precipitation stations used in the water budget and the spatial variation of the average annual precipitation over the region. Annual average precipitation decreases moving North to South along the UTRSPA from about 1060 millimetres per annum (mm/a) in the north (Stratford) to about 990 mm/a in the south (London) and 950 mm/a in Woodstock. On average, the Upper Thames River Source Protection Area receives about 1000 mm per year of precipitation.

3.2.2 Evapotranspiration

Evapotranspiration (or ET) is the precipitation which either evaporates into the atmosphere or is used by the plants. Water used by plants is also given back to the atmosphere through a process known as transpiration. Together the evaporation and transpiration are known as Evapotranspiration. There is little variation across the region other than as a result of the variation in precipitation. Map 3-3 shows the evapotranspiration across the region. Water which evaporates or is used by the plants is not available as supply and is therefore subtracted from the precipitation in the supply calculations. ET accounts for more than half of the precipitation in the region.

Irrigation, although also used by plants and lost back to the atmosphere through evaporation and transpiration, is considered in the *demand* part of the water budget. Irrigation water is removed from a groundwater or surface water source, and is consumptive to that source. ET, on the other hand, is loss from the precipitation component of the water budget. Another important distinction is that irrigation occurs only in very localized areas where it is required by a crop. ET is directly related to precipitation and temperature and is fairly uniformly distributed across the watershed.

3.2.3 Surface Runoff

Precipitation which falls in the watershed and does not evaporate or get absorbed into the plants either infiltrates into the ground or runs off into streams and rivers. The runoff from the watershed is not available for the supply as it leaves the watershed quickly. Although some of the water which infiltrates into the ground also leaves the watershed relatively quickly, most of the water which seeps deeper into the ground is said to recharge the aquifers, which is discussed in the following section.

3.2.4 Recharge

Recharge is the water from precipitation which soaks into the ground and recharges the aquifers in the ground. This is the water which maintains stream flow during periods between runoff events and is referred to as base flow. The water budget assumes that over time the recharge is equivalent to the base flow discharge from the watershed. This relationship is considered more closely in Tier 2 and 3 of the water budget work where calibrated surface and groundwater models are used to describe the components of the water budget including recharge.

In the Tier 2 Water Budget for the Upper Thames River Source Protection Area, recharge was estimated based on a combination of surficial geology and land use. At the Tier 3 level, a closer examination of the hydrologic response units in the GAWSER surface water model was completed. This allowed for a better representation of pervious and impervious areas in an urban setting, This provides a better representation of recharge than was provided in the Tier 2 Water Budget.

3.2.5 Water Use (Demand)

Water use in the water balance and stress calculations is referred to as *Demand*. While *demand* would be the simplest of the terms to monitor, records of water use are not required, except where permits for the use are required. Water use of more than 50,000 L/day, other than domestic and livestock watering, requires a Permit to Take Water, however until recently, records of water used were not required to be recorded and submitted. Even where the records are required as part of the permit process, they have only been required for the past few years. This recent record keeping is undertaken by the permit holder with little or no quality control on the data entered. This information is submitted by the permit holder and has only become available to the water budget team near the completion of much of this water budget work. In future revisions to the water budget the actual use records will provide a better estimate of the *demand*. For the Tier 1 and Tier 2 Water Budget work, estimations of actual use were based on adjusted maximum permitted values, or other sources of estimation in some cases. Large water users were polled to provide a better estimate of water *demand*.

Estimates of water use not requiring a permit to take water (often referred to as *non-permitted* water use) were also included in the calculations of *demand*. While municipal systems require a permit to take water and records of this *demand* is well established through municipal pumping records, an estimate of the water used from private water systems is also required. Generally, this *demand* is minor; however, it is important that it not be neglected in the water budget and stress assessment. Non-municipal system domestic *demand* is estimated based on per capita consumption estimations multiplied by population reported in census data.

Livestock watering also does not require a permit. This *demand* was estimated in a similar manner using livestock census data and typical water use by livestock type (Kreutzwiser & de Loë, 1999).

Both of these non-permitted uses are assumed to be distributed evenly across groundwater and surface water sources.

The Permit to Take Water information was analyzed to determine the *demand* in each *subwatershed* and combined with the *non-permitted demand* discussed above. Water use was considered separately for surface water and groundwater as required by the *Technical Rules 2013: Assessment Reports*. Consumptive factors were applied to the surface water *demand* based on the use of the water taken. These factors were recommended by the province in the water budget guidance. The consumptive factors applied to water use are shown in the Tier 1 and Tier 2 Water Budgets. Consumptive factors were generally not applied to groundwater use as water removed from aquifers is generally not returned to the same aquifers. Groundwater is usually returned to surface water bodies after it is used, resulting in the use being completely consumptive. Water taken for aggregate washing and wildlife conservation are exceptions where consumptive factors were applied. In these cases, permits allow for large quantities to initially fill ponds, but then only a small amount is taken to compensate for evaporation and/or water removed in product in the case of aggregate extraction.

Irrigation *demand* is estimated based on permitted values. As discussed in the section on evapotranspiration, most of the water applied to crops is used by the crops or evaporates back into the atmosphere. This is even truer for irrigation where the amount of water applied is intended to saturate the root zone and not result in any significant runoff or recharge. As such, the consumptive factors for irrigation reflect that little, if any, water is returned to the source from which it was taken.

Tables 3-1 (groundwater) and 3-2 (surface water) summarize the water *demand* in the area by type and source. Note that Table 3-1 data (except for the Thames River between the Forks and Dutton subwatershed), is derived from the Tier 2 Water Budget, and Tables 3-2 is derived from Tier 1. Surface water use was not specifically re-evaluated in the Tier 2 catchments and so is reported based upon Tier 1. It is important to realize that water use by industry and institutions supplied by municipal systems does not require a separate permit and is therefore included in the permitted values for the municipal system. Demands are only considered if they are taken from within the subwatershed under examination. Water taken from the Great Lakes for municipal supply is not included in Table 3-1 as a demand as it is withdrawn from outside the subwatershed being analyzed. Lake water discharged to the surface water through sewage treatment effluent is however considered as part of the supply for surface water.

A complete listing of all surface water permits for each Tier 1 subwatershed is included in the Appendix A of the Tier 1 water budget. A complete listing of all groundwater permits for the Tier 2 subwatersheds is included in the Appendix D of the Tier 2 water budget. The Tier 1 and Tier 2 Water Budget Reports are available at the Thames-Sydenham and Region website: http://www.sourcewaterprotection.on.ca/resources_publications_links.html

Table 3-1 Groundwater use in the UTRSPA (m^3/day)

Ground-water Use	Agricultural	Commercial	Construction	Dewatering	Industrial	Institutional	Miscellaneous	Recreational	Remediation	Water Supply	Non-Permitted	**Total**
Black Ck/ Avon R	0	0	0	0	0	0	0	0	0	147	1249	**1396**
Cedar Ck	0	0	0	0	0	0	953	0	0	22243	315	**23511**
Flat Ck	0	0	0	0	0	0	0	0	0	0	352	**352**
Middle Thames R	114.8	3241.1	0	2882	5130.4	0	0	0	0	518.1	1576	**13462**
North Thames R/ Medway R	117	563.2	0	0	5328.8	0	4255	0	0	257.9	1,838	**12360**
North Thames R/Whirl Ck	150.7	0	0	78.5	0	0	0	0	0	2335	1,592	**4156**
Reynolds Ck	28.7	840.6	0	0	0	0	0	0	0	240.8	741	**1851**
Thames R Above Ingersoll	0	224.3	0	60559.1	3084	0	0	0	194.5	6846.8	898	**71807**
Thames R Above Pittock Reservior	395.4	1277.7	0	0	0	0	0	0	0	2307	1,606	**5586**
Trout Ck/North Thames R	30.2	1405.9	0	8182	12977.8	0	0	0	0	3231.9	1,175	**27003**
Upper Avon R	0	0	16.4	0	94.7	500	0	0	0	12149.4	774	**13535**
Waubuno Ck/Thames R Tribs	292.9	1084.2	0	0	4319.3	0	872.8	235.3	0	2000.4	1,678	**10483**
Thames R. btwn Forks and Dutton*	3439	2423	0	0	720	0	0	0	0	1755	2002	**10339**
Total	**4569**	**11060**	**16**	**71702**	**31655**	**500**	**6081**	**235**	**195**	**54032**	**15796**	**195841**

* Subwatershed Thames R. between the Forks and Dutton crosses over the Upper and Lower Thames boundary, and as such numbers reported are for both source protection authorities in this subwatershed. This subwatershed was not evaluated in Tier 2, and numbers are taken from the Tier 1 water budget. All other data from Tier 2 water budget.

Table 3-2 Surface Water use in the UTRSPA (m^3/day)†

Surface Water Use	SW Code	Agricultural	Commercial	Construction	Industrial	Miscellaneous	Recreational	Water Supply	Non-Permitted	**Total**
North Thames River/Whirl Cr.	01T	0	215	0	0	0	0	0	907	**1122**
Flat Cr./North Thames Tributaries	02T	0	0	0	0	0	0	0	240	**240**
Black Cr./Avon River	03T	10	199	0	0	0	0	0	930	**1139**
Trout Cr.	04T	0	31	0	0	0	16	0	584	**631**
N. Thames/Medway R.	05T	0	4050	0	4248	0	0	0	952	**9250**
Thames R. above Pittock Reservoir	06T	256	0	0	818	331	0	0	860	**2265**
Cedar Cr.	07T	0	532	0	0	0	0	0	195	**727**
Reynolds Cr./Thames R. above Ingersoll	08T	158	86	0	3125	267	0	0	833	**4469**
Middle Thames R.	09T	200	88	0	115	0	0	0	959	**1362**
Waubuno Cr./Thames R. Tributaries	10T	1325	540	0	0	13998	41	0	371	**16275**
Thames R. between the Forks and Dutton*	11T*	3633	2708	0	0	183	44	0	430	**6998**
Total		**5582**	**8449**	**0**	**8306**	**14779**	**101**	**0**	**7261**	**44478**

* Subwatershed 11T crosses over the Upper and Lower Thames boundary, and as such numbers reported are for both source protection authorities in this subwatershed
† Data from Tier 1 Water Budget.

3.2.6 Water Budget Summary

Each *subwatershed* in the region is examined in terms of the water budget components for both surface and ground water systems on an annual average basis. Components include:

Q_P, precipitation,
Q_{SW-in}, surface water flows in,
Q_{GW-in}, groundwater flows in, (assumed zero in Tier 1)
Q_{ET}, Evapotranspiration,
Q_{SW-out}, surface water flows out,
Q_{GW-out}, groundwater flows out, (assumed zero in Tier 1)
Q_{GW-C}, consumptive groundwater use,
Q_{SW-C}, consumptive surface water use, and
ΔS, change in storage (assumed zero in Tier 1)

The water budget equation can be summarized as:

$$Q_P + Q_{SW-in} + Q_{GW-in} = Q_{ET} + Q_{SW-out} + Q_{GW-out} + Q_{GW-C} + Q_{SW-C} + \Delta S$$

Table 3-3 summarizes the annual water budget in units of annual average m^3/day, from the Tier 2 water budget analysis. In Tier 2 the Q_{SW-C} term is not included, as it was not evaluated for the Tier 2 subwatersheds. However, this is not a significant factor as the amount of annual average surface water demand, in terms of the average annual supply, is negligible. For example, in the Whirl Creek/North Mitchell subwatershed there is an average annual surface water demand of 1123 m^3/day (from previous Tier 1 analysis), compared to a supply of 820,561 m^3/day, or 0.14%; a similar relationship holds true for all subwatersheds. The surface water demand is significant on a monthly basis, but not when considered annually. Note that in the last row of Table 3-3, the Thames R. between the Forks and Dutton subwatershed was not evaluated in Tier 2, and so results from Tier 1 are presented. No groundwater modeling was conducted for Tier 1, and so the Q_{GW-out} and Q_{GW-in} terms are absent for this subwatershed.

Table 3-3 Tier 2 water budget summary (m^3/day)

Sub-watershed	Q_{ET}	Q_P	Q_{sw-out}	Q_{sw-in}	Q_{gw-out}	Q_{gw-in}	Q_{gw-c}
Black Creek/Lower Avon River	321458	587618	836929	571377	29030	13133	173
Upper Avon River	202505	365341	162080	0	26957	2246	12787
Trout Creek/North Thames River above St Marys	412700	740400	1265692	939029	96077	40435	18317
Medway Creek/North Thames river above London	875592	1542140	1929678	1265692	184723	82339	10454
Cedar Cr.	138789	231627	92317	0	32054	41299	23155
Reynolds Cr	247516	417016	168107	0	49162	19008	1123
Thames R. above Ingersoll	296796	517286	497000	336989	46181	64541	70762
Middle Thames R.	483021	798152	312437	0	96768	45274	9158
Thames River above Pittock	354842	600867	244672	0	87782	25056	3974
Waubuno Creek/Dorchester	439767	820562	1416685	1036733	129514	61862	8813
Whirl Creek/North Mitchell	473232	835064	360969	0	30067	538358	2419
Flat Creek/Glengowan	193512	344411	511397	360969	15120	19094	0
Thames R. between the Forks and Dutton*	1167292	1998777	4224578	3402509	-	-	10337

* The subwatershed Thames R. between the Forks and Dutton crosses over the Upper and Lower Thames boundary and, as such, numbers reported are for both source protection authorities in this subwatershed. Numbers from this subwatershed derived from Tier 1 analysis

3.3 Phases of Water Budget Work

3.3.1 Conceptual Water Budget

The Conceptual Water Budget, or conceptual understanding, is the first phase of the water budget development. In this stage, background information is collected on the components of the water budget. The information is analyzed to determine the various components of the water budget based on historical and readily available data on a coarse scale. The conceptual Water Budget was completed for the entire region. The region was divided into 6 *subwatersheds* for the purposes of this analysis. The Conceptual Water Budget is included as Appendix 6 of the Assessment Report.

3.3.2 Tier 1 Water Budget

The Tier 1 Water Budget utilizes the information collected and analyzed in the Conceptual Water Budget. In Tier 1, the potential for stress is assessed in *subwatersheds* within the region. As with the Conceptual Water Budget, the Tier 1 Water Budget was documented in one report for the entire Thames-Sydenham and Region. For the purposes of the Tier 1 Water Budget, the region was subdivided into 32 *subwatersheds*, as shown in Map 3-1. Of these 32 *subwatersheds*, ten are fully within the *UTRSPA* while one subwatershed is partially within the *UTRSPA* and partially within the *LTVSPA*. A water budget and stress assessment were completed for each of these 32 *subwatersheds*, and were used to determine if any *subwatersheds* required a Tier 2 analysis. The Stress assessment is discussed further in Section 3.4.

The Thames River is comprised of a south branch and north branch which meet at the forks of the Thames in London. Upstream of London, the North Thames River flows southerly from Mitchell and St. Marys to the forks in London.The south branch flows from Tavistock through Woodstock and westerly through Ingersoll to the forks in London. The south branch is commonly referred to as the South Thames River and is labeled as such in the maps of this report (such as Map 3-1). However, federal and provincial references to the south branch of the Thames River identify this part of the river as the Thames River. As a result, in some places in this section of the report and the Water Budget reports, the south branch may be referred to as the Thames River (such as Thames River above Pittock, or Thames River above Ingersoll). This refers to the part of the Thames River which is labeled in maps and referred to elsewhere in this report as the South Thames River.

Tier 1 considers a future demand scenario, where municipal takings are increased according to the municipalities' Official Plans, and the stress assessment was recalculated with the increased demand. This is discussed in greater detail later in this document.

3.3.3 Tier 2 Water Budget

During the process of conducting the Tier 1 water budget, five *subwatersheds* containing groundwater-based municipal drinking water systems:

- Black Cr./Avon River (03T)
- N. Thames/Medway R. (05T)
- Cedar Cr. (07T)
- Reynolds Cr./S. Thames R. above Ingersoll (08T)
- Middle Thames R. (09T)

within the UTRSPA were found to exhibit a moderate or significant potential for stress. A Tier 2 investigation was undertaken for those *subwatersheds*, however the model domains included all of the *subwatersheds* in the UTRSPA upstream of the forks of the Thames River in London. This accounts for flow into the *subwatersheds* of interest. Information derived from the Tier 2 study is presented in this Assessment Report for groundwater systems in the UTRSPA. The delineation of the *subwatersheds* used for the stress assessment are slightly altered from those examined in the Tier 1 phase, to focus on the municipal systems being investigated. This resulted in a total of eight *subwatersheds* being analyzed in Tier 2:

- Black Cr. (405)
- Avon River (404)
- Trout Cr./North Thames River (406, 407, 408, 410)
- N. Thames/Medway R. (409, 411, 412, 413)
- Cedar Cr. (301, 302)
- S. Thames R. above Ingersoll (304, 305)
- Reynolds Cr. (306)
- Middle Thames R. (307)

Through these revisions it was important to delineate *subwatersheds* which contained all of the wells of a single system with the area contributing to the supply for the wells. These revised *subwatersheds* are illustrated in Map 3-6, which also shows the results of the stress assessment on groundwater systems based on Tier 2 work.

As there are no surface water based municipal drinking water systems within the UTRSPA, Tier 2 investigation of the surface water system was limited to the assessment of groundwater recharge for input to the groundwater model. Therefore surface water stress assessments included in this report are derived from the Tier 1 work. Furthermore, no Tier 2 work was done in the part of the UTRSPA below the forks of the Thames (11T) in ground or surface water systems, as there are no municipal supplies in this subwatershed with evidence of potential stress. Any data presented on subwatershed 11T are therefore based on the Tier 1 analysis.

In the Tier 2 analysis, future water use is considered, as in Tier 1, as well as 2 and 10 year drought scenarios. This scenario analysis is discussed in greater detail in Section 3.4.

3.3.4 Tier 3 Water Budget

The Tier 3 Water Budget, or local area risk assessment, is a local water balance undertaken on the scale of a single drinking water supply system. The Tier 3 Water Budget is intended to examine the reliability of that supply, including testing of drought and future demand scenarios. The purpose of a Water Quantity Stress Assessment is to compare available groundwater and surface water supply to the demand from existing, future and planned drinking water systems. Where the Tier 2 analysis found the ratio of water demand to water supply is high watersheds were classified as having “Moderate” or Significant” potential for water quantity stress and a Tier 3 analysis was required. Tier 2 analysis completed in the Upper Thames River Source Protection Area (SWS 2011) required that 6 municipal systems undergo a Tier 3 analysis. These systems are illustrated in Map 3-6.

A Tier 3 Assessment was therefore completed for the following municipal drinking water systems:

- City of Woodstock, the Town of Ingersoll, and the Community of Beachville, located within the County of Oxford,
- The Town of St. Mary’s,
- The City of Stratford and
- The Village of St. Paul’s located within Perth South

3.3.5 Peer Review of the Water Budget

Each phase of the water budget is subject to a peer review process. The project team and consultants work closely with the peer reviewers to ensure that the work undertaken is technically sound and meets the requirements of the *technical rules* and relevant provincial guidance. As work on the project progresses, the materials are presented to the peer review committee for their comments. Those comments are considered by the peer review team and consultants and are generally incorporated into the final report. The comments, along with their responses, are also incorporated into a peer review record, which becomes a companion to the water budget report. Following completion of the peer review, the draft water budget document is submitted with the peer review record to the Ministry of Natural Resources and Forestry for acceptance.

The Conceptual, Tier 1, 2 and 3 Water Budgets have successfully completed the peer review process and the drafts have been accepted by the MNR. Peer review of the work included in this Assessment Report is not a requirement of the technical rules; however the Source Protection Committee relies on the technical experts on the peer review committee to ensure that the work is suitable for the purposes of developing a Source Protection Plan for the area. The Ministry of Natural Resources and Forestry also relies on the peer review process as part of its review and acceptance of the water budget work.

3.4 Water Quantity Stress Assessment and Local Area Risk Assessment

The level of potential for stress is calculated based on the following formula as defined in the *Technical Rules 2013: Assessment Reports*:

$$\text{\% Water Demand} = \frac{Demand}{Supply - Reserve} x100$$

Percent Water Demand is calculated separately for groundwater and surface water as are the other terms in the above *percent water demand* equation. Percent Water Demand is calculated at both the Tier 1 and Tier 2 stages and is one of the main criteria in determining if more detailed analysis is required.

For surface water, *Demand* is the monthly estimated average *demand* of all surface water sources, *Supply* is the monthly estimated median daily flow, and *Reserve* is the 90th percentile monthly flow, or the flow that is exceeded 90 percent of the time for the month being analyzed.

For groundwater, supply includes a number of components as discussed in section 3.2 above. For the Tier 1 Water Budget, supply is simplified to include only recharge in the subwatershed. For the Tier 2 Water Budget, a calibrated groundwater model is used to estimate groundwater flows into the subwatersheds. This quantity, plus the estimated recharge, is used as the supply. Groundwater flow into the watershed can be calculated through the use of a calibrated groundwater model.

Groundwater reserve is 10% of the supply, as required in the *Technical Rules 2013: Assessment Reports*. A water reserve estimate is intended to protect a portion of water from being considered within the stress calculations, adding a conservative element to this calculation. This water is removed from the supply in the stress assessment.

The *Percent Water Demand* is used as an indication of the stress level in the *watershed* or *subwatershed*. This stress level is described in this document as the "potential for stress" as it better describes the situation given the *uncertainty* associated with the calculations. Generally, a Tier 1 and Tier 2 *stress assessment* are understood to have *uncertainty* associated with the *percent water demand* calculations. The uncertainty is reduced in Tier 2 over that in Tier 1, but cannot be eliminated entirely. At the completion of the Tier 1 and Tier 2 Water Budgets, it is important to understand that conclusions drawn from these analyses are indicative of whether more analysis is required but are not an absolute determination that there is *stress*. Given the level of conservatism, as discussed above, this is especially important when considering the *subwatersheds* which are being described as having a significant potential for *stress*. However, for the *subwatersheds* which are described as having a low potential for *stress*, this conservatism clearly indicates that they do not have a significant level of *stress*.

The sensitivity analysis required for *subwatersheds* which are almost moderate gives even more confidence in this conclusion. This sensitivity analysis ensures that all *subwatersheds* with a moderate potential for *stress* also advance to the next stage of analysis, along with those identified with a significant potential for *stress*. At the next stage, additional analysis is required to improve the *water demand estimate* and, in the case of Tier 2, the *stress* level, with a higher level of confidence. If a moderate or significant potential for *stress* is determined to exist in the Tier 1 or Tier 2 analysis and affects a municipal water supply, additional analysis would be undertaken through the Source Protection program. If a *subwatershed* with a municipal system is found to have a moderate or significant potential for stress in Tier 2, it then moves to a Tier 3 local area risk assessment. In Tier 3 new stress assessments are not made; rather, a risk assessment of the reliability of individual systems to be able to meet demand is conducted.

In assessing the potential for *stress*, various scenarios as identified in the *technical rules* must be considered. These scenarios consider current and future municipal *demand* under both average and drought scenarios. Planned systems must also be considered, however there are no planned systems in the Upper Thames River Source Protection Area. Planned wells in existing systems would be included in the future demand for the systems. Drought scenarios are not considered in the Tier 1 Water Budget, but need to be included in the Tier 2 assessment. These scenario analyses are conducted on *subwatersheds* which contain municipal systems, but under average conditions exhibit low potential for stress. If under average conditions a moderate or significant potential for stress is identified, the next tier work is required, and there is no need for the scenario analysis. The intent of scenario analysis is to ensure *subwatersheds* which exhibit a low potential for stress under average conditions will not be pushed to a higher level by increased future municipal demand, or by drought.

The scenarios modelled in each tier of the water budget analysis are prescribed in the Technical Rules (MECP, 2009). These are further described and outlined in the water budget reports which are include as supplemental document with the Assessment Report and Source Protection Plan. In Tier 2 those scenarios (described in Table 1 of the Technical Rules) focused on the stress on the watershed within which the system is located. The scenarios included normal or average conditions while considering future and planned system demand. They also considered panned or built out land use. The scenarios also considered variable supply represented by certain drought conditions. In Tier 3 the scenarios focused on the exposure of the system to various demand and supply scenarios described in Table 4 of the Technical Rules. The scenarios again included historical climate conditions as well as specified drought conditions from historical records. They also included current and future demand scenarios and land use reflective of both the current and future situations. These scenarios and the various combinations assessed are described in detail in the water budget reports and Technical Rules and presented in Table 3.8.

The *subwatersheds* in the *UTRSPA* to which this applies contain small communities with no future growth forecasted, and thus the future analysis does not change the stress assessment. Drought scenarios are are described below.

Criteria discussed in Table 3-4 below relate to the current and future municipal *demand* scenarios (respectively). As there are no additional planned systems in the Upper Thames River Source Protection Area, the scenario related to planned systems is not applicable and therefore not included in Table 3-4.

Tables 3-5, 3-6a, 3-6b, 3-7a and 3-7b describe the potential for *stress* based on the *percent water demand* for the applicable scenarios which must be compared to the ranges shown in Table 3-4. Table 3-5 shows the surface water stress assessment from Tier 1 as Tier 2 surface water stress assessment was not required due to the low potential for stress in all UTRSPA subwatersheds. Tables 3-6a, 3-6b, 3-7a and 3-7b report the potential for stress for groundwater from the most advanced level of assessment completed,with sub-tables 'a' representing subwatersheds which only attained Tier 1 analysis, and sub-tables 'b' present Tier 2 analysis. If a system was found in Tier 1 to require Tier 2 analysis and a new stress assessment, only the Tier 2 stress assessment is presented to avoid having multiple values for a single area. The full Tier 1 Stress Assessment is available in the Tier 1 study document.

The Table 3-6a and b are for average annual conditions, and Tables 3-7a and b for maximum monthly. Table 3-7b only includes subwatersheds which were not found in the Tier 2 annual average analysis (i.e. Table 3-6a) to have a moderate or significant potential for stress, as an additional check whether they should be included in the Tier 3 work.

Map 3-6 shows the cumulative results of the the most advanced level of analysis completed. As described in section 3.3.2 and 3.3.3 each tier was completed and documented in separate reports. Full results from the Tier 1 and 2 assessments are available in the Tier 1 (Thames-Sydenham and Region, 2010) and Tier 2 (Schlumberger Water Services, 2010) reports.

Additional criteria as described in Rule 32 and 33 are also considered in the stress assessment. If the intake or well was not able to operate due to insufficient quantity of water or a low water level, the potential for *stress* is described as moderate and the *subwatershed* would advance to the next tier.

Table 3-4 Potential for stress based on *percent water demand* under current and future municipal water demand

Potential for Stress	Surface Water % Water Demand	Groundwater % Water Demand	
Based on	Max'm monthly	Max'm monthly	Avg annual
Significant	Greater than or equal to 50%	Greater than or equal to 50%	Greater than or equal to 25%
Moderate	Less than 50% but greater than 20% (or between 18 and 20%, inclusive, but under sensitivity analysis increases to greater than 20%)	Less than 50% but greater than 25%	Less than 25% but greater than10% (or between 8 and 10%, inclusive, but under sensitivity analysis increases to greater than 10%)
Low	Less than or equal to 20% (after sensitivity analysis if between 18 and 20%, inclusive)	Less than or equal to 25%	Less than or equal to 10% (after sensitivity analysis if between 8 and 10%, inclusive)

Table 3-5 Surface water potential for stress based on Tier 1 stress assessment (Month of August)

Subwatershed	Code	Supply (Q_{50}) (m^3/day)	Reserve (Q_{90}) (m^3/day)	Demand (m^3/day)	Percent Water Demand	Potential for stress
North Thames River/Whirl Cr.	01T	8251	907	1466	20%	Low
Flat Cr./North Thames Tributaries	02T	0	0	241	0%	Low
Black Cr./Avon River	03T	36202	20779	1464	9%	Low
Trout Cr.	04T	148349	91584	708	1%	Low
N. Thames/Medway R.	05T	293371	162346	17115	13%	Low
S. Thames R. above Pittock Reservoir	06T	161784	99878	3585	6%	Low
Cedar Cr.	07T	18749	8640	1692	17%	Low
Reynolds Cr./S. Thames R. above Ingersoll	08T	226757	157594	7548	11%	Low
Middle Thames R.	09T	51840	24970	2602	10%	Low
Waubuno Cr./Thames R. Tributaries	10T	396835	258854	23554	17%	Low
Thames R. between the Forks and Dutton*	11T*	933120	606874	29659	9%	Low

* Subwatershed 11T crosses over the Upper and Lower Thames boundary and, as such, numbers reported are for both source protection authorities in this subwatershed

Table 3-6 Groundwater potential for stress (Average Annual Conditions)
a) Tier 1

Subwatershed	Code	Q_{supply} (m^3/day)	$Q_{reserve}$ (m^3/day)	Q_{demand} (m^3/day)	Percent Water Demand	Potential For Stress

North Thames River/Whirl Cr.	01T	114872	11487	5609	5%	Low
Flat Cr./North Thames Tributaries	02T	38459	3846	352	1%	Low
S. Thames R. above Pittock Reservoir	06T	140934	14093	5757	5%	Low
Waubuno Cr./Thames R. Tributaries	10T	201081	20108	9153	5%	Low
Thames R. between the Forks and Dutton*	11T	445491	44549	10337	3%	Low

* Subwatershed 11T crosses over the Upper and Lower Thames boundary and, as such, numbers reported are for both source protection authorities in this subwatershed

b) Tier 2

Subwatershed	Code	Q_{supply} (m^3/day)		$Q_{reserve}$	Q_{demand}	Percent Water Demand	Potential for stress
		Inflow	Recharge	(m^3/day)	(m^3/day)	(m^3/day)	(m^3/day)
Black Cr.	405	13133	49334	2938	1382	2%	Low
Avon River	404	2246	37152	2678	13565	37%	Significant
Trout Cr./North Thames River	406, 407, 408, 410	40435	97632	9590	19354	15%	Moderate
N. Thames/Medway R.	409, 411, 412, 413	82339	212026	18490	12269	4%	Low
Cedar Cr.	301, 302	41299	38102	3197	23501	31%	Significant
S. Thames R. above Ingersoll	304, 305	19008	71798	4925	1814	2%	Low
Reynolds Cr.	306	64541	85536	4666	71712	49%	Significant
Middle Thames R.	307	45274	127267	9677	10714	7%	Low

Table 3-7 Groundwater potential for stress (Maximum Monthly Conditions)
a) Tier 1

Subwatershed	T1 Code	Q_{supply} (m^3/day)	$Q_{reserve}$ (m^3/day)	Q_{demand} (m^3/day)	Percent Water Demand	Potential for Stress
North Thames River/Whirl Cr.	01T	114872	11487	7743	7%	Low
Flat Cr./North Thames Tributaries	02T	38459	3846	352	1%	Low
S. Thames R. above Pittock Reservoir	06T	140934	14093	13589	1%	Low
Waubuno Cr./Thames R. Tributaries	10T	201081	20108	12342	1%	Low
Thames R. between the Forks and Dutton*	11T	445491	44549	34032	11%	Low

b) Tier 2

Subwatershed	Code	Q_{supply} (m^3/day)		$Q_{reserve}$	Q_{demand}	Percent Water Demand	Potential for stress
		Inflow	Recharge	(m^3/day)	(m^3/day)	(m^3/day)	(m^3/day)
Black Cr.	405	13133	49334	2938	1382	2%	Low
N. Thames/Medway R.	409, 411, 412, 413	82339	212026	18490	33869	12%	Low
Reynolds Cr.	306	19008	71798	4925	3974	5%	Low
Middle Thames R.	307	45274	127267	9677	12355	8%	Low

Map 3-5 indicates the Tier 1 potential for stress on surface water sources and Map 3-6 illustrates the Tier 1 and Tier 2 potential for stress on groundwater sources.

From the Tier 2 Stress Assessment, municipal systems which are moving to a Tier 3 analysis include:

- Stratford
- St. Marys
- St. Pauls
- Woodstock
- Beachville
- Ingersoll

Tier 3 work has been completed for these six municipal systems.

Drought

Consideration of drought scenarios is required for all subwatersheds classified in the Tier 2 water budget analysis as having a low potential for stress based on historic conditions and percent water demand analysis, Subwatersheds included are:

- Black Creek / Lower Avon River
- Medway Creek / North Thames River above London
- Reynolds Creek
- Middle Thames River

The methodology for completing the drought scenarios began by running a 2-year drought scenario, which was accomplished by running the numerical groundwater model in transient mode for 2 years with zero recharge using average annual pumping rates for all municipal wells in the subwatershed. The head in the pumping well was then checked to make sure that the height of water above the pump was sufficient for normal operation of the well. In all cases, the height of water above the pump (depth to pump minus depth to final water level) did not drop below a level considered sufficient for normal operation of the pump.

Based on the 2-year drought scenario analysis, there are no changes to stress categories that were determined in the assessment based on historic conditions or the percent water demand analysis. As the 2 year drought is considered the 'worst case scenario' the 10 year drought was unnecessary to run.

3.4.1 Uncertainty in the Stress Assessment

As the *stress* assessment for the Upper Thames River Source Protection Area was completed as part of the Tier 1 and Tier 2 Water Budgets, some uncertainty in the data and analysis is expected. Tier 2 work reduces uncertainty from what is expected in Tier 1, but does not eliminate it, and thus the requirement to move ahead with Tier 3 in some areas, where uncertainty must be further reduced. It is especially important that the uncertainty associated with the Tier 1 analysis be considered in interpreting the surface water stress assessment. Although this *uncertainty* has no effect on the Source Protection Plan it is of considerable importance in interpreting this analysis for use in other programs such as the Permit to Take Water Program.

While the stress assessment is based on best estimates of consumptive water demand, water supply and water reserve, there is uncertainty associated with these estimates that may affect the classification. Other sources of uncertainty exist in the stress assessment and include, but are not limited to, the data that was used to develop the conceptual model, the numerical models that were used to represent the conceptual model, and the calibration of these models that was based on limited observation data. However, to address uncertainty in the final subwatershed stress classifications, a sensitivity analysis was completed on both the average annual percent water demand and maximum monthly percent water demand analysis to determine how sensitive the subwatershed stress classifications were to changes in recharge and flow. This sensitivity analysis was designed based on the sensitivity analysis completed in the Tier 1 stress assessment, and includes the following scenarios:

- Increase groundwater recharge by 20%;
- Reduce groundwater recharge by 20%;

- Increase groundwater demand by 20%; and,
- Reduce groundwater demand by 20%.
- Reduce groundwater in component to zero

The net result of this analysis was that the associated uncertainty for each subwatershed investigated in Tier 2 remained in the low category for all uncertainty scenarios.

3.4.2 Local Area Risk Assessment (Tier 3 Assessment)

Map 3.6 outlines the Groundwater Potential for Stress Areas identified in the Tier 2 assessment. If a subwatershed with a municipal system is found to have a moderate or significant potential for stress in Tier 2 (Table 3-6 (b)), it then moves to a Tier 3 local area risk assessment which looks at each municipal system, or combination of systems where the local areas may overlap. In Tier 3 new stress assessments are not made; rather, a risk assessment of the reliability of individual systems to be able to meet demand was conducted. Six municipal systems, identified in the Tier 2 assessment, with a moderate or significant potential for stress advanced to the Tier 3. A Local Area Risk Assessment (Tier 3) was completed for the following municipal drinking water systems:

- the City of Woodstock, the Town of Ingersoll, and the Community of Beachville, located within the County of Oxford,
- the Town of St. Marys,
- the City of Stratford, and
- the Village of St. Paul's located within Perth South.

The following is a synopsis from the Executive Summary of the Tier 3 Assessment and Local Area Risk Assessment Reports (Matrix, 2014). These Reports are provided in their entirety as supporting documents to this Assessment Report.

The groundwater supply system of the City of Woodstock consists of 11 wells constructed in both bedrock and overburden aquifers, while the seven groundwater wells in Ingersoll and single well in Beachville draw water solely from bedrock aquifers in the Cedar Creek and South Thames above Ingersoll subwatersheds. Despite the Tier 2 indication of potential stress, to date, the City of Woodstock, Town of Ingersoll and Community of Beachville have not had any issues meeting their water quantity requirements.

The groundwater supply system of the Town of St. Marys consists of three wells constructed in bedrock aquifers. The Tier 2 Water Quantity Stress Assessment identified the Trout Creek/North Thames River subwatershed as having a Moderate potential for groundwater stress. Despite this indication of potential stress, to date, the Town of St. Marys has not had issues meeting their water quantity requirements.

The groundwater supply system of the City Stratford consists of 11 bedrock wells, while that of the Village of St. Paul's consists of a single bedrock well. The Tier 2 Water Quantity Stress Assessment identified the Avon River and Trout Creek / North Thames River subwatersheds as having a Significant and Moderate potential for groundwater stress, respectively. Despite this indication of potential stress, to date, the City of Stratford and Village of St. Paul's have not had issues meeting their water quantity requirements. These systems are illustrated in Map 3-7.

Three groundwater models were constructed to complete the three Tier 3 Local Area Risk Assessment. The Tier 3 Risk Assessment undertook a detailed review and representation of the physical system within the Stratford/St. Paul's Area, St. Marys Area and the Woodstock-Ingersoll-Beachville Area. The conceptual model used within the Tier 3 Assessment was refined and enhanced from earlier conceptualizations, Ontario Geological Survey aquifer mapping information was utilized where available and insights gained from more detailed local and regional studies were incorporated. The GAWSER surface water model that was developed for the Tier 2 Assessment was updated for the current assessment to provide refined estimates of groundwater recharge for groundwater modelling. Where the model domains extended beyond the UTRCA watershed, the GAWSER model was not available The GAWSER model was calibrated using data from non-regulated stream gauges in the greater study area. A groundwater flow model was developed for each study area using MODFLOW for St. Marys and Stratford and St. Pauls. The model included a finite difference grid that was refined around municipal pumping wells to assess groundwater flow and the potentiometric surface impacts at a well field scale. Similarly, a FEFLOW groundwater flow model was created for the Woodstock, Beachville and Ingersoll area. The groundwater flow models were calibrated to a fine level of detail with close attention to both local and regional observed water levels, stream baseflow estimates, recharge estimates from the GAWSER model, as well as municipal pumping and high quality water level observation data. As such, the Tier 3 models were calibrated at the municipal well field-scale to both steady-state (long term average) and transient (time-varying) conditions. As the surface water and groundwater models were both satisfactorily calibrated to observed steady-state and transient water levels and flows, they are considered to be reliable tools for water budget estimation.

The groundwater and surface water models were used to assess the reliability of the systems under various scenarios. The scenarios are identified in the Technical Rules (MECP, 2009). The scenarios include various combinations of average annual and drought conditions under current, and future demands. The scenarios also include consideration of the effects of future development on recharge. Each of the scenarios are assessed to determine whether the water levels in the wells are drawn down below a level at which they are safe to continue to operate (Safe Additional Available Drawdown).The scenarios are presented in Table 3.8 from the Matrix, 2014 report.

Table 3-8 Risk Assessment Model Scenarios (Matrix, 2014)

Scenario	Time Period	Model Scenario Details			
		Land Cover of the Local Area	Water Demand	Other Permitted Water Takings	Model Simulation
C	Average of Climate Record (1950-2005)	Existing	Existing	Existing	Steady-state, simulate water levels and flows using average annual recharge and pumping
D	Full Climate Record (1950-2005), Including Drought Periods	Existing	Existing	Existing	Transient, using monthly recharge and monthly pumping
G(1)	Average of Climate Record (1950-2005)	Planned, reduction in recharge	Allocated	Anticipated	Steady-state, simulate water levels and flows using average annual recharge and pumping
G(2)		Existing	Allocated	Existing	
G(3)		Planned, reduction in recharge	Existing	Anticipated	
H(1)	Full Climate Record (1950-2005), Including Drought Periods	Planned, reduction in recharge	Allocated	Anticipated	Transient, using monthly recharge and monthly pumping
H(2)		Existing	Allocated	Existing	

Table 3-8 Risk Assessment Model Scenarios (Matrix, 2014)

Scenario	Time Period	Model Scenario Details			
		Land Cover of the Local Area	Water Demand	Other Permitted Water Takings	Model Simulation
H(3)		Planned, reductions in Recharge	Existing	Anticipated	

A Local Area was delineated surrounding the municipal supply wells in the Study Area. This area was delineated as outlined in the Province's Technical Rules (MECP 2008) based on a combination of 1) the cone of influence of the municipal wells (WHPA-Q1), and 2) land areas where recharge has the potential to have a measurable impact on water levels at the municipal wells (WHPA-Q2). GUDI systems, such as St Marys, also have an upstream contributing area (similar to an IPZ-Q1) as they rely on surface water supply from upstream as part of the ground water supply. Map 3-7 illustrates these vulnerable areas.

Based on the results of the Risk Assessment modelling scenarios, provided in Tables 4.4 of each Tier 3 Water Budget and Water Quantity Risk Assessment (Matrix, 2014), all Local Areas assessed were classified as having a Low Risk Level. This is largely due to an abundance of capacity in municipal supply wells. Following the Technical Rules, no consumptive water users or potential reductions to groundwater recharge within the Local Area are classified as significant water quantity threats. Under all scenarios investigated, municipal wells were able to withdraw their allocated quantity of water, without exceeding safe available drawdown thresholds within the well, or without impacts to other water uses.

Despite the indication of potential stress in earlier investigations, none of the six had issues meeting their water quantity requirements. The 6 systems were classified as having a Low Risk Level. As a result, the Local Areas were assigned a "**Low**" Risk level. This is largely due to an abundance of capacity in municipal supply wells; also due to low anticipated growth and low forecast increase in water demand, as well as an abundance of additional water in municipal supply wells.

3.4.3 Uncertainty in the Tier 3 Assessment

As part of the Tier 3 Assessment, existing surface and groundwater models were enhanced, using a detailed characterization of wells and decreased area of investigation. Additional detailed hydrogeologic and/or hydrologic characterization was undertaken within and surrounding the municipal wells. More specifically, the Tier 3 analysis identified the low water operating constraints of the municipal wells, included individual municipal well water level measurements and pumping data and local area characterization gleaned from local studies. The representation of the groundwater flow system was calibrated to available hydraulic head data, pumping rates at municipal wells and streamflow measurements using a set of parameters (e.g., recharge and hydraulic conductivity) that are consistent with the conceptual model. The surface water model was calibrated to both overall streamflow, as well as low flow conditions and was used to generate estimates of groundwater recharge. While the numerical model is considered appropriate for the Tier 3 Assessment, consideration of the certainty of the Risk Level Assignment was completed based on a number of factors observed throughout the completion of this Tier 3 Assessment. Factors 1-4 are common through all study areas, Factors 5 & 6 are limited to the Stratford / St; Pauls areas. The areas to which the factors apply are shown in brackets with each factor. These factors include:

1) Slow growth or higher historical Demand - the resulting effect of increased withdrawals on future water levels and flows is expected to be minimal (Stratford, St Marys, St Pauls, Beachville and Ingersoll). Stratford system has historically pumped at a much higher rate (as much as 30% higher in the mid 1990's).
2) Conservative estimates of SAAD – The estimates of Safe Additional Available Drawdown (SAAD) are considered conservative based on the estimate of the safe water level in each well. (Oxford, St Marys Stratford and St Pauls)
3) High capacity – The Capacity, represented by the amount of SAAD, is more than able to meet future growth projections (Oxford, St Marys, Stratford and St Pauls)
4) Flexibility of the water supply systems – if increased demand caused an undesirable amount of drawdown the operator has sufficient flexibility to re-proportion the increased demand to one or more of the remaining wells. (Stratford, St Marys, Woodstock and Ingersoll)

5) Reduced simulated recharge – During numerical model calibration, the magnitude of recharge derived from the GAWSER surface water model, representing existing conditions, was decreased by 7% in areas of coarser grained surficial deposits to reduce localized mounding (simulated hydraulic head values above ground surface) in the numerical model. Therefore, even before simulated recharge was reduced due to development proposed in the OP (Scenarios G(1), G(3), H(1), and H(3)), recharge was already conservatively low in Existing conditions. (Stratford and St Pauls)
6) Predominance of confining clay till – Due to the extent and thickness of the fine-grained overburden, which separates the surficial systems from the deeper bedrock production aquifers, there is an intuitively higher degree of certainty that there would be a negligible impact on surface water features due to increased municipal pumping. Additionally, land use development is predicted to have a much smaller impact on recharge reduction (Stratford and St Pauls)

All of the factors listed above contribute to a High confidence in the Low Risk Level that was assigned to the Local Area of all assessed systems.

3.5 Significant Groundwater Recharge Areas

Significant Groundwater Recharge Areas (*SGRA*s) are delineated through the water budget work. These areas are determined through the use of the recharge calculated in the Tier 3. The same methodologies were used as in Tier 2, however, improvements of the GAWSER surface water numerical model improved the representation of recharge in urban areas. Improvements to the classification of soils and land use in urban areas allowed better representation of impervious and pervious areas. Rule 44 allows recharge to be compared with the average recharge of the area, or to the effective precipitation (precipitation less evaporation) of the area to determine if the recharge at that location is significant. Rule 44 identifies the criteria for determining whether a recharge area is significant:

- the area annually recharges water to the underlying aquifer at a rate that is greater than the rate of recharge across the whole of the related groundwater recharge area by a factor of 1.15 or more; or

- the area annually recharges a volume of water to the underlying aquifer that is 55% or more of the volume determined by subtracting the annual evapotranspiration for the whole of the related groundwater recharge area from the annual precipitation for the whole of the related groundwater recharge area.

As required by the Technical Rules, Significant Groundwater Recharge Area mapping was updated as part of the Tier 3 Assessment. Using Rule 44(1) of the Technical Rules, a threshold of 115% of the average groundwater recharge rate was applied against the groundwater recharge rates estimated by the Tier 3 GAWSER surface water model. Similar to the Tier 2 SGRA mapping exercise, a 25 ha filter was applied to remove small isolated identified areas, or to infill small non-identified areas that were surrounded by identified areas. The average recharge of the entire Upper Thames River is 132 mm/a.

The majority of SGRAs are located in the southern portions of the Upper Thames River Conservation Authority, in pervious surficial materials surrounding and within the City of London and the municipality of Thames Centre. There are localized SGRAs surrounding Woodstock and Ingersoll, as well as St. Marys. Moving north to Stratford, tills become the predominant geology, and SGRAs are minimal. Overall, the identified SGRAs are similar to where sand and gravel deposits have been delineated within the surficial geology mapping.

Rule 45 indicates that the area must have "a hydrological connection to a surface water body or aquifer that is a source of drinking water for a drinking water system". For the purposes of this rule a drinking water system can be any water well including a single residential water well. Map 34 in the Thames Watershed Characterization Report summary included as Appendix 5 illustrates that wells are located throughout the region. In areas where shallow sandy deposits provide for recharge areas, well installation is simple through the use of sand points driven to a modest depth. These types of water wells are, in most cases, installed without a permit and therefore not included in the water well information system used to produce Map 34. Further, it is not intended by the *technical rules* that the connection be direct or immediate, but rather that there is a "hydrologic connection". This recognizes that water not only flows vertically through the ground but also flows laterally from areas of higher levels to areas of lower water levels. Thus, it is generally accepted that aquifers are recharged from areas up gradient from the aquifer as well as directly above. Thus, a precautionary and conservative approach is warranted and all areas which meet the criteria for significance are included as *SGRA*.

Rule 46 allows professional judgement in the determination of areas deemed to exhibit significant recharge or not. For example, if an area is known to provide significant recharge on a local scale due to its unique physiography, but does not show up as significant using the methodology described above, it can be changed in the SGRA mapping to be significant. In the modelling done for SGRA determination in the TSR, river valleys and flood plain areas were shown to be SGRAs. In the opinion of some of the Water Budget Peer Review Committee (PRC) members, these areas are more appropriately defined as groundwater discharge rather than recharge areas, due to their low elevations and to the general groundwater hydraulic gradient towards them. However, there is also a body of research which shows that river valley areas can potentially exhibit both types of behaviour, dependent upon the season, and other PRC members felt it was appropriate to consider them as recharge areas. In the end it was agreed that they would be considered discharge areas, and thus removed from the SGRA mapping. Map 4-2-1 illustrates the *Significant Groundwater Recharge Areas* in the Upper Thames River Source Protection Area.

It is important to note that overlaying the groundwater vulnerability onto the *SGRAs* creates “overlay artifacts” or “sliver polygons”. This occurs where the boundary of a contiguous groundwater vulnerability area falls close to the boundary of the *SGRA*. Since the datasets do not perfectly align to each other, the slight gaps and overlaps between the boundaries create small, uniquely valued polygons.

3.6 Data Gaps and Next Steps

Table 3-8 summarizes data gaps identified through the Tier 1 and Tier 2 Water Budgets and Water Quantity Stress Assessments. As the *stress* assessment was completed through a combination of Tier 1 and Tier 2 Water Budgets, it is expected that there would be data gaps. In the case of surface water analysis, if work were to proceed to Tier 2, many of these gaps would need to be addressed at that time. In the case of groundwater analysis, Tier 3 analysis improved the local understanding and reduced the uncertainty.

These gaps do not affect the reliability of the analysis for use in the development of the Source Protection Plan.

Table 3-9 Data gaps related to Water Budget and Water Quantity Stress Assessment

Gap	Description
Improved understanding of water use	• Obtain actual water use data from all significant water users through the PTTW reporting system • Requires reassessment after sufficient data has been reported, perhaps when Assessment Report requires future update
Un-gauged Areas	• Surface Water Model to better understand distribution of flows in un-gauged subwatersheds
Climate Change	• Requires an understanding of the local climatic conditions resulting from global climate change which is not yet available • Consider the change in local climatic conditions in the water budget and the stress assessment when that information is available
Refine ET	• Improve calculation of ET to include consideration of soil types and land use at a local level

4.0 Vulnerability Assessment

In order to protect drinking water sources it is necessary to identify areas where activities can affect the drinking water sources. The Clean Water Act refers to these areas as *Vulnerable Areas* and requires that they be identified in the Assessment Report. The Vulnerability Assessment section of the Assessment Report summarizes the work to delineate these *vulnerable areas* which was undertaken through various studies. The studies involved the operating authorities of the water systems and were undertaken through partnerships involving the Conservation Authorities in the region. The Clean Water Act also requires that these *vulnerable areas* be assessed to determine their relative level of vulnerability. There are three types of *vulnerable areas* which must be identified and assessed:

- *Intake Protection Zones* (*IPZ*)
- *Wellhead Protection Areas* (*WHPA*)
- *Highly Vulnerable Aquifers* (*HVA*)

Activities in these *vulnerable areas* will be reviewed to determine the *risks* that they pose to the drinking water sources. The vulnerability of the area, combined with the hazard associated with the activity, provide a relative indication of the level of *risk* associated with a *threat*. The *Source Protection Plan* is focused on reducing the level of *risk* associated with *threats*. As such, the identification of the *vulnerable areas* and the assessment of vulnerability are cornerstones to the development of the *Source Protection Plan*. There are no surface water intakes located within the UTRSPA, and therefore no *IPZ* related to surface water intakes are delineated wthin this SPA.

Each type of *vulnerable area* is described in the following sections which summarize the identification and assessment of the vulnerability within the areas.

4.1 Peer Review of Vulnerability Assessment

All aspects of the vulnerability assessment are subject to a thorough peer review process. This process is described in Peer Review of Vulnerability Assessment, Terms of Reference (March 2008). This process includes the forming of a peer review committee comprised of four professionals with extensive experience in one or more of the areas related to the vulnerability assessment of the *vulnerable areas*. Two members of the committee are professional geoscientists familiar with the assessment of groundwater vulnerability; one with experience related to *Groundwater Under the Direct Influence* (*GUDI*) wells, while the other is also a member of the peer review committee for the Water Budget work. The third member of the peer review committee has extensive experience related to the surface water vulnerability assessment and is working on similar projects in other regions. A fourth member joined the committee in the peer review of vulnerability assessment studies of groundwater systems spanning the County of Oxford and Perth County in the Upper Thames River Source Protection Area (*SPA*) and the Lake Erie Source Protection Region (*SPR*). The peer review committee reviewed each technical report, met with the consultants and project teams to discuss the project and submitted comments based on their review and the discussion. Comments were considered and responded to by the consultant or project team members. These comments and the responses form part of the peer review record along with the terms of reference for the peer review committee discussed above. The peer review process added considerable value to the technical report by ensuring that the work was well documented.

One point that involved considerable discussion by the peer reviewers was the uncertainty analysis undertaken in the technical studies. The *rules* allow for uncertainty to be determined as either high or low. While it was generally reported that the uncertainty associated with the vulnerability assessment or delineation of the *vulnerable areas* was acceptable for the intended purpose, there was a wide variation in what consultants viewed as a low level of uncertainty. The uncertainty reported in this report reflects that which has been identified in the technical reports. However, following the completion of the peer review of all of these studies, it has been suggested that the peer reviewers provide a relative comparison of the uncertainty of the projects so that a consistent interpretation between studies is available. This may result in changes to the uncertainty reported in this Assessment Report, which would be documented in a subsequent amendment to the Assessment Report.

4.2 Intake Protection Zones

An *Intake Protection Zone* (*IPZ*) is delineated around an intake in a surface water body. In the Upper Thames River Source Protection Area there are no surface water intakes. Although many of the municipalities in the region rely on surface water, the intakes are located in other Source Protection Areas.

4.3 Wellhead Protection Areas

Wellhead Protection Areas or *WHPAs*, as they are often referred to, are the *vulnerable areas* which are delineated around groundwater sources of drinking water. Wells are used to extract the water from aquifers in the ground where water is contained in spaces, voids or fractures in the soil or rocks. Often many wells are used in an area to extract sufficient water to supply the needs of the customers. Multiple wells in an area are often referred to as a wellfield.

A *WHPA* can be delineated through one of the methods identified in Rule 42:

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

In the Upper Thames River Source Protection Area, *WHPAs* have been delineated using computer based three-dimensional groundwater flow models as discussed in the Technical Studies section below. The models are used to calculate the time it takes for water to travel to the wells through the aquifer. For each well or wellfield, three areas are delineated based on the time of travel, while one is a fixed radius around the wells.

WHPA-A – 100 m fixed radius around each well
WHPA-B – 2 year time of travel to the well, excluding the area of WHPA-A
WHPA-C – 2 to 5 year time of travel to the well
WHPA-D – 5 to 25 year time of travel to the well

Two other *WHPAs (E* and *F)* can be delineated for wells which are under the direct influence of surface water (*Groundwater Under the Direct Influence* or *GUDI*). These are further described in Section 4.3.4.

4.3.1 Technical Studies

The models used to delineate the time of travel based zones were originally developed through the county groundwater studies. The models for the systems in the Upper Thames River Source Protection Area were developed in the Middlesex-Elgin Groundwater Study, Final Report, July 2004; Perth County Groundwater Study, Final Report April, 2003; Phase II Groundwater Protection Study County of Oxford, March, 2001. Through *MECP* technical studies the models were updated and refined by Dillon Consulting Limited as part of a project led by the City of London, Golder Associates Limited led by the County of Oxford and Schlumberger Water Services (Perth County) led by the Upper Thames River Conservation Authority and Lotowater Technical Services Incorporated led by Thames Centre. Two *GUDI* system studies each were led by the County of Oxford and the St. Clair Region Conservation Authority (SCRCA). Dillon Consulting Limited carried out the work for these two studies. The third *GUDI* study was conducted by the Upper Thames River Conservation Authority. The final draft vulnerability reports are listed in Table 4-1 below.

Table 4-1 Summary of Technical Reports for UTR Municipal Systems

Report Reference	Consultant	Date	UTR Groundwater Intake Municipal Systems
London, Middlesex Centre & Thames Centre Wellfield Source Protection Study Vulnerability Assessment Report	Dillon Consulting Limited	October 2009	Birr, London Back up wells (Fanshawe and Hyde Park), Melrose
London, Middlesex Centre & Thames Centre Wellfield Source Protection Study Vulnerability Assessment Report: Thorndale and Dorchester	Dillon Consulting Limited	March 2010	Dorchester and Thorndale
Source Protection Technical Studies - Report on the Groundwater Vulnerability Assessment for the Wellhead Protection Areas in the County of Oxford	County of Oxford	April 2011	Beachville, Embro, Hickson, Ingersoll, Innerkip, Lakeside, Mount Elgin, Tavistock, Thamesford and Woodstock
Vulnerability Assessment - Perth County Municipal Drinking Water Systems	Schlumberger Water Services	March 2010	Mitchell, Sebringville, Shakespeare, St. Pauls, St. Marys and Stratford
Town of St. Marys Wellhead Protection Area Modelling: Draft Calibration and WHPA Delineation Technical Memorandum	Schlumberger Water Services	July 2010	St. Marys
St. Marys Well 1 WHPA E Delineation Draft	Upper Thames River Conservation Authority	April 2011	St. Marys (*GUDI* study)
WHPA-E Delineation and Vulnerability Assessment – Thamesford, Woodstock and Tillsonburg Municipal Water Supplies.	Dillon Consulting Limited	May 2011	Thamesford and Woodstock (*GUDI* study)
WHPA-E and F Delineation and Vulnerability Assessment – Dorchester, Fanshawe and St. Marys Municipal Water Supplies.	Dillon Consulting Limited	May 2011	Dorchester, Fanshawe and St. Marys (*GUDI* study)

Through the peer review of the Perth study (SWS, 2010) it was identified that the uncertainty associated with the St. Marys WHPA was too great to rely on for Source Protection Planning. A single layer model, originally developed by International Water Consultants in 2002, had been used in the subsequent studies for delineation of time of travel based capture zones. The SWS work utilized the same model; however the pumping rates were altered. Although this model was conservative, there was a concern that it may be overly conservative. The Town and the

Source Protection Committee agreed that it was necessary to improve the understanding of the hydrogeology of the area. As a result, Schlumberger Water Services (SWS) was retained by the town to refine the conceptual understanding and develop a numerical model which could be used to delineate the WHPAs for the St. Marys system (Town of St. Marys Wellhead Protection Area Modelling- Conceptual Model Report, SWS, May, 2010). Schlumberger compiled groundwater investigation reports and data from the area, and consulted with other researchers who were working in the area. This information was used to develop a conceptual model which was peer reviewed prior to the completion of computer modelling. Results from the model were discussed with the peer reviewers and scenarios were developed to explore the uncertainties in the delineation of the WHPA. The scenarios were assessed to ensure that they were equally likely through the use of the calibration statistics. Due to the uncertainty associated with this fractured rock aquifer, these scenarios were included in the delineation of the WHPA. Those scenarios which resulted in a significantly poorer calibration were not included in the WHPA delineation. This results in the reasonably conservative WHPA shown in Map 4-1-21. The consultants, peer reviewers, project team, and Source Protection Committee are satisfied that this WHPA is adequate for the purposes of Source Protection Planning.

The Thames Centre systems in Dorchester and Thorndale also were the subject of additional study. Since the Thorndale modelling was completed in the original Middlesex-Elgin Groundwater Study completed by Dillon and Golder Associates, 2004 report, the municipality has progressed with providing municipal water to the rest of the village and an additional subdivision is currently under development. This has significantly increased the future pumping rates used for the previous modelling. The March 2010 report noted above includes the results from re-running the model based on new forecasts for future water needs. Dorchester was also the subject of refined estimates of future water use as well as modelling refinements through an external peer review undertaken (Frind and Associates, 2008).

Planned wells in existing systems in Woodstock and Mount Elgin were considered through updated modelling undertaken by Golder Associates (April 2011) following well tests undertaken on these planned wells. Previous models were updated to include the additional well and appropriate changes to planned pumping rates.

4.3.2 WHPA-A

WHPA-A is a fixed 100 metre radius around the well(s) and is not a function of modelling. Locations of the wells were confirmed with the municipality and compared against orthographic imagery. A circle with a 100 m radius was delineated around the well using Geographic Information System (GIS) tools. This zone is shown with the other parts of the *WHPAs* in Maps 4-1-1 to 4-1-23.

4.3.3 WHPA-B, WHPA-C and WHPA-D

The *WHPAs* in the Upper Thames River Source Protection Area were delineated with computer models as discussed earlier in the technical studies section. This work involved the development of a conceptual groundwater flow model based on current understanding of the local groundwater flow conditions and the aquifer properties. The aquifer locations and extents are conceptualized at this stage. A computer model was then developed based on the conceptual understanding. United States Geologic Survey (*USGS*) *MODFLOW* numerical groundwater flow model was developed through previous studies (Middlesex-Elgin Groundwater Study (2004), Perth County Groundwater Study (2003), and the Phase II Groundwater Protection Study, County of Oxford (2001)). Additional refinement of the modelling has been completed on many of the systems since these investigations were completed. Any new or proposed wells within the existing systems were added to those models. The models were calibrated and *MODPATH* was used to simulate particle movement in the capture zones. These results were used to determine the extent of the travel time based *WHPA*. This estimates the horizontal travel time (within the aquifer) to the well. The model is run in reverse to determine where particles arriving at the well within the specified travel time could have originated.

The *WHPAs* in the Upper Thames River Source Protection Area are illustrated in Maps 4-1-1 to 4-1-23.

4.3.4 WHPA-E and WHPA-F

Two other *WHPAs (E* and *F)* can be delineated for wells which are under the direct influence of surface water (*Groundwater Under the Direct Influence* or *GUDI*). There are *GUDI* wells in Dorchester; Thamesford; Woodstock; and St. Marys. Systems were previously assessed through requirements of the Safe Drinking Water Act, 2002 (subsection 2(2) of O. Reg. 170/03) to determine if they are *GUDI*. Operators of systems that are designated as *GUDI* are required to determine if there are surface water bodies or water courses which can deliver surface water to the well, effectively short circuiting the natural protection assessed in the vulnerability assessment. Should a surface water system influence effectively bypass the aquifer's protection, a *WHPA-E* must be delineated. Rule 49(3) states that a *WHPA-E* is to be defined if the interaction between surface water and groundwater has the effect of decreasing the time of travel of water to the well when compared to the time it would take water to travel to the well if the raw water supply for the well was not under the direct influence of surface water.

Rule 50 (1), (2) and (3) require that *WHPA-F* be delineated if a *WHPA-E* is delineated, and the well is subject to *issues* (known to be partially or wholly due to anthropogenic causes), which originate from outside the other parts of the *WHPA*. *Issues* are discussed in Section 5 – Issues Evaluation.

The work on *GUDI* systems has been undertaken in the Thames-Sydenham and Region Source Protection Region. The systems outlined in Table 4-2 are included in this project. Additional work is planned for the First Nations *GUDI* system in the Lower Thames Valley SPA.

Table 4-2 Thames-Sydenham and Region GUDI wells

GUDI wells in the Upper Thames River Source Protection Area (UTRSPA)	
Middlesex systems	Dorchester (overburden wells 2PW-1, 3PW-1, 3PW-2B, 3PW-4A, 3PW7 and 3PW-8)
Oxford systems	Thamesford Wells 1 and 2 (often referred to as overburden wells or River Wells)
	Woodstock (Wells 1, 2, 3, 4, 5, 8 - Thornton and Tabor wellfields)
Town of St. Marys system	St. Marys (Wells 1 and 3)

The *WHPA-E* represents the extent of influence of a surface water feature on the affected well. According to Technical Rule 47 (5), the *WHPA-E* is delineated as an *Intake Protection Zone-2* (*IPZ-2*) as if the intake was located at the point where surface water would flow into the groundwater (i.e. the point of interaction). In the event that the point of interaction is not known, the closest point in the surface water body to the well is used.

A general description of the *WHPA-E* delineation methodology in the Upper Thames River SPA is provided below, followed by system specific information. Vulnerability scoring for *GUDI* systems is described in Section 4.3.5.

As per Rules 65 and 66, *WHPA-E* is the area within each surface water body that contributes water to the intake based on a surface water travel time of at least two hours, and a certain setback where it abuts land. The distance that *WHPA-E* extends upstream from the point of groundwater and surface water interaction depends on the time it takes for the drinking water treatment plant operators to respond to an adverse condition or emergency (such as a spill). The Technical Rule 66 requires that a minimum of two hours be used as the response time. Discussions with the *GUDI* system operators determined that a longer time was not required. As such, a 2 hour travel time was used to delineate *WHPA-E*. The travel time was estimated using stream velocity at bank full stage. It is widely accepted that bank full stage can be approximated by a 2 year return flow, but can vary dependent upon the nature of the watercourse from less than the two year flow, to as high as the five year flow.

Where the delineation abutted land, as per Rule 65 (1) for *IPZ-2* delineation, it was delineated to a setback of 120 meters (measured to the high water mark of the surface water body) or the Conservation Authority Regulatory Limit (for floodplains), or the greater of the two. Further, the *WHPA-E* was extended to include areas that contribute water to *WHPA-E* through a natural or anthropogenic pathway, as per Rules 72 and 73. Transport pathways are typically any structure, land alteration or condition resulting from naturally occurring process or human activity which would increase the probability of a contaminant reaching a drinking water source. Transport Pathways include tile drainage and other drainage works. Parcels immediately adjacent to watercourse buffers and regulated areas have been considered in the *WHPA-E* delineation, and not included in the WHPA-E unless they are believed to be connected due to transport pathways (tile drainage). These parcels have been trimmed to the subwatershed boundary outside of which water is assumed to be directed away from the intake. Also, storm sewersheds which outlet into the *WHPA-E* were included within the *WHPA-E* (within the 2 hour travel time to the intake), as per Rule 65 (2). This is due to their direct connection to a watercourse by storm sewers. The storm sewershed is the catchment area drained by the storm sewer.

The delineation and the assigning of vulnerability scores are influenced by the type of intake. Type C intakes are located in rivers and neither the direction nor the flow of water at the intake is affected by a water impoundment structure. Type D is an intake not already defined by the other Types, for example, an inland lake. In the Thames-Sydenham and Region the *GUDI* wells are considered Type C or D intakes as per the Technical Rules.

According to Rule 47 (6), the *WHPA-F* is delineated as an *Intake Protection Zone-3* (*IPZ-3*), as if the intake were located at the nearest point to the well in the surface water body. As per Rule 70, the *IPZ-3* is composed of the area within each surface water body that may contribute water to the intake, and a setback on land. This setback is 120 meters (measured to the high water mark of the surface water body) or the Conservation Authority Regulatory Limit (for floodplains), or the greater of the two. As mentioned earlier, *WHPA-F* is only delineated if the well is subject to *issues* (known to be partially or wholly due to anthropogenic causes), which originate from outside the other parts of the *WHPA*.

A description of the delineation methodology specific to each *GUDI* system in the Upper Thames River SPA is provided below. Vulnerability scoring for *GUDI* systems is described in Section 4.3.5.

Dorchester *WHPA-E*

The Dorchester system, operated by the Municipality of Thames Centre, consists of nine wells of which six are *GUDI* (wells 2PW-1, 3PW-1, 3PW-2B, 3PW-4A, 3PW7 and 3PW-8). The wells are located in Dorchester, east of Dorchester Road and south of Byron Avenue. Several surface water bodies are present in the area and include Big Swamp Drain, Tap Municipal Drain and Lawton Drain. They combine and discharge into the South Thames River via an outlet from the Dorchester Mill Pond. The Dorchester Swamp, which discharges into these drains, is a predominant feature in the wellhead protection areas.

Intake Type

The delineation of *WHPA-E*, conducted by Dillon Consulting Limited, is based on the locations of the nearest surface water body to the wells, and an intake Type C (located in a river and neither the direction nor the flow of water at the intake is affected by a water impoundment structure). Based on available information, the Dorchester wells were projected to the Big Swamp Drain. These well projections were used as the 'surrogate' intake locations for the *WHPA-E* delineation.

Extent up Surface Water Bodies

In order to delineate the area within the Big Swamp Drain and its tributaries that may contribute water to the well's closest in-stream point within a 2 hour travel time, hydrologic and hydraulic analyses as well as a field trip were conducted. There was no model available for the Big Swamp Drain to simulate hydrologic and hydraulic analyses. Therefore, for the hydrologic analysis, empirical equations combined with a field visit were used to estimate the required 2-year flow. The Moin Index Flood Method (IFM) and the Primary Multiple Regression Method (PMRM) were used to calculate bankfull 2 year flow in the Big Swamp Drain and its tributaries (Lawton Drain, Tributary 'A' and Tap Drain). The more conservative flow (i.e. the larger flow) between IFM and PMRM methods was used for velocity, and eventually travel time analysis. For the hydraulic analysis, instream velocities were estimated by using Manning's Equation combined with the GIS data and field observations. Further, a field survey of the Big Swamp Drain and its tributaries was conducted in March 2011 by the consultant. For each cross-section of interest, the physical condition was noted and the bank and channel geometry was estimated, where possible.

Setbacks on Land, Storm Sewersheds and Transport Pathways

Where the delineation abutted land, it was truncated to the greater of either the setback of 120 meters (measured to the high water mark of the Big Swamp Drain) or the Conservation Authority Regulatory Limit. Further, the tile drainages, channels and ditches were examined for transport pathways. Tile drains and roadside ditches that can contribute water to *WHPA-E* within a 2 hour travel time were examined and included into the *WHPA-E* delineation where applicable. The available tile drain GIS layer did not include the outlets of the tiles, therefore an assumption was made that the tiles drain in the same direction as the general slope of the land. Tiles that touch the 120 m buffer or the Regulation Limits and located within 2 hour travel time from the intake were included in the *WHPA-E* delineation. A stormwatershed east of Oakwood Dr. is located very close to the Big Swamp Drain. However, based on the Dorchester stormwatershed map its outfall is downstream of the well projection, i.e. flows away from the 'surrogate' intake. Based on available information, no stormwatersheds were included in the delineation as transport pathways.

Final WHPA-E Delineation

The final delineation considers the local watershed boundaries, such that only areas that can contribute overland flow to the well are included in the delineation. The Dorchester *WHPA-E* is shown in **Map 4-1-2a**. Vulnerability Scoring is described in Section 4.3.5.

WHPA-F

As mentioned earlier, *WHPA-F* is only delineated if the well is subject to *issues* (known to be partially or wholly due to anthropogenic causes), which originate from outside *WHPA-A to E*. No *issues* were identified for the Dorchester well supply system. Therefore a *WHPA-F* was not required to be delineated.

Fanshawe *WHPA-E*

The Fanshawe wells were part of the City of London's back up water supply, which were decommissioned in 2019. Information regarding these wells has therefore been removed from this Assessment Report.

St. Marys *WHPA-E*

The Town of St. Marys wells consist of three pumping wells, two of which (Well 1 and Well 3) are identified as *GUDI*. Several surface water features including Skinner, Sheldon, Rolston and Waghorn Drains, Trout Creek, Otter Creek and the Thames River cross the St. Marys *WHPAs*.

Intake Type

The intake type is based on the location of the nearest surface water body to the wells. Well 1 is adjacent to Trout Creek and Well 3 is adjacent to the North Thames River. As such an intake Type C (located in a river and neither the direction nor the flow of water at the intake is affected by a water impoundment structure) was used to determine the appropriate rules to apply to the delineation of *WHPA-E* for both wells.

The delineation of that portion of the *WHPA-E* related to the St. Marys Well 1 was completed by the Upper Thames River Conservation Authority (with input from Schlumberger Water Services (SWS)), while the delineation of that portion of the *WHPA-E* related to Well 3 was completed by Dillon Consulting Limited in a separate study. Both studies included work on the *WHPA-E* extent up surface water bodies, setbacks on land, transport pathways and storm sewersheds. The final delineation of *WHPA-E* for the St. Marys *GUDI* wells incorporates the delineations from both studies.

St. Marys Well 3 was projected to the nearest water body, the North Thames River. This point was used as the surrogate for an intake and the *WHPA-E* was delineated from this point. Well 1 was the subject of previous investigations to determine the location of surface water interaction. In the past, the river reach within the general vicinity of the well was the subject of investigation and exploration to locate a point of interaction without success. These well projections which were used to determine the surrogate intake location would have been in the area where the past investigation did not identify a pathway or other interaction point. As such additional work was undertaken by SWS to identify the area within which it is likely that the interaction could occur. This area of potential interaction was used to delineate the *WHPA-E*.

Extent up Surface Water Bodies

The area within the surface water bodies and their tributaries that may contribute water to the surrogate intake was based on a 2 hour time of travel.

a) Delineation of the WHPA-E extent up Trout Creek and its tributaries

The interaction of the surface and groundwater in the St. Marys Well 1 has been the subject of much investigation in the past. This previous exploration focused on trying to locate a potential transport pathway in or near the watercourse in the vicinity of the well. The cause of this interaction or the location at which the interaction occurs could not be determined.

According to the Technical Rules, in the event that the point of interaction is not known, the closest point in the water body to the well is to be used. This would establish the point within the area of the previous investigation. In 2007, Schlumberger Water Services (SWS) conducted a study to determine the area within which it is likely for the point of interaction to occur. This area was called the zone of potential groundwater/surface water interaction. It was determined by comparing surface water elevation levels and groundwater hydraulic heads. If the water elevation in the stream was higher than the hydraulic head in the groundwater at the interface, then it was concluded that water moved from the stream into the groundwater. Stream elevation and bedrock groundwater equipotential maps were examined. Based on review of the available data, a reach along Trout Creek was identified to likely contribute surface water to the groundwater system, and then subsequently to Well 1. Therefore the zone of interaction included Trout Creek and overbank areas a few kilometers upstream of Well 1, and a few hundred meters downstream of this well. In other words, the upper end of the zone of interaction occurs approximately where 14 Line crosses Trout Creek, and the lower end occurs approximately where Church Street North crosses Trout Creek. The SWS study showed that the interaction could be significantly more removed from the well than the nearest point to the well in the water body. As a result it was determined that the *WHPA-E* should be delineated upstream from the zone of potential groundwater/surface water interaction and include the zone of potential interaction. This provided a conservative, but reasonable start for the travel time determination.

The UTRCA conducted the remaining work to delineate the Well 1 *WHPA-E* portion. A 2 hour time of travel up Trout Creek was estimated using Wildwood Dam discharge and stream guage data, as well as HEC-RAS model output. The Wildwood Dam discharges to Trout Creek upstream of the upper end of the zone of interaction (near 14 Line), and upstream of the St. Marys Well 1. There is a stream gauge on Trout Creek at the upper end of the zone of potential interaction near 14 Line, and another stream guage downstream of the confluence of Trout Creek and the North Thames River (but upstream of the Well 3). By examining flows at these two guage stations after Wildwood Dam operations, it was concluded that discharges from the dam occur well within the 2 hour time of travel from the zone of interaction. While this analysis was not performed for bankfull conditions, the discharge volumes are high enough that it is reasonable to arrive at the same conclusion if 2 year flow bankfull conditions were considered. Similarly, by examining the velocities produced by the HEC-RAS model of Trout Creek between Wildwood Dam and the confluence with the North Thames River, it was found that the 2 hour travel time for a 2 year flow from the outlet of the dam is well into the zone of potential interaction. The residence time of Wildwood reservoir is much greater than 2 hours, being in the order of days. Thus any potential contamination occurring upstream of the dam could not make it to the zone of interaction within the prescribed 2 hour limit. It was therefore concluded that the entire length of Trout Creek downstream of Wildwood Dam be included in the *WHPA-E* of St. Marys Well 1.

A 2 hour time of travel up the smaller tributaries that feed Trout Creek was estimated using Manning's equation. This equation was used to calculate velocities and therefore travel times based on the lengths of the tributaries. Cross sections and channel slope are taken from Ontario Base Mapping, and the depth of water in the channel is assumed to be equal to the bank elevation of the most upstream cross section for bankfull flow, based on observed local conditions. Cross sections are assumed to be trapezoidal, with stream widths estimated from aerial photography. Stretches of Birches Creek and Ralston Drain, as well as stretches up tributaries to Birches Creek were included in the delineation. The stretches of Birch Creek tributaries beyond the 2 hour travel time were excluded. The travel time of an unnamed tributary which enters the Trout Creek from the north to the zone of potential interaction was estimated to be approximately half an hour. As the hydrology is quite similar in other areas of this subwatershed below Wildwood Dam, and because the travel distances for other tributaries to the zone of potential interaction are shorter, it was concluded that all additional tributaries, aside from the previously discussed Birches Creek and Ralston Drain, are within the 2 hour time of travel.

b) Delineation of the WHPA-E extent up North Thames River and its tributaries

In order to delineate the area within the surface water bodies and their tributaries that may contribute water to the respective well's closest in-stream point within the 2 hour time of travel, hydrologic and hydraulic analyses as well as a field trip were conducted. The hydrologic analysis helps to estimate a 2 year flow or, as it commonly referred to, bank full discharge. The 2 year flow in the North Thames River and flow change locations along the North Thames River were gathered from the HEC-RAS model calibrated and used by the Upper Thames River Conservation Authority (UTRCA) for flood plain mapping of the area. For small tributaries and for reaches where the existing model did not provide coverage, these empirical equations were used: Moin Index Flood Method (IFM) and the Primary Multiple Regression Method (PMRM) to determine the 2 year flow. The more conservative flow (i.e. the larger flow) between IFM and PMRM methods was used for velocity, and eventually travel time analysis. For the hydraulic analysis of the North Thames River, the HEC-RAS model was used to estimate flow velocities. For the hydraulic analysis of the smaller tributaries, instream velocities were estimated by using Manning's Equation combined with the GIS data and field observations. A tributary field survey was conducted in March 2011 by the consultant. For each cross-section of interest, the physical condition was noted and the bank and channel geometry was estimated, where possible. The 2 year flow velocities were calculated for Otter Creek, Flat Creek, Tributary A, Avon River and Tributary B.

Setbacks on Land, Storm Sewersheds and Transport Pathways

Similar methodologies were used in both studies to determine setbacks on land and extensions to include transport pathways and storm sewersheds. Where the delineation abutted land, it was truncated to the greater of either the setback of 120 meters (measured to the high water mark of the North Thames River, Trout Creek and their tributaries) or the Conservation Authority Regulatory Limit. A number of stormwater outfalls are located in close proximity to the St. Marys wells, and several outlet to Trout Creek within the zone of potential interaction for Well 1. Travel velocities within urbanized areas with sewersheds can be relatively high due to surface grading and storm sewer conveyance. Based on the analysis of available data, all St. Marys stormwatersheds with outfalls upstream of the Well 3, and both upstream and downstream of Well 1 on Trout Creek were included in *WHPA-E*. This results in an overlap of areas around the confluence of the North Thames River and Trout Creek.

Further, tile drainage, channels and ditches were examined for transport pathways. Tile drains and roadside ditches that can contribute water to *WHPA-E* within a 2 hour travel time were examined and included into the *WHPA-E* delineation where applicable. The available tile drain GIS layer did not include the outlets of the tiles, therefore an assumption was made that the tiles drain in the same direction as the general slope of the land. Tiles that touch the 120 m buffer or the Regulation Limits and located within 2 hour travel time from the intake were included in the *WHPA-E* delineation.

While valley slopes and flood plain areas drain directly to the watercourses, wetlands should be screened to determine if they are connected either by natural or anthropogenic transport pathways. There are 2 such wetland areas within the study area. One is at the headwaters of both a watercourse which drains south to Trout creek, and a second watercourse which drains to Wildwood Reservoir. The area draining to Wildwood Reservoir is beyond the area which could flow to the zone of interaction within the 2 hour operator response time. Therefore the part of this wetland area draining to Wildwood Reservoir has been trimmed from the area to be included in *WHPA-E* using catchment areas available with the watercourse information. The other area is between Birches Creek and a tributary north of Birches Creek. Review of the tile drainage information indicates that part of this area is tile drained. The entire area is included in the *WHPA-E*.

Final WHPA-E Delineation

The final delineation considers the local watershed boundaries, such that only areas that can contribute overland flow to the well are included in the delineation. The St. Marys *WHPA-E* is shown in **Map 4-1-21a**. Vulnerability Scoring is described in Section 4.3.5.

WHPA-F

As mentioned earlier, *WHPA-F* is only delineated if the well is subject to *issues* (known to be partially or wholly due to anthropogenic causes), which originate from outside *WHPA-A to E*. No *issues* were identified for the St. Marys well supply system. Therefore a *WHPA-F* was not required to be delineated.

Thamesford *WHPA-E*

The Thamesford well supply system is comprised of 3 wells located near County Road No. 19, north and south of the Canadian Pacific Railway alignment. Two of the wells, Well 1 and Well 2 are classified as *GUDI* wells. Both wells pump water from an alluvial sand and gravel unconfined aquifer. Below the alluvial aquifer are silty tills, which overlay the bedrock limestone aquifer. Both wells are located near the Middle Thames River, with Well 1 and 2 being 20 m and 40 m south of the river, respectively. In addition to the river, there is a small tributary that flows into the Middle Thames River, and is within 70 m of the wells. Based on the close proximity of these wells to the river and their *GUDI* status, a *WHPA-E* is required.

Intake Type

The delineation of *WHPA-E*, conducted by Dillon Consulting Limited, is based on the locations of the nearest surface water body to the wells, and an intake Type C (located in a river and neither the direction nor the flow of water at the intake is affected by a water impoundment structure). Based on available information, the Thamesford wells 1 and 2 were projected to the nearest shore of the Middle Thames River. These well projections were used as the 'surrogate' intake locations for the *WHPA-E* delineation. In addition, the small tributary located around 70 m away from the wells was also considered as potentially having a hydraulic connection to the wells based on its close proximity.

Extent up Surface Water Bodies

In order to delineate the area within the Middle Thames River and its tributaries that may contribute water to the well's closest in-stream point within a 2 hour travel time (based on a 2 year bankfull flow), hydrologic and hydraulic analyses as well as a field trip were conducted.The travel time analysis for the Middle Thames River was completed using the HEC-RAS model (hydraulic analysis). For small tributaries and for reaches of the Middle Thames River not covered through HEC-RAS modeling, the travel time analysis (2-year flow) for was conducted using empirical equations (hydrologic analysis) combined with a field visit. The Moin Index Flood Method (IFM) and the Primary Multiple Regression Method (PMRM) were used to calculate bankfull 2 year flow in the Middle Thames River tributaries of Daymun Drain, George Roberts Drain, Arthur Vanatter Drain, 12th Concession Drain, Mcdonald Drain, Nissouri Creek and the watercourse just southwest of Wells 1 and 2. The more conservative flow (i.e. the larger flow) between IFM and PMRM methods was used for velocity, and eventually travel time analysis. For the hydraulic analysis, instream velocities were estimated by using Manning's Equation combined with the GIS data and field observations. Further, a field survey of the Middle Thames River and its tributaries was conducted in March 2011 by the consultant. For each cross-section of interest, the physical condition was noted and the bank and channel geometry was estimated, where possible.

Setbacks on Land, Storm Sewersheds and Transport Pathways

Where the delineation abutted land, it was truncated to the greater of either the setback of 120 meters (measured to the high water mark of the Middle Thames River) or the Conservation Authority Regulatory Limit. Further, the tile drainages, channels and ditches were examined for transport pathways. Tile drains and roadside ditches that can contribute water to *WHPA-E* within a 2 hour travel time were examined and included into the *WHPA-E* delineation where applicable. The available tile drain GIS layer did not include the outlets of the tiles, therefore an assumption was made that the tiles drain in the same direction as the general slope of the land. Tiles that touch the 120 m buffer or the Regulation Limits and located within 2 hour travel time from the intake were included in the *WHPA-E* delineation. Based on available information, no stormwatersheds were included in the delineation as transport pathways.

Final WHPA-E Delineation

The final delineation considers the local watershed boundaries, such that only areas that can contribute overland flow to the well are included in the delineation. The Thamesford *WHPA-E* is shown in **Map 4-1-16a**. Vulnerability Scoring is described in Section 4.3.5.

WHPA-F

As mentioned earlier, *WHPA-F* is only delineated if the well is subject to *issues* (known to be partially or wholly due to anthropogenic causes), which originate from outside *WHPA-A to E*. The only *issue* identified for the Thamesford well supply system (manganese) is naturally occurring (see Section 5). No other *issues* were identified for this system. Therefore a *WHPA-F* was not required to be delineated.

Woodstock *WHPA-E*

The water supply for Woodstock is predominantly supplied by the Thornton and Tabor rural wellfields, which are located east and southeast of the community of Sweaburg. Wells 1, 3, 5 and 8 of the Thornton wellfield and Wells 2 and 4 of the Tabor wellfield have been designated as *GUDI* wells. nitrate has been identified as an anthropogenic raw water quality issue for both the Thornton and Tabor systems.

The Thornton Wells 1, 3, 5 and 8 draw water from a sand and gravel unconfined aquifer. The pumping test conducted during the *GUDI* study identified a strong hydraulic connection between the aquifer and the local wetland. During periods of pumping, the water table fell below the ground surface resulting in a predominant downward movement of groundwater flow. When the pumping of the well field was stopped, springs and localized ponding occurred, as the groundwater levels rose above the ground surface in some areas.

The Tabor Wells 2 and 4 also draw water from a sand and gravel unconfined aquifer. Water level data suggests a predominant downward movement of groundwater flow.

Intake Type

The delineation of *WHPA-E*, conducted by Dillon Consulting Limited, is based on the locations of the nearest surface water body to the wells, and the intake type. For the purpose of the *WHPA-E* delineation, the Thornton and Tabor *GUDI* wells are classified as a Type D (inland lakes) surface water intake. A Type D designation is deemed appropriate as both wellfields are near the Sweaburg Wetland.

Extent up Surface Water Bodies

The *WHPA-E* delineations are completed separately for the two wellfields of Thornton and Tabor.

The Thornton Wells 1, 3, 5 and 8 are located within 25 to 100 m of a wetland and other surface water bearing features such as creeks, ditches and ponds. Two waterbodies were identified as potential areas of groundwater-surface water interactions: a Cedar Creek tributary and the Sweaburg wetland. Through field investigations, previous reports and communications with various technical staff, a creek running between Wells 1 and 5, a ditch near Well 1, and a pond close to Well 3 were identified and included in the *WHPA-E* delineation. During the field visit, it was confirmed that there is no surface water flow from the adjacent wetlands (which is down slope of the wellfield) to the wells. Rather, surface water flow is away from the wells, towards the wetland. Based on this information, the Sweaburg wetland is not expected to decrease the time of travel for surface water to migrate to the well, and it was not included in the delineation.

For the Tabor Wells 2 and 4, two waterbodies were identified as potential areas of groundwater-surface water interactions: a ditch along Cedar Line that is part of a tributary fed by two ponds (located 0.5 to 1 km south of the wellfield), and a small creek near Well 2 that seems to be spring-fed. During a field survey conducted to investigate these waterbodies, the ditch (along the west of Cedar Line), ponds (south of Wells 2 and 4) and a small creek (near Well 2 that discharges to a ditch along River Road) were identified and included in the *WHPA-E* delineation.

Setbacks on Land, Storm Sewersheds and Transport Pathways

Where the delineation abutted land, the Thornton *WHPA-E* was truncated to a setback of 120 meters, measured to the high water mark of the creek, ditch and pond located near Thornton Well 3. The west side of Sweaburg Road is downstream of the wells and therefore *WHPA-E* was clipped to the east side of the road. This assumption is supported by observed direction of flow in the creek during the field visit.

Based on available information, no tile drained areas or stormwatersheds were included in the Thornton *WHPA-E* delineation as transport pathways.

Where the delineation abutted land, the Tabor *WHPA-E* was truncated to a setback of 120 meters, measured to the high water mark of the tributary, two ponds and the small creek. Cedar Line is a local watershed boundary, and therefore *WHPA-E* was clipped to the road on the west side. This assumption is supported by observed direction of flow in a culvert across Cedar Line, during the field visit.

Based on available information, no tile drained areas or stormwatersheds were included in the Tabor *WHPA-E* delineation as transport pathways.

Final WHPA-E Delineation

The final delineation considers the local watershed boundaries, such that only areas that can contribute overland flow to the well are included in the delineation. The Thornton and Tabor *WHPA-Es* are shown in **Map 4-1-17a**. Vulnerability Scoring is described in Section 4.3.5.

WHPA-F

As mentioned earlier, *WHPA-F* is only delineated if the well is subject to *issues* (known to be partially or wholly due to anthropogenic causes), which originate from outside *WHPA-A to E*. Elevated nitrate levels are identified as an *issue* for the Woodstock-rural well supply system (see Section 5). Information from the University of Waterloo suggests that the nitrate may have originated from surface runoff of adjacent farm fields, and infiltrated into the aquifer. Since the nitrate originates from areas within the *WHPA-A* to *E*, a *WHPA-F* was not required to be delineated.

4.3.5 Vulnerability Assessment of the WHPA

Within the *WHPA-A to D* zones, the vulnerability must be assessed using one of the four methods described in Rule 37 of the *Technical Rules 2013: Assessment Report*:

- *Intrinsic susceptibility index* (*ISI*).
- Aquifer vulnerability index (*AVI*).
- Surface to aquifer advection time (*SAAT*).
- *Surface to well advection time* (*SWAT*).

Rule 15.1 also allows the use of a method which is equivalent or better than these methods provided the reason for the use of this method is documented in the Assessment Report and the Director has provided approval for the use of the alternative method.

Three methods have been used to identify vulnerability in *WHPAs* in the UTRSPA. Intrinsic Susceptibility Index (*ISI*) was used for the vulnerability assessment in the municipal systems in Perth County and the City of London-Middlesex County. The County of Oxford used AVI methodology throughout most of the wells with the exception of SWAT that was used in Ingersoll and Woodstock systems.

The ISI and AVI methods are index methods based on the Ministry of the Environment, Conservation and Parks (*MECP*) Water Well Information System (*WWIS*) which contains borehole information collected at the time of the well construction. The MECP undertook a project to characterize the materials identified in this database so that a 'k' value can be assigned to each material identified in the well log. The 'k' value is then multiplied by the thickness of the material in metres and summed over the depth to the aquifer of interest or the water table. The main difference between the ISI approach and AVI method is that the ISI method takes into account the location of the water table. Therefore, in order to apply the ISI method the water table must be calculated, if this has not previously been done. In the AVI method, the scores are summed to the aquifer. The sum results in a score which is then categorized as high, medium or low as identified in Rule 38 (1). The *ISI and AVI* of the Study *Wellhead Protection Areas* are shown for Middlesex in Maps 4-1-1 through 4-1-7; Oxford 4-1-8 through 4-1-17; and Perth 4-1-18 through 4-1-23. The AVI of the Oxford Study Wellhead Protection Area is shown in Maps 4-1-8 through 4-1-10 and 4-1-12 through 4-1-16.

Professional judgement had a wider degree of variability throughout the various studies and is difficult to summarize in general. The actual studies should be reviewed for more clarification but examples of the rationale are included below. Rationale for decisions using professional judgement included the utilization of cross-sections throughout the wellfield to identify the production aquifer, calculating ISI / AVI scores to the production aquifer, hand contouring to allow interpretation of the hydrogeology and to exclude outliers rather than utilizing computer algorithms. For the uncertainty, a low uncertainty was sometimes assigned to areas, where the underlying ISI / AVI value was clearly within the class boundaries and a high uncertainty, where the ISI / AVI value was close to the class limit. For example, if a vulnerability value is based on a value of 150, it is very unlikely that changing the input parameters for the calculated value would result in an ISI of lower than 80, thus changing the vulnerability class. In areas where the ISI / AVI appeared to be a function of a computer algorithm or poor well log, professional judgement was used either to include or exclude a data point. In general, a conservative approach was incorporated during this review.

As part of an MECP pilot project, the County of Oxford was selected to receive funding to complete a Surface to Well Advection Time (*SWAT)* study to compare to previously completed vulnerability studies (AVI method) and further assess and delineate existing vulnerability in WHPA areas. WHPA *SWAT* is the time it takes for a particle of groundwater to move from the ground's surface to the well. The *SWAT* is comprised of two major components: (1) the time it takes for a particle to move from the ground's surface to the water table in the unsaturated zone (UZAT), and (2) the time it takes for a particle of water to move from the intersection of the water table to the well (WWAT). Two sites were selected for the pilot study to provide contrasting hydrogeological settings including an unconfined sand and gravel aquifer in Woodstock and a multi-aquifer bedrock supply well in Ingersoll. At Ingersoll and Woodstock, the *SWAT* methodology was used to assess the vulnerability of the municipal groundwater wells. A grid of particles to be released at the water table was established. Particles were spaced evenly apart in the area around each well. The travel time of each particle to move from its original position to the water table was then calculated, in order to determine WWAT. *WWIS* data was used for static water levels. UZAT is calculated by considering the depth to the water table, the moisture content and the infiltration rate.

Like the *ISI* and *AVI*, the *SWAT* is also categorized into high, medium, or low vulnerability. Travel time is represented in years and is mapped as: less than 5 years (high), 5 to 25 years (medium), or greater than 25 years (low). A *SWAT* of greater than 25 years represents a low intrinsic vulnerability. The vulnerability is illustrated for each system in the vulnerability maps in Appendix 1. The systems which were assessed using SWAT are illustrated in Maps 4-1-11 and 4-1-17.

Professional judgement is an accepted practice in the process and its documentation varied to some degree between studies. In some cases, systems were applied a low uncertainty because they were felt to be modelled using a consistent and well documented modelling procedure, based on sound hydrogeological interpretations and were considered as having a relatively low level of uncertainty. In many cases, professional judgement was evaluated on individual parameters - the reliability of the numerical model, for example input parameters such as the presence of data gaps, interpreted groundwater flow direction and on the WHPA size. Furthermore, the reliability of the model was judged on the presence of data gaps and on the calibration results. Some evaluations on WHPA uncertainty were based on the size of the WHPA. The rationale for larger size of WHPA is generally associated with a lower uncertainty, since even significant changes of the hydrogeologic parameters, such as conductivity or recharge, result in a relatively small percentage change of the size and shape of the respective WHPAs. The same input parameter changes applied to a small WHPA could however, change size and direction of the WHPA considerably. A high uncertainty therefore, was more associated with smaller WHPAs. For the London-Middlesex systems, there is considerable uncertainty in the recharge and hydraulic conductivity values used. For the Perth systems, all capture zones in fractured bedrock are considered to have high uncertainty. At Stratford, the uppermost bedrock zone is fractured and assigned a higher conductivity than the fresh bedrock below it. At St. Marys fractured bedrock layers were modelled with higher conductivity values. There is a higher uncertainty associated with hydraulic conductivity values and this uncertainty was considered in the WHPA delineation. Similary for the Oxford systems, uncertainty in bedrock fracture increased the uncertainty in hydraulic parameters. For the Oxford systems, in many cases the contact lines between areas of different vulnerability were irregular, and appeared to reflect the grid system and/or the interpolation algorithms associated with presenting the vulnerability information in a GIS system. Smoothing was done in an attempt to have the vulnerability contact lines reflect a more natural condition. For example, a 'saw-tooth' line contact was adjusted into a smooth line contact, similar to how the contacts are shown in geological and hydrogeological maps.

Adjustments to vulnerability to reflect transport pathways (*WHPA-A to D*)

Following the assessment of intrinsic vulnerability, information on constructed *transport pathways* is reviewed in order to examine whether an increase in the vulnerability score in the *WHPA-A to D* due to the presence of the *transport pathways* is needed. The discussion of transport pathways for *WHPA-E* (related to*GUDI* wells) are discussed separately in Section 4.3.4. *Transport pathways* are man-made constructions such as oil wells, pipelines or excavations that may circumvent the natural protective layers above a groundwater aquifer. While the Technical Rules 39-41 define the elements to be considered for increasing the vulnerability rating, they do not address the criteria that should be applied in order to increase the vulnerability. The Technical Rules do not clarify the area of influence of different types of transport pathways within which the vulnerability is to be increased. Some alternatives for considering transport pathways focus on the assumption that it is not the individual occurrence of a feature, but the increased density of the features in an area which affects the vulnerability. The vulnerability of the aquifer should only be increased in areas where the natural vulnerability is well understood and the potential characteristics of the transport pathways is such that an increase in aquifer vulnerability is likely to result due to a change from transport pathways. The methodology to reflect wells as transport pathways was applied slightly different in each of the studies and reflect the differences in the nature of the aquifers and the needs of the municipalities.

Modification of the groundwater vulnerability is performed by increasing the vulnerability of the underlying groundwater vulnerability map from either a low to moderate value, moderate to high value or low to high value. An initial groundwater vulnerability value of high cannot be increased.

The Thames-Sydenham and Region SPC proposed a standardized methodology (Approach to Consideration of Transport Pathways in the Vulnerability Assessment of Groundwater Based Vulnerable Areas, May 2009) for the recommended changes to groundwater vulnerability. One recommendation was that changes should be applied where the system operator is concerned about activities being undertaken in areas which could pose a higher risk to the system than reflected by the vulnerability assigned to the area in which the activity is occurring.

Factors such as hydrogeological conditions, type and nature of *transport pathways*, and cumulative impact of these pathways are considered. Water wells can be *transport pathways* if they are not properly constructed or maintained. An inventory of *transport pathways* was completed by the consultant and reviewed with the system operators. Within a zone of vulnerability, transport pathways such as abandoned wells or quarries can eliminate partially or entirely the protective layers above the aquifers and form a direct conduit between the ground surface and the aquifer. Such features were felt to significantly increase the vulnerability of a localized zone, and this should be reflected in the vulnerability assessment of the area. Identifying the locations of wells in WHPAs, assessing their current state, and properly decommissioning abandoned or poorly constructed wells would help to reduce the risk that these potential conduits pose to the groundwater system. The process is based on professional judgement. The uncertainty due to fracture in bedrock is considered in the WHPA delineation.

Middlesex Centre & Thames Centre Wellfields

Many of the identified *transport pathways* in London, Middlesex Centre & Thames Centre Wellfield Source Protection Study Vulnerability Assessment Report were not considered significant, as these features are of shallow construction relative to the thickness (30 to 50 m) of the clay till aquitard that overlies the pumped aquifer, or there were few transport pathways documented, or the area already had a high vulnerability and therefore could not be increased in vulnerability to reflect the *transport pathway*. *Transport pathways* in this study area that are deemed to penetrate into the aquifer include both potable water wells and oil and gas wells. The density of these wells appears to be low based on the available data, and therefore an increase in the vulnerability of the aquifer is not considered necessary. Potential areas that may warrant a vulnerability increase include former and current wellfields where the potential for yet to be discovered former wells exists.

For discussion purposes, systems with similar aquifers are summarized together with respect to transport pathways - bedrock (Thorndale), deeper overburden (Birr and Melrose) and shallow overburden aquifers (Dorchester).

Thorndale derives its drinking water from a bedrock aquifer. See Appendix 1 Map 4-1-7. The mapped extent of the area where *transport pathways* exist (which involved conservatively assigning a potential water well location at each developed property) is deemed conservative. Furthermore, the degree to which any *transport pathway* has on reducing the natural protection of the overlying aquitard is difficult to assess, mainly due to limited information on the geology of the area.

The rationale for the decision to leave the vulnerability unchanged for Thorndale was that there is already uncertainty associated with the prediction of the capture zones, and that this uncertainty is greater than the effect that transport pathways would have on the vulnerability evaluation. In addition, the only transport pathway type that would potentially be considered to increase the vulnerability would be private wells as these are the only features that would penetrate into the bedrock aquifer below. Most of the properties that may potentially use private wells, or may have abandoned wells on their premises, are those along Fairview and Thorndale Roads. The density of these properties over the entire capture zone is not high, and therefore the risk of significantly increasing the vulnerability of the aquifer is deemed low. Nevertheless, sporadic occurrences of *E. coli* and Total Coliforms have been detected in the raw water. The source of the impacts is not known; however, a report by Lotowater (2009) suggests that it is possible that these parameters may be introduced into the aquifer from any nearby poorly constructed wells. No data are available that indicate that the nearby private wells act as transport pathways; however, future actions such as inspections or sampling could be performed to determine if the local wells are a source of the coliform impacts. The significance of the *E. coli* and Total Coliform concentrations in the raw water is addressed in the Issues Evaluation assessment. More recent discussions with the municipality suggest that the possible pathway may have been eliminated through well decommissioning in the area, however a longer period of monitoring is necessary before the results can be considered conclusive.

Birr and Melrose derive their water from a deeper, confined, overburden aquifer. The decision was made to leave the vulnerability unchanged with respect to *transport pathways* for the above stated reasons and more specific rationale is included as follows. The decision to not modify the groundwater vulnerability based on the location of potential transport pathways both horizontal and vertical was confirmed through discussions with the municipality.

The community of **Birr** is supplied in part by one well that pumps from a confined overburden sand and gravel aquifer and was first developed in 1975. Eighteen lots along Gwendolyn Court are serviced by the municipal system**.** The remainder of the community is serviced by individual private wells. Several potential transport pathways were identified within the capture zones A to D. Areas where the likelihood of improperly abandoned wells is greatest are within *WHPA-A* which already received the highest vulnerability score. See Appendix 1 Map 4-1-1.

The community of **Kilworth-Komoka** was supplied by three wells that pump from a confined overburden sand and gravel aquifer. That well system was decommissioned in October 2010, and the community is now served by the Lake Huron Primary Water Supply System under the Middlesex Centre Distribution System.

The **London-Hyde Park and London-Fanshawe (backup wells)** were decommissioned in 2019 and the City of London is now served entirely by the Lake Huron Primary Water Supply System and the Elgin Area Primary Water Supply System.

The community of **Melrose** is supplied by two wells that pump from a confined overburden sand aquifer. See Appendix 1 Map 4-1-6. The system services a residential subdivision of 64 lots, occupied by approximately 224 residences. While it is possible that abandoned wells may exist along Vanneck Road in Melrose**,** the portion of this area that falls within the most sensitive zones (*WHPA - A* and *WHPA - B*) already is classed as highly vulnerable, and the vulnerability value cannot be increased. Septic systems are present on all developed lots within the capture zones; however, the relatively shallow depth (<1 m) would be insufficient to cause an increase in the groundwater vulnerability.

Dorchester has a shallow overburden aquifer. The vulnerability of this aquifer within the WHPA-A to D is already considered high.

The **Dorchester** system obtains water from nine production wells that pump from both a shallow unconfined sand and gravel aquifer and a deeper confined bedrock aquifer. See Appendix 1 Map 4-1-2. The wells are located in two wellfields. Well Field 2 consists of one production well. Well Field 3 consists of five overburden production wells and two bedrock production wells. The overburden groundwater supply is classified as being *GUDI* (Groundwater Under the Direct Influence of Surface Water) while the bedrock groundwater supply is classified as "groundwater" (i.e., non- *GUDI*). Even though there are numerous transport pathways within the Dorchester WHPA-A to D, the intrinsic vulnerability of the aquifer within these WHPA is already high. Therefore, the aquifer vulnerability cannot be increased, and the final aquifer vulnerability remains the same as the results of the initial groundwater vulnerability assessment. The transport pathways related to *GUDI* wells are described in Section 4.3.4.

Oxford Wellfields

The County of Oxford systems are comprised of deep bedrock wells (Beachville, Embro, Hickson, Ingersoll, Innerkip, Lakeside, and Mount Elgin), a combination of overburden and bedrock systems (Tavistock - intermediate overburden and bedrock; Thamesford shallow overburden and bedrock; and Woodstock with bedrock and shallow overburden wells). The County evaluated transport pathways by plotting well locations (based originally on the MECP Water Well Information System), information on the location of sanitary sewers, septic systems, storm water infiltration facilities, pits and quarries and the location of oil wells, within 100 m of WHPAs on maps and aerial photographs. The hydrogeologist retained for the study reviewed the maps and identified areas where the vulnerability scoring should be adjusted based on his professional judgement.

The **Beachville** water system is supplied by one bedrock production well with casing set to a depth of approximately 33 m and a total well depth of approximately 91 m. See Appendix 1 Map 4-1-8. The water system supplies a population of approximately 180. The Beachville well was incorporated into the Ingersoll Groundwater Model for the purpose of delineating the WHPA

(Golder Associates 2001). Potential transport pathways are mostly limited to the relatively high density of private wells and septic systems located along County Road No. 9 (Beachville Road). The vulnerability was already high within this area, so adjustments to the vulnerability mapping/scoring to account for the transport pathways were not necessary.

The **Embro** water system is supplied by two bedrock wells located near the pump house in the central part of the village. The wells are cased to depths of approximately 38 m and completed as open hole in the bedrock to depths of approximately 60 m. See Appendix 1 Map 4-1-9. The water system supplies a population of approximately 830. The water well records at the Embro well site indicate that the overburden sequence above bedrock consists mostly of low hydraulic conductivity deposits (described as clay, hardpan and till). Other than septic systems, there is no evidence of significant transport pathways within the WHPA and no adjustments to the vulnerability index mapping were made.

The **Hickson** water system services the King subdivision on the east side of the village and is supplied by one bedrock well. See Appendix 1 Map 4-1-10. The water system supplies a population of approximately 100. The Phase II Groundwater Protection Study (2001) report indicates that the well is cased to a depth of 33.5 m and completed as open hole to a depth of 53 m. The review of transport pathways information indicates that there are approximately 12 wells located in the 2 year TOT zone; the 2 year TOT extends through the centre of the village where there are numerous septic systems. As a result, the AVI vulnerability mapping across Zone B was increased from low to moderate, resulting in an increase in the intrinsic vulnerability score from 6 to 8 in Zone B. Vulnerability scores are 4 in Zone C and 2 in Zone D.

The **Ingersoll** water system is supplied by 7 bedrock production wells (**Wells 2, 3, 5, 7, 8, 10, 11**) each at a different location. See Appendix 1 Map 4-1-11. Well 8 is located in the northeast part of the town on the north side of the Thames River. The other wells are located south of the Thames River. The wells are cased to depths ranging from approximately 21 m (Well 3) to 60 m (Well 2). The depth to the bottom of the wells ranges from approximately 109 m (Well 5) to 140 m (Well 2). The water system supplies a population of approximately 13,600. According to the Phase II Groundwater Protection Study (2001), the groundwater model used to delineate the Ingersoll WHPA is based on a four-layer conceptual model with one overburden layer and three bedrock layers. The overburden layer is characterized in accordance with the lower hydraulic conductivity till units that occur over most of the model area, with some higher conductivity areas to account for the presence of glacial outwash and modern fluvial sediments in the vicinity of the Thames River. The WHPA for six of the seven Ingersoll wells show some overlap/interaction with one or more of the others. Adjustments to groundwater vulnerability due to transport pathways is shown in Appendix 1 Map 4-1-11. Transport pathways were considered for each of the WHPA as follows:

- The Phase II study also notes that the capture zone for **Well 2** is affected by two private industrial wells in the vicinity. An adjustment from low to medium vulnerability category was made in the west central portion of the WHPA (north side of Victoria Road/Road 60) to account for private wells (potential transport pathways) serving a settlement in that area (WHPA-D). An adjustment from low to medium vulnerability category was also made to account for private wells on Clarke Road (vicinity of Whiting Street) in the south part of the WHPA (WHPA-D, where it overlaps with the WHPA for Well 10).
- No adjustments were made for **Well 3** for transport pathways.
- A number of private wells exist within the WHPA for **Well 5**, based on information available from the water well record database. However, the number and density of wells were not considered sufficient to warrant an adjustment to account for potential transport pathways.
- No adjustments were made to the mapping for **Well 7** to account for transport pathways.
- An adjustment was made to the vulnerability mapping within the **Well 8** WHPA to account for the concentration of private wells on North Town Line Road as potential transport pathways. The adjustment results in a change in vulnerability score in WHPA-C from 2 to 6 (low to medium vulnerability category); and in WHPA-B the score has been adjusted from a 6 to an 8 (low to medium vulnerability category).
- The **Well 10** WHPA overlaps the portions of the WHPAs for Wells 2, 5 and 11. The adjustment in vulnerability category for potential transport pathways (private wells) on Clarke Road near Whiting Street (noted in the discussion above for Well 2) also applies to the WHPA for Well 10. The area affected by the adjustment for potential transport pathways includes portions of Well 10 WHPA-B, C and D, with a change of low to medium vulnerability in these zones. The resulting vulnerability scores for this area are 8

for the portion within WHPA-B, 6 for the portion within WHPA-C and 4 for the portion within WHPA-D. The remainder of WHPA-B and the other portions of WHPA-C and WHPA-D have vulnerability scores of 6.

- The WHPA for **Well 11** extends approximately 2.5 km to the southeast and is overlain in parts by the WHPAs for Well 3 and Well 10. No adjustments were made to the vulnerability mapping for transport pathways.

The **Innerkip** water system is supplied by two bedrock wells southwest of the village, on the east side of County Road 4. . See Appendix 1 Map 4-1-12. The water system supplies a population of approximately 950. Well 1 is cased to a depth of approximately 19 m with open hole in the bedrock to a depth of 34 metres. Well 2 is cased to a depth of approximately 16 m with open hole in the bedrock to a depth of 35 m. Potential transport pathways within the WHPAs appear to be limited to a few rural private wells and no adjustments to the mapping were made to account for these pathways.

The **Lakeside** water system is supplied by a bedrock well located on the east side of the community. See Appendix 1 Map 4-1-13. The water system supplies a population of approximately 310. The well is cased through a sequence of mainly fine-grained sediments to a depth of approximately 90 m, and completed as open hole in the bedrock to a depth of approximately 100 m. There appear to be few, if any, potential transport pathways in the WHPA.

The **Tavistock** water system is supplied by one overburden (Well 1) and two bedrock production wells (Well 2A, Well 3). See Appendix 1 Map 4-1-15. The water system supplies a population of approximately 2,660. The wells are located in close proximity to each other at a site near the water tower in the south-central part of the town. The overburden well is screened over a depth interval from approximately 16.5 – 19.5 m and is considered to be a completion in the intermediate aquifer. Well 2A is cased to a depth of 41 m and completed as an open well in bedrock to a depth of approximately 62 m. Well 3 is cased to a depth of approximately 35 m and completed as an open well in bedrock to a depth of approximately 48 m. Private wells occur within the WHPA, however, the number and location of the wells were not considered sufficient to warrant an adjustment to the vulnerability. The existing sewage lagoons were also not considered to be a transport pathway as it is understood that the lagoons are excavated no more than about 2 m below the surface, are lined with a clay barrier, and do not penetrate the confining till layer that overlies the intermediate overburden aquifer.

The **Thamesford** water system is supplied by one bedrock well (Well 3 – Stanley Street) and two overburden wells (Wells 1 and 2 - commonly referred to as the River Wells). See Appendix 1 Map 4-1-16. The water system supplies a population of approximately 2000. The bedrock well is located in the northwest part of the community; the overburden wells are located in the northeast part of the community, adjacent to the Thames River. The Stanley Street well is cased to a depth of approximately 25 m and completed as an open bedrock well to a depth of approximately 78 m. The overburden wells are completed in gravel and sand with screen depth settings from approximately 6 – 14 m below surface (shallow aquifer). Potential transport pathways within the WHPA appear to be limited to a few private wells. No adjustments were made to account for these pathways. The transport pathways related to *GUDI* wells are described in Section 4.3.4.

The **Mount Elgin** water system is supplied by one bedrock well (Well 3) and one planned well to come on line located on the north side of the village. See Appendix 1 Map 4-1-14. The water system supplies a population of approximately 370. Well 3 is cased to a depth of approximately 55 m and completed as an open hole in bedrock to a depth of 60 m. Well 5 is undergoing an evaluation for possible connection to the water system. A WHPA has been delineated and is included in the Assessment Report as a planned system. The remaining well (Well 6) will either be retained for monitoring purposes or decommissioned. The Mount Elgin WHPA is based on a forecast pumping rate of 176 m^3/day (2 L/s) and the two WHPAs extend approximately 6 km to the north of the well. The WHPA occurs mostly in a rural area and potential transport pathways appear to be limited to a few private wells. The Mount Elgin wells are completed in the upper bedrock. The available mapping indicates more than 30 m of overburden in the WHPA and most of this appears to be low permeability material (tills, etc.). The County of Oxford landfill is located within the 25 year time of travel for well 5 however the landfill excavation is shallow. Therefore, the landfill was not considered to be a transport pathway, with respect to the WHPA.

The water supply system serving the City of **Woodstock** and the community of Sweaburg is supplied by two major wellfields (Thornton and Tabor - wells 1-5, 8 & 11 and a planned well has been added) completed in the overburden aquifer system southwest of the City and three bedrock wells within the City (wells 6, 7, & 9). See Appendix 1 Map 4-1-17. The water system supplies a population of approximately 36,600. The Thornton and Tabor wells are completed in sand and gravel and screened between 13-32 m below the surface and the bedrock wells are open hole between 20-63 m below surface. Adjustments to the vulnerability mapping were made in three areas to account for *transport pathways*. These areas include:

- The sand/gravel pits located in WHPA-B of the well 2 and 4 of the Tabor wellfield: vulnerability categories were adjusted from medium to high, resulting in an increase in vulnerability score from 8 to 10
- The Village of Sweaburg was previously assessed to account for a higher density of existing private wells and septic systems in WHPA-B and C of the wells 1, 3, 5, 8 and 11 of the Thornton wellfield; vulnerability categories were adjusted from medium to high, resulting in an increase in vulnerability score from 8 to 10 and 6 to 8, however since the previous assessment most of the wells in this area have been decommissioned as part of an Oxford County project to service the village with municipal water, therefore only the properties which have private wells remaining on the property have had their vulnerability adjusted.
- The Pattulo Avenue/Greenly Line portion of WHPA-C and D from bedrock Well 9, to account for a high density of private wells; in WHPA-C, vulnerability categories were adjusted from low to medium, resulting in an increase in vulnerability score from 2 to 6, while in WHPA-D, vulnerability categories were adjusted from low to medium, resulting in an increase in vulnerability score from 2 to 4.

Perth Wellfields

Approximately 80% of the domestic and municipal wells in Perth County are deep bedrock wells with 30 to 50 m of overburden comprised of clay or clay till and limited areas of sand and gravel. All municipal systems in Perth County are developed in bedrock aquifers. The Perth County Groundwater Study (2003) identified abandoned wells as significant transport pathways and were identified as a 'threat' in the report (p.3-5). Due to the identified sensitivity of deep wells, the consultant identified non-municipal water wells in the WHPA as *transport pathways* and included a buffer around the pathway. Horizontal pathways or shallow wells were not identified as *transport pathways* as these features are believed to be shallow and are well separated from the aquifers supplying the municipal systems. The approach taken in the most recent study was to identify all non-municipal water wells within the WHPA and increase the vulnerability within a 50 m buffer by one level for wells reaching the same aquifer as the drinking water system. The buffer size has been chosen as half of the high vulnerability radius (WHPA-A) around the municipal wells. The buffer, based on the consultant's best professional judgement, may help offset well record location errors, and result in a closer look at the buffer area. Each occurrence of water wells within the 25-year capture zone was discussed with the well operator prior to increasing the vulnerability. This adjustment was supported by the Source Protection Committee who discussed the importance that private wells within the WHPA need to be properly constructed, well maintained and, if no longer needed, be properly decommissioned.

The **Mitchell** municipal wellfield is located in the Town of Mitchell. The water supply system is comprised of four wells, which supply water to a population of approximately 4,000 people. All four bedrock wells produce water from depths between 24 to 60 m. See Appendix 1 Map 4-1-18. Transport pathways were discussed with the well operator of the Mitchell well. Only one transport pathway was identified during this discussion, represented by a well, located in the WHPA-B of well 4. Upon further investigation, this well was found to be screened in the same aquifer as the municipal aquifer. As a result, the vulnerability of the well and a surrounding 50 m buffer (which overlaps WHPA-C also) was increased from low to a medium vulnerability, resulting in an increase in vulnerability score of 6 to 8 in WHPA-B, and 4 to 6 in WHPA-C.

The Town of **St. Marys** water supply is obtained from three groundwater wells referred to as Well Number 1, 2a, and 3 and services a population of approximately 6,200. The wells are completed in bedrock. The casing extends into bedrock to a depth of 12 to 18 m. They continue through the bedrock to a depth of between 45 and 47 m as open holes. See Appendix 1 Map 4-1-21. It was determined through previous work that the system is a *GUDI* system. The transport pathways related to *GUDI* wells are described in Section 4.3.4. The following were considered as transport pathways in WHPA-A to D:

- Monitoring wells are located within the WHPA-A (100 m radius) of well 1, however, the vulnerability is already high and cannot be increased.

- There are private wells within the WHPA-B, due to which an adjustment in vulnerability category was made from low to medium, resulting in an increase in vulnerability score from 6 to 8. Also in WHPA-B, private wells occurring in a vulnerability category of medium resulted in a category of high, and an increase in vulnerabiity score from 8 to 10.
- There are private wells within the WHPA-C, due to which an adjustment in vulnerability category was made from low to medium, resulting in an increase in vulnerability score from 4 to 6. Also in WHPA-C, a private well occurring in a vulnerability category of medium resulted in a category of high, and an increase in vulnerabiity score from 6 to 8.
- There are private wells within the WHPA-D, due to which an adjustment in vulnerability category was made from low to medium, resulting in an increase in vulnerability score from 2 to 4.

St. Pauls drinking water system consists of a single well serving a population of approximately 90 people. This drinking water system consists of a 70.4 m deep drilled bedrock well. See Appendix 1 Map 4-1-22. Potential transport pathways within the St. Pauls capture zone consist of a variety of unused/ abandoned dug wells throughout the town, which were identified by the water well technician. As these wells occur within the 100 m radius, having already a vulnerability score of 10, there is no further vulnerability increase.

The **Sebringville** drinking water system includes one well serving a population of approximately 90 people. The Black Creek subdivision well reaches a depth of 55.5 m. The overburden has an average thickness of 20 m across Sebringville. See Appendix 1 Map 4-1-19. A few potential transport pathways were identified by the municipality, including unused/ abandoned dug wells found in the Sebringville community and some tile drains in the 5-year and 25-year capture zones. These features have not been located yet and are, therefore, not included at this time. However a few private wells, the locations of which are known, are identified as transport pathways. The vulnerability category around these transport pathways in WHPA-D was increased from low to medium, resulting in an increase in vulnerability score from 2 to 4.

The **Shakespeare** well system is located in bedrock which is found at considerable depths in this area and serves a population of approximately 220. The Miller well is 85 m deep and is being protected by approximately 44 m of overburden material, consisting of silt, sandy silt and sand lenses. The bedrock completion is open hole. See Appendix 1 Map 4-1-20. The area around Shakespeare has a low vulnerability. Transport pathways were discussed with the well technicians for the Shakespeare municipal system. Given the considerable depth of the aquifer, only abandoned bedrock wells are anticipated to represent a significant risk. Within the modest area covered by the Miller well capture zone, no potential transport pathways have been identified.

The City of **Stratford** currently encompasses 6 wellfields with a total of 11 wells. This supply provides drinking water to a population of approximately 30,460 people. All wells pump water from the bedrock aquifer. The bedrock contact is located at a depth of 33 m (Romeo #4) to 47 m (Dunn well). All wells are cased to the bedrock and then completed as open hole, with a total well depth of 139 m at the deepest well. See Appendix 1 Map 4-1-23. The largest concern for the Stratford water supply system is non-municipal private wells which are completed to the bedrock aquifer. There is currently a ban on the installation of any well within the Stratford area as a protective measure. However, geothermal wells supersede this ban under the Green Energy Act and have been installed west of the Romeo wellfield into the same depth as the municipal aquifer; exact locations are yet to be determined. A number of wells have been decommissioned in Stratford and the abandonment records will need to be considered in subsequent Assessment Reports. A municipal monitoring well is located in the Romeo wells WHPA, to the west of Romeo Street and to the south of Vivian Street. A water level transducer is installed on this well to record water level data. The monitoring well is part of the municipal system and is inspected every week as per the Permit to Take Water, and is not considered as a transport pathway.

The following were considered as transport pathways in the City of Stratford WHPA:

- There are private wells within the O'Loane Well WHPA-B, due to which an adjustment in vulnerability category was made from low to medium, resulting in an increase in vulnerability score from 6 to 8.
- There are private wells within the Mornington Well WHPA-B, due to which an adjustment in vulnerability category was made from low to medium, resulting in an increase in vulnerability score from 6 to 8.

- There are private wells within the Mornington Well WHPA-C, due to which an adjustment in vulnerability category was made from low to medium, resulting in an increase in vulnerability score from 4 to 6.
- There are private wells within the Mornington Well WHPA-D, due to which an adjustment in vulnerability category was made from low to medium, resulting in an increase in vulnerability score from 2 to 4.
- There are private wells within the Romeo Well WHPA-B, due to which an adjustment in vulnerability category was made from low to medium, resulting in an increase in vulnerability score from 6 to 8.
- There are private wells within the Romeo Well WHPA-C, due to which an adjustment in vulnerability category was made from low to medium, resulting in an increase in vulnerability score from 4 to 6.
- There are private wells within the Romeo Well WHPA-D, due to which an adjustment in vulnerability category was made from low to medium, resulting in an increase in vulnerability score from 2 to 4.
- There are private wells within the Dunn Well WHPA-D, due to which an adjustment in vulnerability category was made from low to medium, resulting in an increase in vulnerability score from 2 to 4.

Vulnerability Scoring within WHPA-A, B, C, D

Vulnerability of an area within a *WHPA* is assigned a score of 2 to 10 dependent on the *WHPA* zone that it is within (*WHPA-A*, *WHPA-B*, *WHPA-C*, *WHPA-D*), the method used to assess vulnerability (such as *ISI, AVI* or *SWAT*), and the vulnerability category (high, medium or low). Table 4-3 summarizes the possible vulnerability scoring using *ISI*, *AVI* or *SWAT*, according to the *Technical Rules 2013: Assessment Reports*. A higher score signifies a greater vulnerability to contamination.

Table 4-3 WHPA vulnerability scoring (Technical Rules Table 2 a and b)

Groundwater Vulnerability Category	Vulnerability Score			
	WHPA-A	WHPA-B	WHPA-C	WHPA-D
Using ISI and AVI				
High	10	10	8	6
Medium	10	8	6	4

Low	10	6	4	2
		Using SWAT		
High	10	10	8	6
Medium	10	8	6	4
Low	10	6	2	2

The results of the vulnerability assessment for the *WHPA* in the Upper Thames River Source Protection Area are shown in the vulnerability maps in Appendix 1 (Maps 4-1-1 to 4-1-23). Vulnerability scores for the UTRSPA are summarized below in Table 4-4.

Table 4-4 List of Groundwater Wells and Vulnerability Scores for WHPA-A, B, C, D

Groundwater Intake	**Vulnerability Score**				**Vulnerability Comments**
	WHPA-A	WHPA-B	WHPA-C	WHPA-D	H= high, M= moderate, L= Low
London Middlesex Study					
Birr	10	6	4	2	Vulnerability is low
Dorchester Overburden & Bedrock	10	10, 6	8, 4	6, 2	Vulnerability is high in overburden and low in bedrock
Melrose	10	10	8,6	6,4,2	H for WHPA-B, H and M for WHPA-C; H, M and L for WHPA-D
Thorndale	10	6	4	2	Vulnerability is Low in WHPA
Oxford Study					
Beachville (larger and smaller)	10	8, 6	8, 4	6,4,2	High for WHPA-B & C; High, Medium & Low for WHPA-D, (Smaller WHPA) Medium for part of WHPA-B & low for WHPA-C & D
Embro	10	6	4	2	L for all WHPA-D
Hickson	10	8	4	2	M for part of WHPA-B but all included as moderate, L for WHPA-C & D
Ingersoll	10	10, 8, 6	6, 2 (H & L SWAT)	8*, 6*, 4*, 2	Ingersoll was completed with SWAT Table 2b. WHPA values different. H, M, & L for WHPA-B; M & L for WHPA-C & D
Innerkip	10	8	8, 6	4, 2	WHPA-B: M, WHPA-C: H & M; WHPA-D: M & L
Lakeside	10	6	4	2	WHPA-B-D all low vulnerability
Mount Elgin	10	6	4	2	WHPA-B-D all low vulnerability

Table 4-4 List of Groundwater Wells and Vulnerability Scores for WHPA-A, B, C, D

Groundwater Intake	**Vulnerability Score**				**Vulnerability Comments**
	WHPA-A	WHPA-B	WHPA-C	WHPA-D	H= high, M= moderate, L= Low
Tavistock	10	6	4	2	WHPA-B-D all low vulnerability
Thamesford (bedrock & overburden WHPA)	10	10*, 8*, 6	10*, 8*, 4	10*, 8*, 4, 2 No D for over-burden	WHPA-B-D bedrock well are all low vulnerability; WHPA-B-D are all high for overburden wells
Woodstock	10	10, 8, 6	8,6, 2	10*, 8*, 6*, 4, 2	Woodstock was completed with SWAT. WHPA values table 2b.WHPA-B: H, M, & L; WHPA-C: M & L; & WHPA-D: M, L (H, M & L in overlap wells)
Perth Study					
Mitchell	10	6	4	2	WHPA-A-D vulnerability is low
Sebringville	10	10	4	2	WHPA-A-D are all in low vulnerability areas. WHPA-B appears to be beneath WHPA-A
Shakespeare	10	6	4	2	WHPA-A-D are all in low vulnerability areas.
St. Pauls	10	6	4	2	WHPA-A-D are all in low vulnerability areas.
St. Marys	10	10, 8, 6,	6, 4	6, 4, 2	WHPA B and D- high, medium and low vulnerability, WHPA-C has medium and low vulnerability areas
Stratford	10	6	4	2	WHPA-A-D vulnerability is low

*Note: These vulnerability scores for these WHPA are a result of overlapping areas.

Vulnerability Scoring within *WHPA-E*

The vulnerability score of a *WHPA-E* is calculated as per the Technical Rules on vulnerability scores for *Intake Protection Zone-2* (*IPZ-2*). A higher score signifies a greater vulnerability to contamination. The vulnerability score must be calculated based on the vulnerability of the source and the area in the *WHPA-E,* which in turn are based on a number of factors described below. The vulnerability score is a product of the area vulnerability factor and the source vulnerability factor. **Table 4-5** summarizes the vulnerability scores of the *GUDI* well systems in the UTRSPA.

Table 4-5 List of GUDI Wells and Vulnerability Scores for *WHPA-E*

GUDI Well System	Intake Type	*WHPA-E* Area Vulnerability Factor	*WHPA-E* Source Vulnerability Factor	*WHPA-E* Vulnerability Score
Dorchester	C	7.0	0.9	6.3
St. Marys	C	8.0	0.9	7.2
Thamesford	C	7.0	0.9	6.3
Woodstock – rural - Thornton	D	7.0	1.0	7.0
Woodstock – rural - Tabor	D	7.0	1.0	7.0

Area Vulnerability factor: According to the *Technical Rules*, the area vulnerability factor for a *WHPA-E* is assigned in the same manner of assigning a factor to a surface water intake *IPZ-2*. Therefore the area vulnerability factor for a *WHPA-E* ranges between 7 and 9. A higher number corresponds to a higher vulnerability. The area vulnerability factor is dependent on the percentage of area that is land in the *WHPA-E*, land cover, soil type and permeability of the land, slope of any setbacks, and the hydrological and hydrogeological conditions in the area that contribute water to the area through *transport pathways*. The above mentioned criteria have been given equal weight based on professional judgement.

Source Vulnerability factor: According to the Technical Rules, the area vulnerability factor for a *WHPA-E* is assigned based on the type of intake. The source vulnerability factor for a Type C intake can be 0.9 or 1.0 and is based on certain criteria: depth of the intake from the top of the water surface, distance of the intake from land, and number of recorded drinking water issues related to the intake. The source vulnerability factor for a Type D intake can be 0.8 to 1.0 and is based on the same criteria.

The consideration of the above criteria in assigning area and source vulnerability factors to each *GUDI* system's *WHPA-E* is described below.

Dorchester WHPA-E Area and Source Vulnerability Factors

The Dorchester *WHPA-E* consists primary of the Dorchester swamp, wetlands and agricultural lands. Soils are predominantly organic and fine sand loam with high runoff potential. A number of agricultural tile drainages cross the *WHPA-E*. The surficial geology consists of mainly glacial outwash sand deposits. Modern alluvium, consisting mainly of silty sand, occurs within the floodplains of the Big Swamp Drain and its tributaries. *WHPA-E* is relatively flat with 73% of its area having overland slopes less than 1%. From a range between 7 and 9, an area vulnerability factor of 7 (low value) was assigned to the Dorchester *WHPA-E*. The decision was mainly based on flat topography, low soil permeability and low percentage of urban area.

The Dorchester *GUDI* wells pump water from a shallow overburden unconfined aquifer consisting of glaciofluvial sand and gravel. The overburden thickness is in the order of 24 m at the well fields. In the general vicinity of the well field, the aquifer varies in thickness from 4 m to 17 m. A relatively homogenous till underlies the sand and gravel aquifer. The wells are located about 100 to 200 m from the Big Swamp Drain. Considering that the wells are not located in the immediate vicinity of the Big Swamp Drain and no historical drinking water issues were recorded, a source vulnerability factor of 0.9 was assigned to *WHPA-E*. The factor, which is at the low end of the recommended range for a Type C intake, reflects the condition that the well does not pump directly from surface water, has no water quality issues and is located relatively far from the potential surface sources of contamination.

Fanshawe WHPA-E Area and Source Vulnerability Factors

The *WHPA-E* is mostly cultivated grass (golf course) and roads, with forests and some waterbodies. The soils are mainly sandy loams. The soils are moderately to well permeable. Overland slopes are mild, mainly less than 5%. A number of kettle ponds are located around the well field. These kettles generally contain less than 1 m of standing water and are disconnected and do not have outlets. These ponds are vertically hydraulically connected to the water supply. The pumped aquifer consists of a 15 m to 20 m thick deposit of unconfined sand and gravel. The water table is fairly shallow, being approximately 1 m to 5 m below surface. From a range of 7 to 9, an area vulnerability factor of 7 (low value) was assigned to the Fanshawe *WHPA-E*. The decision was mainly based on low percentages of paved areas, high permeability of soils, and mild slopes.

Considering that the aquifer is very shallow (1 to 5 m), the Fanshawe wells are located in the immediate vicinity of kettle ponds, the identified drinking water *issue* (organic nitrogen) and Type D intake, a high source vulnerability factor of 1.0 was assigned. This high factor considers that the wells pump groundwater that is susceptible to water quality impacts from surface water contamination.

St. Marys WHPA-E Area and Source Vulnerability Factors

The St. Marys *WHPA-E* primarily consists of the urban land uses of St. Marys and agricultural land upstream of St. Marys. Soils are predominantly clay loam and silty loam with relatively poor permeability. A number of agricultural tile drainages cross the *WHPA-E*. The *WHPA-E* has generally mild slopes, mainly less than 5%; however in areas close to the river channel slopes may be steep. From a range between 7 and 9, an area vulnerability factor of 8 (middle value) was assigned to the St. Marys *WHPA-E*. The decision was mainly based on percentage of urban area and concentration of transport pathways (St. Marys stormwatersheds and tile drainages), low permeability of soils and relatively steep slopes.

The wells pump water from the bedrock which is relatively deep around the wells. The zone of interaction with the surface water is located several hundreds metres away from the well projections. The major source of water to the well is attributed to groundwater, however, a small, and unknown portion of water may potentially originate from a surface water source. No drinking water issues were recorded in the St. Marys wells. Considering that the wells are located in deep bedrock, and the zone of interaction is several hundreds meters away from the wells and no historical drinking water issues were recorded, a source vulnerability factor of 0.9 was assigned to *WHPA-E*. The factor is at the low end of the recommended range for a Type C intake.

Thamesford WHPA-E Area and Source Vulnerability Factors

The *WHPA-E* is mostly agricultural, with some wetlands and forests. The overburden in the area is part of the Oxford Till Plain, which consists of sandy-silt to clayey silt soils. Alluvial and glaciofluvial sand and gravel are observed in the drainage channels and valleys. The topography is relatively flat. A large number of agricultural tile drainages and some road ditches exist in *WHPA-E*. From a range between 7 and 9, an area vulnerability factor of 7 (low value) was assigned to the Thamesford *WHPA-E*. The decision was mainly based on flat topography, low percentage of water in the area and low to moderate soil permeability.

Both Thamesford wells are installed in alluvial sands and gravels in an unconfined aquifer. Well 1 is 14.5 m deep and Well 2 is 9.4 m deep. The two wells are located close to the Middle Thames River, with Well 1 and Well 2 being approximately 20 m and 40 m away from the river, respectively. In addition, there is a tributary approximately 70 m south of the wells. Raw water in the wells may be vulnerable to contamination from these surface water features; however, no existing drinking water issues were recorded. Considering that no drinking water issues were recorded and wells are relatively deep, a source vulnerability factor of 0.9 was assigned to *WHPA-E*. The factor, which is at the low end of the recommended range for a Type C intake, reflects the condition that the potential vulnerability of the well to surface water impacts may be low.

Woodstock WHPA-E Area and Source Vulnerability Factors

Both the Thornton and Tabor wellfield *WHPA-Es* encompass a high percentage of rural land. The land cover is predominantly forest for Thornton wellfield, and agriculture for Tabor wellfield. Soils are very permeable, being predominantly sandy loam for Thornton wellfield and loam for Tabor wellfield. No tile drainages within *WHPA-E* were mapped or observed for either wellfield. The topography is moderately flat for both systems, with 98% of their areas having overland slopes less than 5%. Considering these criteria, an area vulnerability factor of 7 (lowest value) was assigned to the Thornton and Tabor wellfields *WHPA-Es*. The decision was based on the percentages of land, relatively high permeability of soils, flat slopes and absence of transport pathways (i.e. tile drainages).

The depth of the Thornton wells ranges from 11 to 32 m below ground surface. The Tabor wells are approximately 14 to 24 m deep. The Thornton and Tabor wells are located very close to the surface water features. Nitrate was identified as a drinking water issue for both wells. Considering these criteria and the intake type (D), a source vulnerability factor of 1.0 (highest value) was assigned for both wellfields.

4.3.6 Uncertainty in WHPA Vulnerability

Based on our understanding of the Technical Rules, the uncertainty assessment is to include the following:

- an evaluation of the uncertainty associated with the assessment of the vulnerability of groundwater within the area of interest (low, medium, high vulnerability);
- an evaluation of the uncertainty associated with the delineation of the WHPA; and
- an assignment of an uncertainty rating (high or low) for each vulnerable area (WHPA).

The *technical rules* states that an analysis of the uncertainty, characterized as high or low, shall be made with respect to the delineation and assessment of groundwater *wellhead protection areas*. The factors to be considered in the analysis include:

- the distribution, variability, quality and relevance of data used;
- the ability of the methods and models used to accurately reflect the flow processes in the hydrological / hydrogeological system;
- the quality assurance and quality control procedures applied;
- the extent and level of calibration of models; and
- the accuracy of the groundwater vulnerability categories to effectively assess the relative vulnerability of underlying hydrogeological features.

For uncertainty in vulnerability scoring for *WHPA-E* associated with *GUDI* wells, the accuracy to which the area vulnerability factor and the source vulnerability factor effectively assesses the relative vulnerability of the hydrological features must also be considered.

The evaluation of uncertainty varied between studies and is discussed in Appendix 13.

The peer reviewers have had considerable discussion with the consultants who have undertaken the studies for both surface water and groundwater vulnerability assessment in the Thames-Sydenham and Region. Through that discussion it has become apparent that there is considerable subjectivity to the assignment of the uncertainty factors. It is important to understand that a high uncertainty associated with any aspect of the work does not suggest that the conclusions are inappropriate for the purposes that the results are being used. This is merely an acknowledgement of the potential for a better understanding with further analysis or data. If it were identified that the uncertainty was too great, additional work would have been undertaken to reduce the level of uncertainty. Availability of data to support additional work would also need to be considered. Even with the completion of additional work, it is unlikely that all uncertainty can be eliminated. The Source Protection Committee is satisfied that the uncertainty of the vulnerability assessment is low enough for the purposes intended.

4.4 Highly Vulnerable Aquifers

As discussed earlier, there are four methods with which the vulnerability of an aquifer can be assessed. These methodologies were applied to the assessment of the *wellhead protection areas* as discussed above. These same methodologies can be applied, on a much larger scale, to the assessment of the vulnerability (or intrinsic susceptibility as it is also referred to) of the first significant aquifer across the entire Source Protection Region. Areas which are identified through these methods as being highly vulnerable, and the aquifers beneath them, are to be identified as *Highly Vulnerable Aquifers* according to Rule 43 of the *Technical Rules: Assessment Report*.

In the Thames-Sydenham and Region, *Highly Vulnerable Aquifers* (*HVA*) were mapped using the Intrinsic Susceptibility Index described above. *ISI* was available across the entire region from the county groundwater studies. In some local areas the other vulnerability assessment methodologies (*AVI* and *SWAT*) have been calculated and mapped, however they have not been applied across the entire region. A seamless product across the region is needed. It is acknowledged that there will likely be challenges in matching the vulnerability assessment map discussed here, with the mapping products developed by neighbouring source protection regions. This will need to be considered in subsequent Assessment Reports after all of the neighbouring regions' products have been developed. This will present a challenge for municipalities which are within more than one Source Protection Region. These differences will also need to be considered in the development of the *Source Protection Plan* in those areas.

In determining which vulnerability assessment method to apply in the region it was also important to consider the data which are available to support the methodology. As the data necessary to apply other methods were not available in many of the areas, it was not possible to apply the other methods across the entire region without undertaking considerably more work. As such, *ISI* was used to assess the vulnerability in the Thames-Sydenham and Region.

Although the county groundwater studies followed a consistent terms of reference and methodology and were reviewed through an *MECP* developed peer review process, there were significant challenges when edge-matching the work between adjacent studies. Many of the products developed through the groundwater studies (such as water table elevation and overburden thickness) were edge-matched in the Southwest Region Edge-Matching Study Results (Waterloo Hydrologic Inc., 2005). *ISI*, however, was not able to be seamlessly matched throughout the region. Instead, a product was developed which identified the areas of overlap between study areas where the *ISI* index was one or two levels different (Map 18 of Appendix 5). In order to use this product to describe the intrinsic vulnerability in the region, it needed to be updated to ensure seamless mapping across the entire region. Further, it is important that consistent methodologies be applied to all areas within the region. The work described in this section is described in detail in the Highly Vulnerable Aquifer Identification (Upper Thames River Conservation Authority, November 2009) report.

The *ISI* scores from the wells across the region were obtained from the data of the county groundwater studies. The updated *WWIS* had been corrected to reduce the locational uncertainty of many of the data points. The *ISI* calculations consider the vulnerability only at points where information on the depth and type of materials overlaying the water table is available. The information source for this geologic interpretation was the Water Well Information System (*WWIS*). This database includes a characterization of the materials encountered in the drilling of water wells. Materials are described by the drillers and then entered into this information system along with other details associated with the well, such as the static level of the water in the completed well. As discussed earlier, the *ISI* score had previously been calculated at each well. These data were used as the basis for the initial vulnerability map. Geographic Information System (*GIS*) tools are often used to interpolate values between the discrete points where the value is known. These tools determine the best fit of a surface through the thousands of values across a region. Various computer algorithms are available in the *GIS* programs to undertake this interpolation or smoothing. The county groundwater studies used different tools to undertake this smoothing of the *ISI*. For a seamless product across the entire Source Protection Region it was necessary to use the same algorithms across the entire region. The ‘Natural Neighbour’ method was used by many of the studies to provide an interpolation of data between neighbouring water well locations. In some of the studies, the results were similar to a computer algorithm method. Natural Neighbour is, however, simpler to apply with fewer options as to how to apply the method. This is an advantage as this method will be better able to be reproduced and updated in the future. Natural Neighbour was therefore used for the seamless update of the *ISI* across the region.

Another difference between the studies was in which values of intrinsic vulnerability were interpolated. In some studies the *ISI* scores were interpolated, whereas other studies interpolated an index which represented whether the score was high, medium or low. As discussed above, an *ISI* score of less than 30 results in a high vulnerability. These were assigned an index value of 1, whereas medium vulnerabilities were assigned an *ISI* of 2 and lows were assigned an *ISI* of 3. In many of the county groundwater studies, these 1, 2 and 3 values were interpolated across the study areas. This resulted in a continuously variable surface with values ranging from less than 1 to greater than 3. It was therefore necessary to determine the breakpoints between high, medium and low within this continuous surface to determine where the lines should be between the high, medium or low area. In investigating this, the study team found that this was not well documented and that it was apparent that various breakpoints were used for the separation of high, medium and low areas. For the purposes of this update, the scores were interpolated rather than the index values, allowing the breakpoints specified in the *rules* to be used in the delineation between high, medium and low vulnerability.

As discussed above, an *ISI* score is only calculated at points where the WWIS contained information. Even with the extensive number of wells which were used, there are areas where there are no wells to define the vulnerability. A simple illustration of this is to consider where wells are generally located. They will normally be located in an area where there are homes or other buildings. The buildings tend to be located close to the roads. As a result, areas between the roads tend not to have many wells. Sand and Gravel information from the Surficial Geology (*OGS*) was used to define features which were not well represented in the *ISI* data. In some areas, the Surficial Geology defined sand and gravel areas suggest that small areas of high vulnerability identified through the *ISI* mapping may be more extensive or connected to other areas which the *ISI* had identified as high vulnerability. This required professional judgement through an extensive comparison of the well records within and around these features to determine whether areas of *highly vulnerable aquifers* were missed in the *ISI* mapping that was developed. This work was undertaken by the region's staff hydrogeologist and was peer reviewed as described in the peer review section above. Where the sand and gravel information agreed with the water well records, the extent of the surficial geology feature (sands and gravels) was used to connect smaller pockets of high vulnerability. Where water well information did not seem to agree with the surficial geology information, examination of the well record and air photo interpretation were used to determine if the well record should be included in the *ISI* interpolation. Further, an assessment as to whether the sand and gravel area identified in the surficial geology features is likely to contain an aquifer was also undertaken where these areas were being added to the highly *vulnerable areas* identified through the seamless *ISI*. Where individual pixels smaller than 200 m square were identified in the seamless *ISI* mapping they were screened out.

The areas where the *ISI* score was calculated or interpolated to be less than 30 are identified as *Highly Vulnerable Aquifers*. The use of a second data source (surficial geology features) and professional judgement to supplement and confirm the results of the *ISI* work give more certainty to the areas delineated as *Highly Vulnerable Aquifers*. This also resulted in a more comprehensive identification of *highly vulnerable aquifers* across the region than could be provided by the *ISI* information calculated and interpolated from well locations. Map 4-3-2 illustrates the *highly vulnerable aquifers* within the Upper Thames River Source Protection Area. All HVAs are assigned a vulnerability score of 6 according to the technical rules.

These areas of high vulnerability identified as *HVA*s were overlaid over the areas of medium or low vulnerability from the seamless *ISI* developed as described above to produce a seamless vulnerability mapping across the region. In this manner, areas identified as *Highly Vulnerable Aquifers* were assigned a vulnerability of high. Those areas which were not identified as *highly vulnerable aquifers* retained the low or medium vulnerability from the seamless vulnerability mapping. The resulting regional scale map is included as Map 4-3-1.

4.4.1 Uncertainty of HVA

The uncertainty associated with the delineation of HVA is largely associated with the uncertainties related to the data sets used. The use of a second information source greatly reduces the uncertainty associated with the HVA, especially in the areas where the 2 data sources agree. This is described in detail in the Highly Vulnerable Aquifer Identification report (UTRCA, 2009) and summarized in Appendix 13. Although there is still a high level of uncertainty, the Source Protection Committee is satisfied that the uncertainty of the HVA is low enough for the purposes intended.

4.5 Significant Groundwater Recharge Areas

Significant Groundwater Recharge Areas or *SGRA*s are delineated through the Water Budget Process. In the Upper Thames River Source Protection Area these were delineated through the Tier 2 Water Budget and updated through the Tier 3 Water Budget. The delineation of the *SGRA*s is described in detail in Section 3 – Water Budget and Water Quantity Stress Assessment.

Rule 44 defines *Significant Groundwater Recharge Areas* as those areas where the recharge is:

1) more than 1.15 times the average recharge in the area or
2) 55% or more of the volume determined by subtracting the annual evapotranspiration for the whole of the related groundwater recharge area from the annual precipitation for the whole of the related groundwater recharge area.

For the purposes of identifying SGRA in the Upper Thames River Source Protection Area, areas were assessed to determine if they exceeded 1.15 times the average recharge of the SPA (method 1 above). The areas which meet this criterion are shown in Map 4-2-1 which shows the delineated *SGRA*. Map 4-2-1 filters out areas which are based on single grids from the analysis (less than 25 ha in area).

Rule 46 allows professional judgement in the determination of areas deemed to exhibit significant recharge or not. For example, if an area is known to provide significant recharge on a local scale due to is unique physiography, but does not show up as significant using the methodology described above, it can be changed in the SGRA mapping to be significant. In the modelling done for SGRA determination in the TSR, river valleys and flood plain areas were shown to be SGRAs. In the opinion of some of the Water Budget Peer Review Committee (PRC) members, these areas are more appropriately defined as groundwater discharge rather than recharge areas, due to their low elevations and to the general groundwater hydraulic gradient towards them. However, there is also a body of research which shows that river valley areas can potentially exhibit both types of behaviour, dependent upon the season, and other PRC members felt it was appropriate to consider them as recharge areas. In the end it was agreed that they would be considered discharge areas, and thus removed from the SGRA mapping in Map 4-2-1.

4.5.1 Uncertainty of SGRA

The uncertainty associated with the delineation of the SGRA is discussed in the Significant Groundwater Recharge Area technical memorandum (UTRCA, May 2010). Recharge is a difficult parameter to estimate. The recharge used in the delineation of the SGRA for the Upper Thames River Source Protection Area is derived from a calibrated surface water model which was coupled with a calibrated groundwater model. While the calibration of both models reduces the uncertainty in the recharge, the resulting SGRA still has a degree of uncertainty. The Source Protection Committee is satisfied that the uncertainty of the SGRA is low enough for the purposes intended.

4.6 Data Gaps and Next Steps

The data gaps encountered in the assessment of vulnerability are listed in Table 4-6.

Table 4-6 Vulnerability Assessment Data Gaps Relevant to the Upper Thames River SPA

Data Gap	Description
Groundwater model parameters (vertical and horizontal hydraulic conductivity, recharge, hydraulic head)	Lack of data; might be an opportunity for future monitoring and testing
WHPA Transport Pathways	Locations of water, oil and gas wells in WHPA
Edge-matching of HVA and SGRA with neighbouring regions	This work will be considered when neighbouring regions' HVA and SGRA maps are complete

Table 4-6 Vulnerability Assessment Data Gaps Relevant to the Upper Thames River SPA

Data Gap	Description
Water well data in portions of SPR, for HVA determination	Lack of data; might be an opportunity for future monitoring
Aquifer mapping	Better understanding of the conceptual geologic model including mapping of the lateral extent of the aquifers and aquitards and recharge areas feeding these aquifers

5.0 Issues Evaluation

Under the Clean Water Act (2006), drinking water quality *issues* must be identified for *drinking water systems* included in the Assessment Report. In the Upper Thames River Source Protection Area (*UTRSPA*), there are groundwater municipal *drinking water systems*, shown in Map 1-3. Surface water municipal *drinking water systems* located outside of the source protection region also serve residents of the *UTRSPA*. A drinking water quality *issue* is a *parameter* (substance) or *pathogen* (disease-causing microorganism) shown to deteriorate, or trend towards a deterioration of raw (untreated) water quality. This Section of the Assessment Report describes what substances in source (untreated) water may be considered *issues* as well as the methodology used to identify *issues*. A list of drinking water quality *issues* identified in the *UTRSPA* is also provided.

5.1 What is a Drinking Water Quality Issue?

The *Technical Rules: Assessment Report* indicates which substances can be considered in the identification of drinking water quality *issues* in raw (untreated) source water. They are the Schedule 1, 2 and 3 *parameters* of the Ontario Drinking Water Quality Standards (O. Reg. 169/03 of the Safe Drinking Water Act, 2002) and Table 4 *parameters* of the Technical Support Document for the Ontario Drinking Water Standards, Objectives and Guidelines (an MECP publication, PIBS4449e01, June 2006). *Pathogens*, which are disease-causing organisms, can also be considered in the identification of drinking water quality *issues*.

The *Schedule 1 parameters* are the two indicator microorganisms, total coliform and *Escherichia coli (E. coli)*. These *parameters* are routinely tested in raw source and treated water, and also in distribution systems, under the Safe Drinking Water Act (2002). The testing of *Schedule 1 parameters* in raw water helps indicate possible pathogenic contamination in the raw water prior to treatment.

The *Schedule 2 parameters* are chemical substances such as lead, nitrate and atrazine. The *Schedule 3 parameters* are radioactive material such as uranium-235. The Schedule 1, 2 and 3 *parameters* have human health based treated drinking water standards called *Maximum Acceptable Concentrations (MAC)*. The Schedule 1, 2 and 3 *parameters* and their safe levels (in treated drinking water) are listed in Tables 5-1, 5-2 and 5-3.

The *Table 4 parameters* are physical (such as taste, colour and turbidity) and chemical (such as sodium, iron and chloride) substances. Some of these affect the aesthetic quality of the water (taste, odour), and hence their treated water criteria are called *Aesthetic Objectives (AO).* Yet other Table 4 substances may interfere with the efficient and effective treatment, disinfection and distribution of the water (alkalinity, hardness), and their treated water criteria are called *Operational Guidelines (OG).* The Table 4 *parameters* and their objectives and guidelines (in treated drinking water) are listed in Table 5-4.

Pathogens are disease-causing protozoa, bacteria or viruses. Protozoa and bacteria are single-celled microscopic living organisms, while viruses are smaller than, and can live in, a single cell. *Pathogens* can cause severe or fatal waterborne illness in humans. Some are resistant to commonly used disinfectants at water treatment plants. Examples of *pathogens* include *Salmonella, Campylobacter, E. coli* strain O157:H7, *Legionella* and *Helicobacter pylori* (waterborne bacteria), noroviruses, hepatitis A and rotaviruses (intestinal viruses), and *Giardia* and *Cryptosporidium* (protozoa). In the *Technical Rules: Assessment Report*, unlike *parameters* listed in Schedule 1, 2 and 3, and Table 4, *pathogens* are not limited to a specific list. The *Schedule 1 parameters* (total coliform and *E. coli*) are routinely monitored, as described earlier, to indicate possible pathogenic contamination of raw water sources. However, specific *pathogens* are not monitored routinely in raw water sources unless there is an indication that monitoring of a specific *pathogen* is warranted.

Table 5-1 Schedule 1 Parameters (from O. Reg. 169/03 of the Safe Drinking Water Act, 2002) and their Treated Drinking Water Quality Standards

Item	Microbiological Parameter	Standard (MAC, counts/100 mL)
1.	*Escherichia coli* (*E. coli*)	Non detectable
2.	Total coliforms	Non detectable

Table 5-2 Schedule 2 Parameters (O. Reg. 169/03 of the Safe Drinking Water Act, 2002) and their Treated Drinking Water Quality Standards

Item	Chemical Parameter	Standard (MAC, mg/L)	Item	Chemical Parameter	Standard (MAC, mg/L)
1.	Alachlor	0.005	40.	Diuron	0.15
2.	Aldicarb	0.009	41.	Fluoride	1.5 [b]
3.	Aldrin + Dieldrin	0.0007	42.	Glyphosate	0.28
4.	Antimony	0.006	43.	Heptachlor + Heptachlor Epoxide	0.003
5.	Arsenic	0.025	44.	Lead	0.010 [c]
6.	Atrazine + N-dealkylated metabolites	0.005	45.	Lindane (Total)	0.004
7.	Azinphos-methyl	0.02	46.	Malathion	0.19
8.	Barium	1.0	47.	Mercury	0.001
9.	Bendiocarb	0.04	48.	Methoxychlor	0.9
10.	Benzene	0.005	49.	Metolachlor	0.05
11.	Benzo(a)pyrene	0.00001	50.	Metribuzin	0.08
12.	Boron	5.0	51.	Microcystin LR	0.0015
13.	Bromate	0.01	52.	Monochlorobenzene	0.08
14.	Bromoxynil	0.005	53.	Nitrate (as nitrogen)	10.0 [d]
15.	Cadmium	0.005	54.	Nitrite (as nitrogen)	1.0 [d]
16.	Carbaryl	0.09	55.	Nitrate + Nitrite (as nitrogen)	10.0 [d]
17.	Carbofuran	0.09	56.	Nitrilotriacetic Acid (NTA)	0.4
18.	Carbon Tetrachloride	0.005	57.	N-Nitrosodimethylamine (NDMA)	0.000009
19.	Chloramines	3.0	58.	Paraquat	0.01
20.	Chlordane (Total)	0.007	59.	Parathion	0.05
21.	Chlorpyrifos	0.09	60.	Pentachlorophenol	0.06
22.	Chromium	0.05	61.	Phorate	0.002
23.	Cyanazine	0.01	62.	Picloram	0.19
24.	Cyanide	0.2	63.	Polychlorinated Biphenyls (PCB)	0.003
25.	Diazinon	0.02	64.	Prometryne	0.001
26.	Dicamba	0.12	65.	Selenium	0.01
27.	1,2-Dichlorobenzene	0.2	66.	Simazine	0.01
28.	1,4-Dichlorobenzene	0.005	67.	Temephos	0.28
29.	Dichlorodiphenyltrichloroethane (DDT) + metabolites	0.03	68.	Terbufos	0.001
30.	1,2-Dichloroethane	0.005	69.	Tetrachloroethylene (perchloroethylene)	0.03
31.	1,1-Dichloroethylene (vinylidene chloride)	0.014	70.	2,3,4,6-Tetrachlorophenol	0.1
32.	Dichloromethane	0.05	71.	Triallate	0.23
33.	2,4-Dichlorophenol	0.9	72.	Trichloroethylene	0.005
34.	2,4-Dichlorophenoxy acetic acid (2,4-D)	0.1	73.	2,4,6-Trichlorophenol	0.005
35.	Diclofop-methyl	0.009	74.	2,4,5-Trichlorophenoxy acetic acid (2,4,5-T)	0.28
36.	Dimethoate	0.02	75.	Trifluralin	0.045
37.	Dinoseb	0.01	76.	Trihalomethanes (THMs)	0.100 [e]
38.	Dioxin and Furan	0.000000015 [a]	77.	Uranium	0.02
39.	Diquat	0.07	78.	Vinyl Chloride	0.002

Notes: (a) Total toxic equivalents when compared with 2,3,7,8-TCDD. **(b)** When added to drinking water, it is recommended to adjust the fluoride concentration to be 0.5 to 0.8 mg/L for optimal level of tooth decay control. Where supplies contain naturally occurring levels higher than 1.5 mg/L but less than 2.4 mg/L, the Ministry of Health and Long Term Care recommends an approach through local boards of health to raise public and professional awareness to control excessive exposure to fluoride from other sources. **(c)** This standard applies to water at the point of consumption. **(d)** Where both nitrate and nitrite exist, the total of both should not exceed 10 mg/L. **(e)** This standard is expressed as the running annual average of quarterly samples measured at point reflecting the maximum residence time in the distribution system.

Table 5-3 Schedule 3 Parameters (O. Reg. 169/03 of the Safe Drinking Water Act, 2002) and their Treated Drinking Water Quality Standards

Item	Radiological Parameter	Standard (MAC, in becquerels per litre)	Item	Radiological Parameter	Standard (MAC, in becquerels per litre)
Natural Radionuclides			Artificial Radionuclides Continued		
1.	Beryllium-7	4000.0	40.	Iron-55	300.0
2.	Bismuth -210	70.0	41.	Iron-59	40.0
3.	Lead-210	0.1	42.	Manganese-54	200.0
4.	Polonium-210	0.2	43.	Mercury-197	400.0
5.	Radium-224	2.0	44.	Mercury-203	80.0
6.	Radium-226	0.6	45.	Molybdenum-99	70.0
7.	Radium-228	0.5	46.	Neptunium-239	100.0
8.	Thorium-228	2.0	47.	Niobium-95	200.0
9.	Thorium-230	0.4	48.	Phosphorus-32	50.0
10.	Thorium-232	0.1	49.	Plutonium-238	0.3
11.	Thorium-234	20.0	50.	Plutonium-239	0.2
12.	Uranium-234	4.0	51.	Plutonium-240	0.2
13.	Uranium-235	4.0	52.	Plutonium-241	10.0
14.	Uranium-238	4.0	53.	Rhodium-105	300.0
Artificial Radionuclides			54.	Rubidium-81	3000.0
15.	Americium-241	0.2	55.	Rubidium-86	50.0
16.	Antimony-122	50.0	56.	Ruthenium-103	100.0
17.	Antimony-124	40.0	57.	Ruthenium-106	10.0
18.	Antimony-125	100.0	58.	Selenium-75	70.0
19.	Barium-140	40.0	59.	Silver-108m	70.0
20.	Bromine-82	300.0	60.	Silver-110m	50.0
21.	Calcium-45	200.0	61.	Silver-111	70.0
22.	Calcium-47	60.0	62.	Sodium-22	50.0
23.	Carbon-14	200.0	63.	Strontium-85	300.0
24.	Cerium-141	100.0	64.	Strontium-89	40.0
25.	Cerium-144	20.0	65.	Strontium-90	5.0
26.	Cesium-131	2000.0	66.	Sulphur-35	500.0
27.	Cesium-134	7.0	67.	Technetium-99	200.0
28.	Cesium-136	50.0	68.	Technetium-99m	7000.0
29.	Cesium-137	10.0	69.	Tellurium-129m	40.0
30.	Chromium-51	3000.0	70.	Tellurium-131m	40.0
31.	Cobalt-57	40.0	71.	Tellurium-132	40.0
32.	Cobalt-58	20.0	72.	Thallium-201	2000.0
33.	Cobalt-60	2.0	73.	Tritium	7000.0
34.	Gallium-67	500.0	74.	Ytterbium-169	100.0
35.	Gold-198	90.0	75.	Yttrium-90	30.0
36.	Indium-111	400.0	76.	Yttrium-91	30.0
37.	Iodine-125	10.0	77.	Zinc-65	40.0
38.	Iodine-129	1.0	78.	Zirconium-95	100.0
39.	Iodine-131	6.0			

Table 5-4 Table 4 Parameters (from the Technical Support Document for the Ontario Drinking Water Standards, Objectives and Guidelines, MECP 2006) with their Treated Drinking Water Aesthetic Objectives and Operational Guidelines

Table 4 Parameter	AO	OG
1,2-Dichlorobenzene	0.003[a] mg/L	
1,4-Dichlorobenzene	0.001[a] mg/L	
2,4-Dichlorophenol	0.0003[a] mg/L	
2,3,4,6-Tetrachlorophenol	0.001[a] mg/L	
2,4,6-Trichlorophenol	0.002[a] mg/L	
2,4,5-Trichlorophenoxy acetic acid (2,4,5-T)	0.02[a] mg/L	
Alkalinity (as $CaCO_3$)		30-500 mg/L
Aluminum		0.1 mg/L
Chloride	250 mg/L	
Colour	5 TCU	
Copper	1 mg/L	
Dissolved Organic Carbon	5 mg/L	
Ethylbenzene	0.0024 mg/L	
Hardness (as $CaCO_3$)		80-100 mg/L
Heterotrophic Plate Count (HPC)-General bacteria population expressed as colony counts on a heterotrophic plate count		f
Iron	0.3 mg/L	
Manganese	0.05 mg/L	
Methane	3L/ m^3	
Monochlorobenzene	0.03[a] mg/L	
Odour	Inoffensive	
Organic Nitrogen		0.15 mg/L
pH		6.5-8.5 (no units)
Pentachlorophenol	0.03[a] mg/L	
Sodium	b	
Sulphate	500[c] mg/L	
Sulphide	0.05 mg/L	
Taste	Inoffensive	
Temperature	15^0C	
Toluene	0.024 mg/L	
Total Dissolved Solids	500 mg/L	
Turbidity	5 NTU[d]	e
Xylenes	0.3 mg/L	
Zinc	5 mg/L	

Notes: (a) Refer to Table 5-2 (Schedule 2 parameters) for MAC standard. **(b)** The AO for sodium in drinking water is 200 mg/L. 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. **(c)** When sulphate levels exceed 500 mg/L, water may have a laxative effect on some people. **(d)** Applicable for all waters at the point of consumption. **(e)** The OGs for filtration processes are provided as performance criteria in the Procedure for Disinfection of Drinking Water in Ontario. **(f)** Increases in HPC concentrations above baseline levels are considered undesirable.

5.2 Impact of Identifying an Issue

According to Rules 114, 115, 131 and 141, *activities* or *conditions* that contribute to drinking water quality *issues* (known to be partially or wholly due to *anthropogenic* sources), are deemed *significant* drinking water *threats* regardless of assigned vulnerability scores. This applies to intake protection zones and wellhead protection areas only, for drinking water systems identified in the Source Protection Area Terms of Reference.

If an *issue* is identified, the *activities* that contribute to the identified *issue* and the areas where they occur (within *vulnerable areas*, as described above) must also be identified. A third intake protection zone (*IPZ-3*) for surface water intakes, or a *WHPA-F* for groundwater wells may be delineated to include the *activity* and area known to contribute to the drinking water quality *issue*. As discussed in Section 4.3.4, the Technical Rule 50 (2) and (3) require that *WHPA-F* be delineated if the well is subject to *issues*, which originate from outside the other parts of the *WHPA*, and only if a *WHPA-E* has already been delineated.

For the *activities* or *conditions* contributing to *issues* that are deemed to be *significant threats* as described above, the *risks* the *activities* or *conditions* pose must be reduced through the source protection plan.

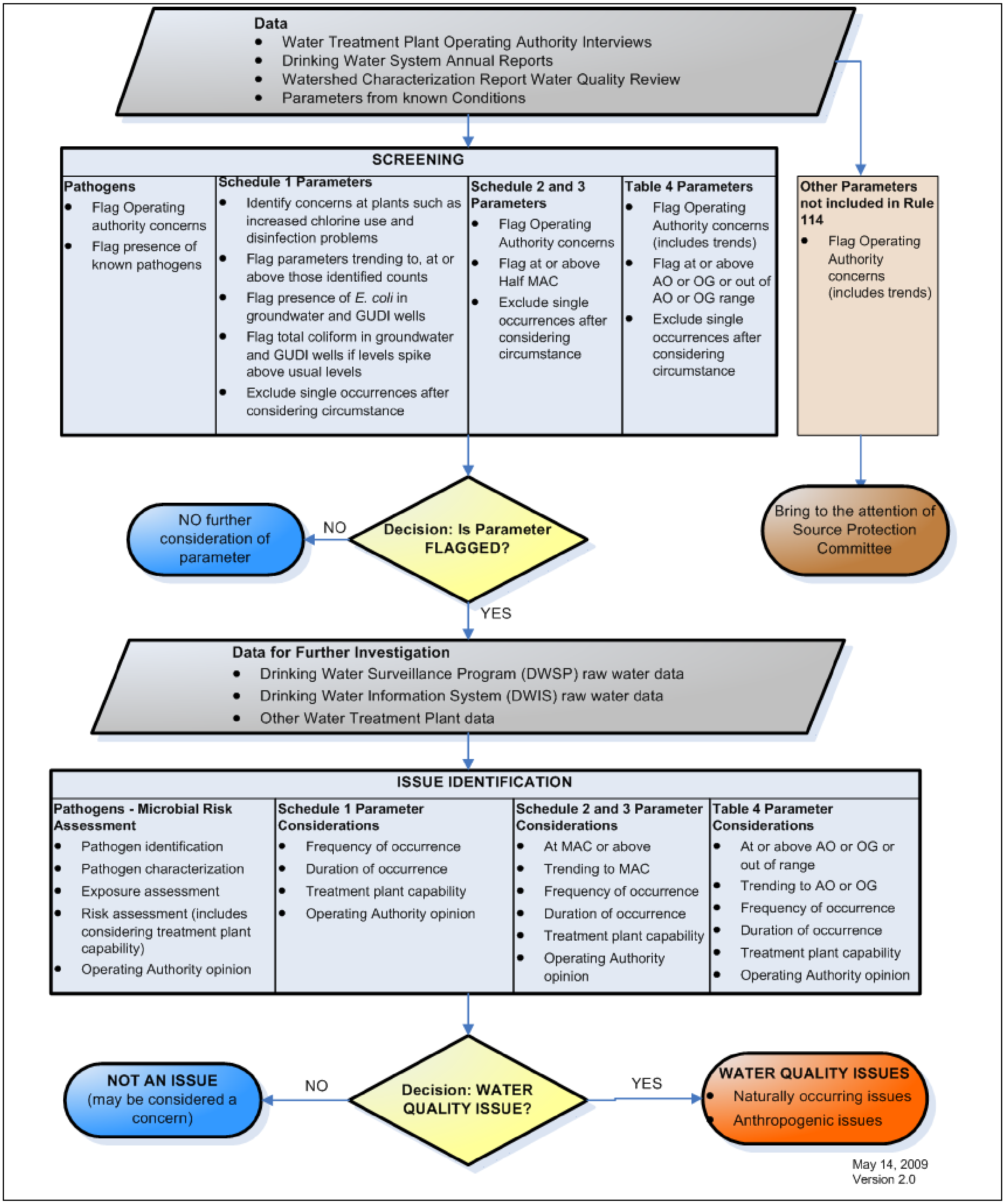
Further, *issues* in *HVAs* or those linked to a system not identified in the Terms of Reference may lead to the identification of moderate drinking water threats (not significant threats). Systems not identified in the Terms of Reference may be those included in the source protection planning process through municipal council resolution or by the Minister (MECP).

5.3 Issue Evaluation Methodology

Identifying *issues* is a key step in the overall process of protecting drinking water quality. *Issues* were identified in the Upper Thames River Source Protection Area by following the Thames-Sydenham and Region Issues Evaluation Methodology (May 14, 2009), depicted in Figure 5-1. The methodology is provided in Appendix 8. The evaluation is a two-step process. Firstly, in the screening step, raw (untreated) water quality data are compared to a benchmark and *parameters* may be flagged if they meet the screening criteria. The benchmarks for chemical, physical and radioactive *parameters* are generally half the applicable human health based Ontario drinking water standards (*Maximum Acceptable Concentrations* or *MAC*), and the full levels of the *Aesthetic Objectives (AO)* and *Operational Guidelines (OG)*, and any plant operating authority concerns. Secondly, in the identification step, an investigation of the *parameters* flagged through the first step is undertaken. This includes a review of trends and spikes, frequency and duration of occurrence, presence at or trending towards the applicable *MAC*, *AO* or *OG* benchmark, consideration of existing water treatment plant capabilities and discussions with the water treatment plant operating authority.

Pathogens are also evaluated in a two-step process that differs from the evaluation of the Schedule 1, 2, 3 and Table 4 *parameters*. In the first step (screening), *pathogens* are flagged if they are a concern to the operating authority, known to occur in raw water, persist in treated water, or have caused a waterborne outbreak in the past. A *pathogen* that is flagged through the screening process must be subject to a microbial risk assessment to identify whether it is an *issue*. This assessment involves *pathogen* characterization, exposure assessment and risk characterization. Some of the elements considered in a microbial risk assessment are: pathological characteristics, infection mechanisms, resistance to control or treatment, survival, persistence, seasonality, reliability of treatment processes and route of human exposure.

Figure 5-1 Thames-Sydenham and Region Issues Evaluation Methodology



5.4 Issues Evaluation Technical Studies

As described in Section 4.0 Vulnerability Assessment, projects led by the City of London, the Upper Thames River Conservation Authority (*UTRCA*) and the County of Oxford were initiated through various partnerships, involving the *UTRCA*, the municipalities and the water treatment plant operators. These projects included 22 well supply systems in the Upper Thames River Source Protection Area. Similarly, through these partnerships and projects, the issues evaluation work was completed, as shown in Table 5-5 below. The consultants contracted for the issues evaluation work were Dillon Consulting and Schlumberger Water Services (formerly Waterloo Hydrologic Inc.) while the County of Oxford completed the work themselves. The City of London, Middlesex Centre, Thames Centre, County of Oxford, City of Stratford, Town of St. Marys, and member municipalities of the County of Perth East were active partners in the projects and participated in the technical steering of the projects.

The technical studies are listed below in Table 5-5.

Table 5-5 Technical Studies on Drinking Water Quality Issues Evaluation

Drinking Water Systems (Municipality)	Technical Study on Issues Evaluation
Fanshawe, Hyde Park (City of London); Birr, Melrose (Middlesex Centre), Dorchester, Thorndale (Thames Centre)	London, Middlesex Centre & Thames Centre Well Field Source Protection Study - Source Water Issues & Concerns Report June 2010.
Beachville, Embro, Hickson, Ingersoll, Innerkip, Lakeside, Mount Elgin, Tavistock, Thamesford, Woodstock (County of Oxford)	1. Source Water Protection Drinking Water Systems Issues Evaluation Report. Oxford County Public Works Department. October 2009. 2. Source Water Protection Drinking Water Systems Issues Report Update. Thamesford Drinking Water System. Oxford County Public Works Department. March 2011.
Mitchell, Sebringville, St. Pauls (Perth County); St. Marys (Town of St. Marys); Stratford (City of Stratford), Shakespeare, Milverton (Perth East) (Note: Milverton is not in the TSR SPR, but was included in this study through a partnership with the Lake Erie SPR)	Technical Memorandum. Issues Assessment – Perth County Municipal Drinking Water Systems. Schlumberger Water Services. March 2010
Final Tabor 2/4 and Tillsonburg 4/5 Municipal Well Nitrate Contributing Areas	Technical Memorandum Matrix Solutions Inc, December 20, 2013
Woodstock Rural (Thorton Wellfield)	Technical Memorandum, AR Lottimer Woodstock Thorton Wellfield, Issue Contributing Area for Nitrate, April 22, 2014

Woodstock Rural (Thorton Wellfield)	Thorton Issue Contributing Area Workplan Oxford County, July 3, 2014
Woodstock, Ingersoll and Beachville	Tier Three Water Budget and Local Area Risk Assessment Oxford County Matrix Solutions Inc. March 2014
Woodstock Rural (Tabor)	Technical Memorandum Final Tabor 2/4 and Tillsonburg 4/5 Municipal Well Nitrate Contributing Areas Matrix Solutions, December 20, 2013

5.5 Identified Issues

Certain *parameters* that met the screening criteria, in the first step of *issues* evaluation, were flagged. In the second step of *issues* evaluation, flagged *parameters* were further investigated to identify drinking water quality *issues* in the Upper Thames River SPA. The identified *issues* are listed and described in Table 5-6. Certain *parameters* may be due to *anthropogenic* (man-made) sources, i.e. due to the activities on land, or naturally occurring, or both. No *pathogens* are identified as *issues* in the raw (untreated) source water in the Upper Thames River SPA. It is important to note that the drinking water quality *issues* identified in Table 5-6 are based mainly on raw (untreated) water quality and do not represent the quality of water after treatment. The operation of a water treatment plant including treatment and distribution are governed separately by the Safe Drinking Water Act (2002).

The flagged *parameters* that were not identified as drinking water quality *issues* include those of aesthetic concern and naturally occurring substances. More information on flagged *parameters* is provided in Appendix 9 of the Assessment Report. The identified *issues* and flagged *parameters* will be subject to a re-evaluation in subsequent Assessment Reports.

Table 5-6 Drinking Water Quality Issues Identified in the Upper Thames River Source Protection Area

MUNICIPALITY/ System – Wellfield (no. of wells)	*Issue**	Brief Description of Evaluation	Natural or *Anthropogenic* Source
MIDDLESEX COUNTY			
Birr (1 well)	Hardness	Hardness levels for all the wells range between 128 to 200 mg/L (data from 2005 to 2008), and are above the treated water OG of 80 to 100 mg/L. Hardness is naturally high in the aquifer and is therefore considered a natural-based issue.	Naturally occurring
Melrose (2 wells)	Hardness	Hardness levels for all the wells range between 130 to 240 mg/L (data from 2005 to 2008), and are above the treated water OG of 80 to 100 mg/L. Hardness is naturally high in the aquifer and is therefore considered a natural-based issue.	Naturally occurring
	Turbidity	Turbidity ranged between 5.73 to 10.04 NTU (data from 2004 and 2006 to 2008). These levels are above the treated water AO of 5 NTU. This parameter should continue to be monitored, as there is no filtration incorporated in this water system, and increasing turbidity can ultimately hinder the disinfection process.	Naturally occurring
Thorndale (2 wells)	Fluoride (both wells)	Fluoride in the raw water has consistently been above the treated drinking water MAC of 1.5 mg/L between 2003 and 2006, and in 2008. In 2007, it was above the half MAC. Fluoride concentrations are considered to be naturally high in the aquifer. A Fluoride Fact Sheet, provided by the Middlesex London Health Unit (MLHU), is distributed annually to all Thorndale water system customers.	Naturally occurring
Dorchester (9 wells)	None	None identified.	
CITY OF LONDON (Back up systems) – DECOMMISSIONED			
City of London – Fanshawe wellfield (6 wells) - DECOMMISSIONED	Hardness (all wells)	Hardness levels for all the wells range between 150 to 449 mg/L (data from 1994 to 2008 for all wells except well no. 2, for which data was from 2000 to 2008). These levels are above the treated water OG of 80 to 100 mg/L. Well 5 appears to have the highest reported hardness. Hardness is naturally high in the aquifer.	Naturally occurring
	Manganese (well no. 2 to 6)	Concentrations in wells 2, 3, 4, 5 and 6 are above the treated water AO of 0.05 mg/L at least once between 2000 and 2008, with a high level of 0.27 mg/L in Well 3 in 2005. Concentrations in Well 4 appear to be increasing. Elevated levels are typically due to interaction between the groundwater and manganese mineral deposits.	Naturally occurring
	Turbidity (well no. 3)	In well 3, concentration (7.06 NTU) in 2007 is above the treated water AO of 5 NTU. The source would be iron or dissolved solids naturally occurring in the aquifer. This parameter should continue to be monitored, as there is no filtration incorporated in this water system, and increasing turbidity can ultimately hinder the disinfection process.	Naturally occurring
	Organic nitrogen (all wells)	Concentrations of organic nitrogen are regularly above the 0.15 mg/L treated water OG in all wells between 1994 and 2005. There is no specific trend to the data. Elevated concentrations appear to occur randomly but regularly in all wells, with a high of 1.2 mg/L in Well 3 in 2002.	Possibly both natural and *anthropogenic* causes, further investigation required

Table 5-6 Drinking Water Quality Issues Identified in the Upper Thames River Source Protection Area

MUNICIPALITY/ System – Wellfield (no. of wells)	*Issue**	Brief Description of Evaluation	Natural or *Anthropogenic* Source
City of London – Hyde Park wellfield (1 well) - DECOMMISSIONED	Hardness	The available data (2003 to 2008) indicate that the raw water hardness averaged 360 mg/L and was consistent throughout the data period. The average hardness level at the well exceeds the treated water OG of 80 to 100 mg/L. Hardness is considered naturally high in the groundwater, and is therefore considered a natural-based issue.	Naturally occurring
	Total Dissolved Solids	Data from 2003 to 2008 show levels of Total Dissolved Solids in the range of 486 to 591 mg/L with the average being 545 mg/L. Although the reported levels of TDS are above the treated water AO of 500 mg/L, they are not substantially over the limit. It is likely that the high levels are a result of natural geology and are identified as a natural-based issue.	Naturally occurring
OXFORD COUNTY			
Beachville	None	None identified.	
Embro	None	None identified.	
Hickson	None	None identified.	
Ingersoll (7 wells)	Hydrogen Sulphide (all wells)	All wells in Ingersoll are above the treated water AO of 0.05 mg/L for hydrogen sulphide between 2001 and 2009. Levels are reported as ranging from 0.26 to 6.02 mg/L. It is believed that the levels in Ingersoll source water are higher than some of these results indicate, as the parameter easily volatilizes in air. When not removed from the water prior to disinfection, the hydrogen sulphide can cause significant water quality and treatment issues. For this reason hydrogen sulphide is being identified as an issue for the system even though it is naturally occurring and does not have a health related impact.	Naturally occurring
Innerkip	None	None identified.	
Lakeside	None	None identified.	
Mount Elgin	None	None identified.	
Tavistock	None	None identified.	
Thamesford (3 wells)	Manganese (well no. 1 and 2)	The raw water in wells 1 and 2 have levels of manganese that are above the treated water AO of 0.05 mg/L, with concentrations of 0.14 to 0.35 mg/L (data 2001 to 2009). No increasing trend is evident. The treatment facility removes manganese through an oxidation and filtration process. Failure of this process could potentially result in decreased clarity of the water which would impact the effectiveness of the UV disinfection.	Naturally occurring
Woodstock (10 wells)	Nitrates (well no. 1, 2, 3, 4, 5, 8	Nitrate occurs in the Thornton wellfield (well no. 1, 3, 5, 8 and 11) and Tabor wellfield (well no. 2 and 4) of the Woodstock well supply. Nitrate levels in wells 1, 2, 3, 5, 8	Anthropogenic

Table 5-6 Drinking Water Quality Issues Identified in the Upper Thames River Source Protection Area

MUNICIPALITY/ System – Wellfield (no. of wells)	*Issue**	Brief Description of Evaluation	Natural or *Anthropogenic* Source
	and 11)	and 11 are routinely above half of the treated water MAC (nitrate MAC is 10 mg/L). In well 4, the concentration is typically below the half MAC threshold but has occasionally been marginally above the half MAC. In 2008 the concentration ranged from 3.7 to 11.5 mg/L in the raw water. Well 3 typically has the highest Nitrate concentrations. Data for all wells is 2001 to 2009. Nitrate is not typically a naturally occurring parameter in groundwater at levels around the MAC and may be from anthropogenic sources. Nitrate concentrations at the Thornton wells (well no. 1, 3, 5, 8 and 11) had been increasing. Currently water from this wellfield is combined with water from the Tabor wellfield to ensure nitrate levels in the distribution system remain low.The Thornton wellfield represents a significant portion of the total supply to the Woodstock system and therefore Nitrate has been identified as an issue in the Thornton Wellfield. Further assessment in 2013/14 has identified the potential for the levels in some of the wells to be leveling off or decreasing. This may be attributed to the modified nutrient management plans used on the properties in municipal ownership within this vulnerable area. Additional monitoring is required to assess whether an ICA is required and whether Nitrate remains an Issue at the Thorton wellfield. Levels at the Tabor wellfield (well no. 2 and 4) are significantly lower than those seen in the Thornton wellfield (around half of the MAC), but appear to be trending upwards. The wellfield contains two highly productive wells that are a main supply of water to the system. Increased levels of nitrate in this wellfield could reduce the effectiveness of blending the water with Thornton to lower the overall nitrate concentration in the system. Therefore Nitrate is an issue in the Tabor wellfield.	
PERTH COUNTY			
Mitchell (4 wells)	Fluoride	Fluoride levels are above the treated water AO of fluoride, 1.5 mg/L. Levels ranged from 1.6 to 1.9 mg/L between 2003 and 2008.	Naturally occurring
Shakespeare (1 well)	None	None identified.	
Sebringville (1 well)	Fluoride	Fluoride levels are above the treated water AO of fluoride, 1.5 mg/L. Levels ranged from 2.06 to 2.74 mg/L between 2003 and 2008.	Naturally occurring
	Iron	From the limited iron data, iron levels are slightly above the OG of 0.3 mg/L, at 0.35 mg/L (in 2005) and 0.4 mg/L (in 2008). An operations manager at the Ontario Clean Water Agency (OCWA), who maintains the wells, has indicated that there are no problems in treatment due to the iron levels, and will continue to monitor iron levels.	Naturally occurring

Table 5-6 Drinking Water Quality Issues Identified in the Upper Thames River Source Protection Area

MUNICIPALITY/ System – Wellfield (no. of wells)	*Issue**	Brief Description of Evaluation	Natural or *Anthropogenic* Source
St. Pauls (1 well)	Fluoride	Fluoride levels are above the treated water AO of fluoride, 1.5 mg/L. Levels ranged from 1.59 to 1.69 mg/L between 2003 and 2006.	Naturally occurring
CITY OF STRATFORD			
Stratford (11 wells)	Fluoride	Fluoride levels are at or above the treated water AO of fluoride, 1.5 mg/L. Levels ranged from 1.5 to 2.6 mg/L between 2004 and 2008.	Naturally occurring
TOWN OF ST. MARYS			
St. Marys (3 wells)	None	None identified.	

*Issues identified as allowed under Technical Rule 115.1

5.6 Issues Contributing Area

Rule 115 requires an Issue Contributing Area (ICA) to be delineated for issues identified as being partially or entirely anthropogenic and the activities contributing to the issue must be identified. Nitrate is identified for the well numbers 1, 3, 5, 8 and 11 (Thorton wellfield) and well numbers 2, 4 (Tabor wellfield) of the Woodstock drinking water system. The County of Oxford engaged Matrix Solutions to undertake a study to delineate the land uses and areas contributing nitrate to the municipal wells, or Issue Contributing Area (ICA), within the previously mapped Well Head Protection Areas (WHPAs) for Woodstock Wells 2 and 4 (Tabor). The ICA mapping was then used by Oxford County to complete the nitrate activity and condition mapping within the contributing areas as specified in the Technical Guidance for ICA delineation (MECP, 2010).

Nitrate is the most common form of nitrogen found in water. Nitrate is usually introduced into groundwater through widespread or diffuse sources, commonly called non-point sources. Nitrate nitrogen is a naturally occurring essential plant nutrient. The Ontario Drinking Water Quality Standards (MECP, 2006a) specify a Maximum Allowable Concentration (MAC) of 10 mg-N/L is set to protect infants from methemoglobinemia (blue baby syndrome). Nitrate is naturally occurring in groundwater however the nitrate level of most ambient groundwater is low, generally less than 1 mg/l (as N). The presence of nitrate in groundwater greater than 3 mg/l usually reflects the impact of human activities (anthropogenic). Nitrate is highly soluble and there is no mineral in the soil that can precipitate or bind it to limit its concentration and therefore

Nitrate persists and accumulates. In general, overburden wells have higher nitrate concentrations than bedrock wells (3 CA groundwater study).

The applied methodology is based upon experience from research completed by the University of Waterloo assessing nitrate contributing areas and transport to the Woodstock Wells No. 1, 3, 5, 8 and 11 (Thornton Wellfield). The final ICA delineation was completed for areas within the established WHPAs developed as part of the Source Protection work by Golder (2010).

- **Nitrate Sources**

The activities associated with agriculture (fertilizer and ASM), residential development (septic effluent) and wetlands (decaying organic material) are known sources of nitrate in groundwater which are present in the WHPA. Agriculture is the dominant land use in the WHPAs and application of nitrate fertilizers has been increasing in Canada since the 1950s. Nitrate contributions from septic systems and decaying organic materials were assumed to be negligible given the small land area within the WHPAs and typical loadings associated with these features.

Table 5-7 Activities Identified as Contributing to Nitrate Issues within an Issue Contributing Area

Prescribed Drinking Water Threat	Threat Subcategory
The application of agricultural source material to land.	Application Of Agricultural Source Material (ASM) To Land
The application of commercial fertilizer to land.	Application Of Commercial Fertilizer To Land
The application of non-agricultural source material to land.	Application Of Non-Agricultural Source Material (NASM) To Land (Including Treated Septage)
The establishment, operation or maintenance of a waste disposal site within the meaning of Part V of the Environmental Protection Act.	Application Of Untreated Septage To Land
The use of land as livestock grazing or pasturing land, an outdoor confinement area or a farm-animal yard.	Management Or Handling Of Agricultural Source Material - Agricultural Source Material (ASM) Generation (Grazing and pasturing)
	Management Or Handling Of Agricultural Source Material - Agricultural Source Material (ASM) Generation (Yards or confinement)
The establishment, operation or maintenance of a system that collects, stores, transmits, treats or disposes of sewage.	Sewage System Or Sewage Works - Combined Sewer discharge from a stormwater outlet to surface water

	Sewage System Or Sewage Works - Discharge Of Untreated Stormwater From A Stormwater Retention Pond
	Sewage System Or Sewage Works - Industrial Effluent Discharges
	Sewage System Or Sewage Works - Sanitary Sewers and related pipes
	Sewage System Or Sewage Works - Septic System
	Sewage System Or Sewage Works - Septic System Holding Tank
	Sewage System Or Sewage Works - Sewage treatment plant bypass discharge to surface water
	Sewage System Or Sewage Works - Sewage Treatment Plant Effluent Discharges (Includes Lagoons)
	Sewage System Or Sewage Works - Storage Of Sewage (E.G. Treatment Plant Tanks)
The storage of agricultural source material.	Storage Of Agricultural Source Material (ASM)
The handling and storage of commercial fertilizer.	Storage Of Commercial Fertilizer
The handling and storage of non-agricultural source material.	Storage of Non-Agricultural Source Material (NASM)
The storage of snow.	Storage Of Snow
The establishment, operation or maintenance of a waste disposal site within the meaning of Part V of the Environmental Protection Act.	Storage, Treatment And Discharge Of Tailings From Mines
	Waste Disposal Site - Landfilling (Municipal Waste)
	Waste Disposal Site - Landfilling (Solid Non Hazardous Industrial or Commercial)

The prescribed drinking water threats within the ICA which contribute to the nitrate issue are enumerated in section 7.2.18

- **Modelling Tools**

A conceptual hydrogeological model and MODFLOW numerical model were developed to define WHPA's in the Woodstock area. As part of the Tier 3 Water Quantity Risk Assessment, refinements to the conceptual and numerical models included the development of a new, more detailed, peer reviewed FEFLOW numerical model and further refinement to recharge through the GAWSER surface water model.

The Tier 3 FEFLOW model was used to estimate the time of travel through the saturated zone from the point of recharge (water table) to the well. This analysis uses backward particle tracking methods and is consistent with the approach used by Golder (2010) to delineate time of travel capture zones and WHPAs. The MECP SAAT guidelines (2006) were utilized to estimate the unsaturated zone time of travel and were based on soil texture and mobile moisture content estimates.

The total estimated time of travel (total time lag) from the ground surface to Woodstock Wells 2 and 4 (Tabor wellfield) and was delineated by adding the average saturated zone time of travel to average unsaturated zone time of travel for each land use mapped in GIS. The total time of travel exceeds 60 years in areas southwest of the Tabor wells due to thick till and lower recharge. Within the areas contributing recharge to the wells, time of travel is less than 60 years and as short as about 5 years. In this area, the overlying till is thinner and the rate of recharge is higher. The largest contribution of Nitrate mass is from the 25 to 60 years time of travel category. This is consistent with the observed increase in nitrate concentrations over decades at both well fields.

The Nitrate Issue Contributing Areas forWoodstock well numbers 2 and 4 (Tabor), have the following characteristics:

1. They lie within the land area that contributes 100% of the recharge to each well field.
2. The land use is primarily agriculture.
3. The total travel time from ground surface to the well is less than 60 years.

The areas contributing recharge to the well, but not considered to have significantly contributed to the measured nitrate at the well are:

a. The non-agricultural land use areas.
b. The areas with the total time of travel greater than 60 years.

The Issue Contributing Area (ICA), contained within the WHPA, is shown in Map 4.1-17b and reflects the areas with a total time of travel through the saturated and unsaturated zones of 60 years or less. It should be noted that the WHPA-B through D zones are delineated based on travel time through the saturated zone only (within the aquifer) and do not include time of travel from the surface to the saturated zone. As a result the 60 year total travel time used to delineate the ICA Is largely within the WHPA-D (25 year time of travel).

Activities contributing to the Nitrate issue within this ICA are considered significant drinking water threats. The source protection plan will include policies which when implemented will ensure that these activities cease to be or never become significant drinking water threats. The existing activities which are contributing to the nitrate issue are enumerated in section 7.

Since inorganic nitrogen fertilizer application became common during the last 60 years it was assumed that the nitrate mass at the wells has a total travel time less than 60 years. The majority of the nitrate mass (65%) is estimated to have a total time of travel of 25 to 60 years. Only 6% of the nitrate mass has total time of travel less than 5 years. As the majority of mass has a long time of travel to the wells from the point of nitrate application and the large amount of mass currently resident in the unsaturated zone, it’s expected that significant reductions in fertilizer application will take at least ten years before a significant reduction in nitrate concentrations at the well would be observed. This is supported by experience in the Thorton wellfield where enhanced nutrient management plans have been utilized since 2003 on lands owned by the municipality. After a decade of reduced nitrate application, reductions in nitrate levels are starting to be observed at the wells. Continued management efforts and monitoring will be necessary to confirm this trend and assess the effectiveness of the SPP policies over decades of implementation.

5.6.1 Work Plan

If a drinking water quality *issue* is identified as per Rule 114, the area and the activity contributing to a drinking water quality *issue* must also be identified as per Rule 115. In the Upper Thames River SPA, some of the *issues* are naturally occurring and are therefore understood to not be subject to Rule 115. The sources or causes of some of the other *issues* are yet to be determined. If more information becomes available to the SPC it may be possible to determine the source or cause of an *issue*. If it is determined that an *issue* (identified as per Rule 114) is wholly or partially due to anthropogenic sources, the work (to identify the area and activities contributing to the *issue*, as per Rule 115), or the work plan (as per rule 116) would be included in a subsequent assessment report.

Nitrate in the Thorton and Tabor wellfields have been identified as anthropogenic. An ICA has been delineated for the Tabor wellfield. Nitrate data from Thorton wells suggests that the levels may be leveling off and decreasing. This may be attributed to the enhanced nutrient management plans used on properties owned by the municipality. Additional monitoring is required to confirm the trend and determine if nitrate should remain an issue at these wells. The following workplan is being implemented by the County of Oxford and the Issue will be re-assessed as part of the next update to the Assessment Report.

Table 5-8 Woodstock Thorton ICA Workplan

	Task	Timeline
	Continue with Enhanced Nutrient Management Plans on County-owned farmland within the wellfield	2014 – 2015
	U. of Waterloo to monitor nitrate migration across landscape to improve conceptual understanding and refine model	On-going
	Monitor nitrate levels at each well	On-going
	Prioritize negotiation of Risk Management Plans associated with nitrate application within the wellfield	Upon effect of the TSR SPP
	Retain 3rd party consultant to analyze data, and provide recommendation regarding nitrate issue designation	2019/2020
	If necessary: • delineate ICA using Tier 3 Water Budget hydrogeological model and U. of Waterloo conceptual understanding of nitrate movement through the aquifer • identify the associated significant drinking water threats • amend Assessment Report	2020/2021

5.7 Data Gaps

Schedule 2 (chemical), Schedule 3 (radiological) and Table 4 (aesthetic and operational) data for the well raw water were limited due to infrequent sampling or short periods of data. Additional data collection would facilitate future *issues* evaluation.

There is usually no long-term (more than ten years) groundwater quality data available for *parameters* that can be considered *issues* under the Clean Water Act, making it difficult to determine long-term trends. Continued data collection in the future would aid in determining trends and better facilitate future *issues* evaluation.

As mentioned in Section 5.6, the sources or causes of some of the *issues* are yet to be determined. This is a data gap. Details of how to accomplish this determination is provided in Table 5-7. Filling of this data gap, as more information becomes available to the SPC, may help identify *issues* as per Rule 114, and possibly lead to identifying the area and activity contributing to those *issues* as required by rule 115.

Section 9.0 Data Gaps and Next Steps lists those data gaps considered to be a priority in filling, in order to meet the requirements of the Assessment Report. The 'area and activity contributing to an *issue*' data gap is brought forward to Section 9.0.

Table 5-9 Determination of Sources of an Issue

System	*Issue*	Brief Description of Work
Fanshawe (all 6 wells)	Organic nitrogen	This *issue* is possibly due to both natural and *anthropogenic* causes. Organic nitrogen may be attributed to natural sources or by *anthropogenic* sources. In groundwater aquifers, possible sources include potential use of organic fertilizers or decaying plant matter. The owner's representative agrees that prior elevated results may have been attributed to anthropogenic activities in the wellfield, and mention that recent levels are mainly low, below the detection limit. Sampling for organic nitrogen in the well raw water and soil would need to be conducted. An investigation of the ambient groundwater quality data may help further confirm the cause of the organic nitrogen. This may require additional aquifer sampling. Organic nitrogen content in the vulnerable area soil may be compared to that of an area known to not have any anthropogenic contribution of this parameter.

Table 5-9 Determination of Sources of an Issue

System	*Issue*	Brief Description of Work
Woodstock (well no. 1, 2, 3, 4, 5, 8, 11)	Nitrates	Nitrate is a naturally occurring ion that is part of the global nitrogen cycle and is ubiquitous in the environment. The main anthropogenic sources of nitrate in groundwater are the use of fertilizers, septic tanks and agricultural processes. Nitrate is not typically a naturally occurring parameter in groundwater at levels around the health related nitrate MAC of 10 mg/L and may be from anthropogenic sources. University of Waterloo has confirmed that the presence of the parameter is likely due to historical nutrient application practices on the surrounding agricultural fields. Nitrate concentrations at the wells have been increasing and the research has found that concentrations within the Wellhead Protection Area are higher than those currently seen in the production wells. (Sources of information: Bekeris, L. 2007, Haslauer, C. 2005, Padusenko, G. 2001, Robertson, W. and Sebol L. 2004). A further assessment of levels in 2014 suugests that levels may be decreasing in the Thorton wells. Additional sampling is needed to confirm the trend and assess whether nitrate is still an Issue at the Thorton wellfield. .
Birr, Melrose, Fanshawe, Hyde Park	Hardness	Identified to be naturally occurring. No further action required for this *issue* according to MECP guidance.
Melrose, Fanshawe	Turbidity	Identified to be naturally occurring. No further action required for this *issue* according to MECP guidance.
Hyde Park	Total dissolved solids	Identified to be naturally occurring. No further action required for this *issue* according to MECP guidance.
Fanshawe, Thamesford	Manganese	Identified to be naturally occurring. No further action required for this *issue* according to MECP guidance.
Sebringville	Iron	Identified to be naturally occurring. No further action required for this *issue* according to MECP guidance.
Thorndale, Mitchell, Sebringville, St. Pauls, Stratford	Fluoride	Identified to be naturally occurring. No further action required for this *issue* according to MECP guidance.
Ingersoll	Hydrogen Sulfide	Identified to be naturally occurring. No further action required for this *issue* according to MECP guidance.

6.0 Conditions Assessment

In order to protect drinking water sources, it is necessary to identify the *threats* that pose a *risk* to drinking water sources. The drinking water threats that may be considered in identified *vulnerable areas* are those due to: *prescribed activities*, *other activities*, *conditions* (past activities) and activities contributing to identified drinking water quality *issues*. A *condition* is the result of a past activity and may pose a *risk* to a drinking water source. This Section of the Assessment Report describes the situations in which a *condition* may exist, and the preliminary investigation made in assessing *conditions* in the Upper Thames River Source Protection Area. Section 5 – Issues Evaluation describes the drinking water quality *issues* identified in this source protection area, while Section 7 – Threats and Risk Assessment describes the assessment of *risks* due to *prescribed activities* and *other activities*.

The Source Protection Committee is required to identify, as a drinking water *threat*, any *Condition* of which it is aware. The *Source Protection Plan* is focused on reducing the level of *risk* associated with *threats*. The identification of *threats* in *vulnerable areas*, including those due to *conditions*, is an important step in the development of the *Source Protection Plan*. The Clean Water Act requires that *significant threats* be managed to the point that they are no longer significant. The Source Protection Committee may also develop policies for *moderate and low drinking water threats*, however it is anticipated that the types of policies which can be applied to *moderate and low threats* may not be as broad as for the *significant threats*. Policies for conditions are however anticipated to be significantly different than those for *prescribed activities* because the *activity* is no longer being undertaken and that the contaminant has already been released into the environment.

Conditions must be identified in *vulnerable areas*. The vulnerable areas are *Intake Protection Zones (IPZ), Wellhead Protection Areas (WHPA), and Highly Vulnerable Aquifers (HVA).*The delineation and assessment of *vulnerable areas* is described in Section 4 - Vulnerability

Assessment of this Assessment Report. In the Upper Thames River Source Protection Area, there are no *Intake Protection Zones*. The *Wellhead Protection Areas* are delineated around the wellheads of 22 groundwater drinking systems. Map 4-1 shows an overview of the locations of the *WHPA* in the UTRSPA, while Maps 4-1-1 to 4-1-23 show the *WHPA* for each drinking water system's wellheads. Map 4-3-2 show the *HVA* delineations.

Through the technical work on Threats and Risk Assessment, a preliminary review of data made available by the Ministry of Environment, Conservation and Parks (*MECP*) for the assessment of *conditions* was undertaken. The Threats and Risk Assessment studies involved the operating authorities of the drinking water systems and were undertaken through partnerships involving the municipalities and Conservation Authorities in the region. These studies are described in detail in Section 7 - Threats and Risk Assessment. The technical reports for these studies are listed in Table 6-1.

Table 6-1 Technical Studies on Drinking Water Threats and Risk Assessment

Drinking Water Systems	Technical Study on Threats and Risk Assessment
City of London back up wells (Fanshawe and Hyde Park wellfields), Birr, Melrose, Dorchester and Thorndale	London, Middlesex Centre and Thames Centre Wellfield Source Protection Study. Water Quality Threats and Risk Assessment Final Report.June 4, 2010. Dillon Consulting Limited.
Embro, Lakeside and Tavistock	Upper Thames River Source Protection Area. Embro, Lakeside, Mount Elgin and Tavistock Well Systems Threats Assessment. March 31, 2011. County of Oxford.
Ingersoll	Upper Thames River Source Protection Area. Ingersoll Well Systems Threats Assessment. March 31, 2011. County of Oxford.
Beachville, Hickson, Innerkip, Thamesford	Upper Thames River Source Protection Area. Beachville, Hickson, Innerkip and Thamesford Well Systems Threats Assessment. March 31, 2011. County of Oxford.
Woodstock (urban wellfield)	Upper Thames River Source Protection Area. Woodstock - Urban Well Systems Threats Assessment. March 31, 2011. County of Oxford.
Mount Elgin (existing and planned wells)	Upper Thames River Source Protection Area. Mount Elgin Threats Assessment. March 31, 2011. County of Oxford.
Woodstock - Rural Well Systems (existing and planned wells)	Upper Thames River Source Protection Area. Woodstock - Rural Well Systems Threats Assessment. March 31, 2011. County of Oxford.
Mitchell, Sebringville, St. Pauls, Stratford, St. Marys	Draft Threat Assessment – Perth County Municipal Drinking Water Systems. Schlumberger Water Services. June 2010.
Shakespeare	Draft Threat Assessment – Milverton and Shakespeare Municipal Drinking Water Systems. Schlumberger Water Services. May 6, 2010.

6.1 Conditions Assessment Methodology

6.1.1 Situations Where Conditions May Exist

The *Technical Rules: Assessment Report* identifies the types of situations within a *vulnerable area* that may be considered *conditions*. *Conditions* include any one of the following situations that exist in a *vulnerable area* and result from a past *activity*:

- the presence of a non-aqueous phase liquid in groundwater in a *highly vulnerable aquifer,* or *wellhead protection area*;
- 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*;
- the presence of a contaminant in groundwater in a *highly vulnerable aquifer* or a *wellhead protection area*, if the contaminant is listed in Table 2 of the Soil, Ground Water and Sediment Standards and is present at a concentration that exceeds the potable groundwater standard set out for the contaminant in that Table;
- the presence of a contaminant in surface soil in a surface water *intake protection zone*, if the contaminant is listed in Table 4 of the Soil, Ground Water and Sediment Standards is present at a concentration that exceeds the surface soil standard for industrial/ commercial/community property use set out for the contaminant in that Table; and
- the presence of a contaminant in sediment, if the contaminant is listed in Table 1 of the Soil, Ground Water and Sediment Standards and is present at a concentration that exceeds the sediment standard set out for the contaminant in that Table.
- the presence of a contaminant in groundwater that is discharging into an intake protection zone, if the contaminant is listed in Table 2 of the Soil, Ground Water and Sediment Standards, the concentration of the contaminant exceeds the potable groundwater standard set out for that contaminant in the Table, and the presence of the contaminant in groundwater could result in the deterioration of the surface water for use as a source of drinking water.

Conditions in a *HVA* or *WHPA* may exist as a result of the presence of non-aqueous phase liquids in groundwater. Non-aqueous phase liquids do not mix with water. Light Non-Aqueous

Phase Liquids (*LNAPLs*) float on top of water, and examples are oil and gasoline. Dense Non-Aqueous Phase Liquids (*DNAPLs*) are liquids that do not mix with water and are heavier than water. *DNAPLs* are of concern in groundwater since they sink into the ground, settle at the bottom of and contaminate an aquifer. Examples of where *DNAPLs* are used include: dry cleaning, wood preservation, asphalt operations, machining, and in the production and repair of automobiles, aviation equipment, munitions, and electrical equipment (Source of information: http://www.ec.gc.ca/eau-water/default.asp?lang=En&n=6A7FB7B2-1#sub3).

The Soil, Ground Water and Sediment Standards refer to an MECP publication, 'Soil, Ground Water and Sediment Standards for Use under Part XV.1 of the Environmental Protection Act' (March 9, 2004). This document, consisting of 6 tables (called Tables 1 to 6), sets out the prescribed contaminants and the applicable site condition standards for those contaminants for the purposes of Part XV.1 ('Records of Site Condition') of the *Environmental Protection Act*. The prescribed standards for contaminants are set out by indicating the maximum concentrations of the contaminants in soil, groundwater and sediment for a type of property use (such as agricultural or commercial). These are expressed in microgram per gram (µg/g) dry weight for soil and sediment, and as microgram per litre (µg/L) for groundwater, unless otherwise indicated in the table. Contaminants listed in the tables include metals, nutrients, polyaromatic hydrocarbons, pesticides, petroleum constituents and dense non-aqueous phase liquids.

Table 1 ('Full Depth Background Site Condition Standards') is used to determine if conditions exist in sediments of a vulnerable area. The sediment standards in Table 1 are values within the range of measured background sediment where data are available in the 1993 Sediment Guidelines and are considered to provide a level of human health and ecosystem protection consistent with background, and protective of sensitive ecosystems. These sediment standards are for all property uses. Table 2 ('Full Depth Generic Site Condition Standards in a Potable Ground Water Condition') is used to determine if a condition exists in the groundwater of a *WHPA* or *HVA*, by comparing the contaminant concentration with the standard for potable groundwater, which applies to all property uses. Table 4 ('Stratified Site Condition Standards in a Potable Ground Water Condition') is used to determine if a condition exists in the surface soil of an *IPZ*, in properties used for industrial, commercial or community purposes.

6.1.2 Information Used to Identify Conditions

A preliminary investigation of situations that may be *conditions* has been undertaken based on information available. To date, investigation of *conditions* includes the following measures:

- Those undertaking municipal technical studies were requested to determine if there are *conditions* which the plant operating authorities are aware of. If such a concern was identified, the consultants were to investigate to determine if it was in fact a *condition*.
- *MECP* provided information from their local offices to determine if their files contain any information which might lead to identifying a *condition*. This information was restricted to a fixed radius around intakes and wells. Although it has been provided to the consultants for their consideration, not all of the consultants have been able to review the information. Further, the information does not include the entire *vulnerable areas*.
- It is anticipated that stakeholders, including the public, may identify situations which they believe may be a concern and will require investigation to determine if they are *conditions*. Some of these have been identified, but are yet to be reviewed to determine if they should be considered a *condition*.

The two sets of data made available by the Ministry of Environment, Conservation and Parks (*MECP*) to check for conditions are data from the 'Brownfields Registry' and '*MECP* Data Scanning'. Brownfields are lands on which industrial or commercial activity took place in the past and that may need to be cleaned up before they can be redeveloped. The Brownfields Registry data from *MECP* contained summarized information from individual Records of Site Condition (*RSC*) available on the Brownfields Site Registry. The Brownfields Environmental Site Registry provides access to the individual *RSCs* where contamination information about each individual *RSC* property is documented. Records of Site Condition are not a listing of all contaminated sites in the province (no such list exists). The information provided is only applicable to properties that have undergone a land use change and for which an *RSC* has been accepted. The Brownfields data from *MECP* contained all records up to December 11, 2008. The *MECP* Data Scanning information included all Ministry of the Environment, Conservation and Parks files pertaining to water, within 500 metres around a groundwater wellhead and 1000 m around a surface water intake.

6.1.3 Risk Assessment Methodology for Conditions

Should the committee become aware of a *condition* as described above, the *condition* is to be considered a *drinking water threat*. As with all *drinking water threats*, the *risk score* of a *condition* is identified in the *Technical Rules: Assessment Report*, as the product of the *vulnerability score* and *hazard score*.

Risk = Vulnerability X Hazard

The assessment of *prescribed activities*, *other activities* and a description of the *MECP Table of Drinking Water Threats* 2017 is provided in Section 7 – Threats and Risk Assessment of this Assessment Report. As per Technical Rule 139 (Nov. 2009), the *hazard score* of a *condition* is:

(a) **10**, if there is evidence that the situation is causing off-site contamination

(b) **10**, if the *condition* is on a property where a well, intake or monitoring well (existing and planned drinking water systems that are major residential, included in the Terms of Reference by resolution or upon order of the Director, or serve reserves) is located

(c) **6**, if (a) and (b) do not apply.

The *risk score* of a *threat* due to a *condition* in *IPZ, WHPA, HVA* would depend on the *vulnerability scores*, and whether the *hazard score* of the *condition* is 6, or 10. Table 6-2 shows the general relationship between the *hazard score* and the resulting *threat* level for *conditions*.

Table 6-2 Threat Level Determination for Conditions

Hazard Score	Vulnerability Score	Risk Score	Threat Level
10	8 or greater	80 or greater	Significant*
	6 to less than 8	60 to less than 80	Moderate
	Greater than 4 but less than 6	Greater than 40 but less than 60	Low
	4 or less	40 or less than 40	No threat
6	Not possible	80 or greater	Significant*
	10	60 to less than 80	Moderate

	7 to less than 10	Greater than 40 but less than 60	Low
	Less than 7	40 or less than 40	No threat

*There are additional scenarios where, regardless of the risk score, a threat is considered significant

While the *risk score* helps determine *threat* level, other factors that determine *threat* level for *conditions* are described below. According to Rule 140.1, a *condition* is deemed a *significant threat* in an *Intake Protection Zone* if an *IPZ-3* is delineated due to the *condition*. According to Rule 141, a *condition* resulting from a past *activity* would be deemed a *significant threat* if:

- it is associated with an identified drinking water quality *issue*;
- it is identified as a *threat* that contributes (or may contribute) to an *issue*;
- it is located in an identified *issue*-contributing area within a *vulnerable area*; and
- there is evidence that the *condition* is or may be causing off-site contamination, or the *condition* is on a property where a well, intake or monitoring well is located.

6.2 Conditions Assessment Findings

The efforts completed to date serve as a preliminary screening for known situations which the Source Protection Committee should consider in developing a *Source Protection Plan* for the area. A more comprehensive investigation will be conducted when more information is available. Known situations in the Upper Thames River *Source Protection Area* are described below.

At the Mitchell municipal well supply system, a spill containing polychlorinated biphenyls (*PCBs*) occurred in the WHPA-A of well 4, at a fomer dairy industry site. No further data on this spill are available yet.

At the Stratford municipal well supply system, a former landfill is identified as a potential condition west of the Romeo wells 3, 4 and 6. No data on this former landfill are available yet.

At the St. Marys municipal well supply system, there is an old fuel storage, which was remediated in 2008, located within the St. Marys *WHPA*, to the east of Well No. 1. There is also an old fuel storage and fill area along the Thames River, within the WHPA-A of Well No. 2. In this area, there are buried petroleum and concrete degreasing tanks. Therefore the *MECP* requested an Environmental Assessment to be conducted prior to the construction of Well No. 2. The findings of the 2005 report indicate that the historical activities do not impact the well water quality.

A site of historical contamination occurred at Woodstock within the *HVA*, not in the Woodstock *WHPA*. According to *MECP*, there was a historical underground storage tank leakage site in the late 1990's. Petroleum hydrocarbon related subsurface contamination still exists as of 2010. Impacts include free product light non- aqueous phase liquids, soil contamination, and relatively large groundwater plume.

6.3 Data Gaps and Next Steps for Conditions

Data on past activities that have resulted in potential *conditions* are sparse, thus a comprehensive investigation is yet to be conducted. If information such as:

- data from the Spills Action Centre of the *MECP*;
- additional data from *MECP* regional files (*MECP* Data Scanning) for *WHPA , IPZ , HVA* where the vulnerability is greater than 4

were made available to the Source Protection Committee, this information would be reviewed to determine if the situation might meet the criteria of a *condition*. Findings would be included in a subsequent Assessment Report.

Section 9.0 Data Gaps and Next Steps lists the remaining data and information gaps, including the ‘conditions assessment’.

7.0 Threats and Risk Assessment – Water Quality

In order to protect drinking water sources, it is necessary to identify the *activities* within *vulnerable areas* that pose a *threat* to drinking water sources. It is also necessary to assess the *risks* due to the identified *threats*. This section describes the *threats* and *risk* assessment work pertaining to water quality, conducted in the Upper Thames River Source Protection Area. The *risk* associated with water quantity *threats* is considered in Section 3 - Water Budget and Water Quantity Stress Assessment of the Assessment Report.

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 source of drinking water" (Clean Water Act, 2006). *Risk* Assessment is the process of assessing the *threats* to determine their relative *risk* to the drinking water source. It considers the vulnerability of the area that the *activity* is being undertaken in. It also considers the hazard associated with the *activity*.

Following the completion of the Assessment Report, a *Source Protection Plan* must be developed by the Source Protection Committee. The focus of the *Source Protection Plan* is to reduce *risks* to drinking water sources by managing the *threats* causing those *risks*. The *Source Protection Plan* will contain policies focused on *activities* which are identified as *threats* within the *vulnerable areas*. Hence, the identification of the *threats* and the assessment of *risks* due to the *threats* are key to the development of the Source Protection Plan. Further, the *Source Protection Plan* must mitigate those *risks* to drinking water sources that are deemed to be *significant*. The policies related to *significant threats* are mandatory and must be implemented. Source protection policies may include incentive programs, education and outreach, new or amended provincial instruments, and *risk* management plans.

The *Threats* and *Risk* Assessment studies involved the operating authorities of the drinking water systems and were undertaken through partnerships involving the Conservation Authorities in the region. Dillon Consulting Ltd., Schlumberger Water Services and the Count of Oxford completed the *threats* and *risk* assessment work for the groundwater systems in the Upper Thames River SPA.

The technical reports for the above described studies are listed in Table 7-1 below:

Table 7-1 Technical Studies on Drinking Water Threats and Risk Assessment

Drinking Water Systems	Technical Study on Threats and Risk Assessment
City of London back up wells (Fanshawe and Hyde Park wellfields), Birr, Melrose, Dorchester and Thorndale	London, Middlesex Centre and Thames Centre Wellfield Source Protection Study. Water Quality Threats and Risk Assessment Final Report.June 4, 2010. Dillon Consulting Limited.
Embro, Lakeside and Tavistock	Upper Thames River Source Protection Area. Embro, Lakeside and Tavistock Well Systems Threats Assessment. March 31, 2011. County of Oxford.
Ingersoll	Upper Thames River Source Protection Area. Ingersoll Well Systems Threats Assessment. March 31, 2011. County of Oxford.
Beachville, Hickson, Innerkip, Thamesford	Upper Thames River Source Protection Area. Beachville, Hickson, Innerkip and Thamesford Well Systems Threats Assessment. March 31, 2011. County of Oxford.
Woodstock (urban wellfield)	Upper Thames River Source Protection Area. Woodstock - Urban Well Systems Threats Assessment. March 31, 2011. County of Oxford.
Mount Elgin (existing and planned wells)	Upper Thames River Source Protection Area. Mount Elgin Threats Assessment. March 31, 2011. County of Oxford.
Woodstock - Rural Well Systems (existing and planned wells)	Upper Thames River Source Protection Area. Woodstock - Rural Well Systems Threats Assessment. March 31, 2011. County of Oxford.
Mitchell, Sebringville, St. Pauls, Stratford, St. Marys	Draft Threat Assessment – Perth County Municipal Drinking Water Systems. Schlumberger Water Services. June 2010.
Shakespeare	Draft Threat Assessment – Milverton and Shakespeare Municipal Drinking Water Systems. Schlumberger Water Services. May 6, 2010.
Perth, Town of St. Marys and City of Stratford Sewer Threats Analysis	Technical Memorandum - Sewer Line Threats Assessment - Perth County Municipal Drinking Water Systems. Schlumberger Water Services. May 2011
Pasture Lands and Outdoor Confinement Area Threats Analysis for all systems	Thames-Sydenham and Region. Jason Wintermute. Technical Memo regarding the Assessment of Chemical Threats from the Use of Land as Livestock Grazing, Pasturing Land, and Outdoor Confinement Area or a Farm-Animal Yard. March 2011.
Perth, Middlesex,Chatham-Kent systems	Thames-Sydenham and Region, Technical Memo Terry Chapman, Stephen Clark

From these technical studies, information is compiled and provided in this section of the Assessment Report. This section is organized into discussions on the types of *activities* that may be considered as drinking water quality *threats*, the methodology used to identify *threats* and assess *risks*, the lists of *threats* in *vulnerable areas* with maps showing these, and lastly the next steps and data gaps.

7.1 Drinking Water Quality Threat Identification and Risk Assessment Methodology

Drinking water quality *threats* in *vulnerable areas* must be identified and assessed as to their *risk* to the drinking water source. The *vulnerable areas* are *Intake Protection Zone (IPZ), Wellhead Protection Area (WHPA),* and *Highly Vulnerable Aquifers (HVA) IPZ* are comprised of *IPZ-1, IPZ-2* and *IPZ-3*, while *WHPA* are comprised of *WHPA-A, WHPA-B, WHPA-C, WHPA-D, and possibly, WHPA-E* and *WHPA-F*. The vulnerability assessment (including delineation and assignment of vulnerability scores) of these *vulnerable areas* is described in Section 4 - Vulnerability Assessment of this Assessment Report. In the Upper Thames River Source Protection Area, there are no surface water intakes. The *WHPA-A, WHPA-B, WHPA-C, WHPA-D* and *WHPA-E* are delineated. As discussed in Section 4.3.4, *WHPA-F* was not required to be delineated. In the Upper Thames River Source Protection Area, 21 drinking water systems draw their source water from groundwater aquifers. Map 4-1 shows the location of the *WHPA* around municipal wellheads. Map 4-3-2 shows the delineated *HVA* in the Upper Thames River Source Protection Area.

The drinking water quality *threats* that may be considered in the identified *vulnerable areas* are those due to: *prescribed activities*, *other activities*, *conditions* (past *activities*) and *activities* contributing to identified drinking water quality *issues*. The *Technical Rules: Assessment Report* Part XI describes the listing of drinking water quality *threats*. In the Thames-Sydenham and Region, a local guidance document was developed to provide clarification and local interpretation of the relevant sections in the Clean Water Act, its regulations and the associated *technical rules* pertaining to the *threats* and *risk* assessment. The methodology is included in Appendix 10.

To identify where low, moderate and significant threats can be identified it is recommended to use both the Ontario Drinking Water Threats and Circumstances Table Tool and link that so the WHPAs and IPZs scoring maps.

The sections below summarize the types of *threats* and the methodology followed in the region to identify *threats* and assess *risks*.

7.1.1 Prescribed Drinking Water Threats

Through the Clean Water Act and General Regulation 287/07, a list of 22 *prescribed* drinking water *threats* is provided. That list is reproduced in Table 7-2.

Table 7-2 Activities Prescribed as 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*.
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.
20. An activity that reduces the recharge of an aquifer.
21. The use of land as livestock grazing or pasturing land, an outdoor confinement area or a farm-

Table 7-2 Activities Prescribed as Drinking Water Threats

animal yard.
22. The establishment and operation of a liquid hydrocarbon pipeline. O. Reg.206/18, s. 1

The *risk* associated with *activities prescribed* as water quantity related *threats* (numbers 19 and 20 in the above table) are considered in Section 3 - Water Budget and Water Quantity Stress Assessment of this Assessment Report. The *activities* 1 to 18 and 21 are *prescribed* drinking water *threats* related to drinking water quality and are discussed in this section. They may be summarized into:

- Application, handling and storage of *agricultural source material* (manure), *non-agricultural source material* (bio-solids), commercial fertilizer, pesticide or road salt
- Handling and storage of fuel, *dense non-aqueous phase liquids*, or organic solvents
- Management of runoff that contains aircraft de-icing chemicals
- Livestock grazing or pasturing land, outdoor confinement areas or farm-animal yards
- Snow storage
- Systems that collect, store, transmit, treat or dispose of sewage
- Waste disposal sites

An *activity* may pose a *risk* to drinking water quality based on the following factors which are described further in this section:

- the *vulnerable area* where the *activity* is located;
- the vulnerability score assigned to that area;
- the *circumstances* related to the *activity*; and
- the *hazard score* resulting from the *activity* under the *circumstances* related to the *activity*.

An *activity* is deemed to be a significant, moderate or low *threat* depending on the calculated *risk* score. The *risk* score is calculated by multiplying the vulnerability score assigned to a *vulnerable area* with the hazard score of the *activity*.

Risk = Vulnerability X Hazard

Table 7-3 shows the relationship between the *risk* score calculated and the resulting *threat* level. The highest possible *risk* score is 100. A *risk* score of 80 or greater results in a *significant threat* level. Some exceptions include *issue*-based *threats* which are deemed *significant* regardless of the vulnerability area and score (if the *issue*, identified at a drinking water system included in the Terms of Reference, is partially or wholly due to anthropogenic causes, as per Rules 114 and 115, and activities contributing to it are within an *IPZ* or *WHPA*), and *activities* related to *Dense Non-Aqueous Phase Liquids* (*DNAPLs*) which are *significant threats* in *WHPA-A* (100 m radius), *WHPA-B* (2 year capture zone excluding A), and *WHPA-C* (2 to 5 year capture zone) regardless of the vulnerability score. In *WHPA-D* (5 to 25 year capture zone), *WHPA-E* and *WHPA-F*, *dense non-aqueous phase liquids* (*DNAPLs*) are considered under chemical *threats*. *Pathogens* are not viewed as *threats* outside of *WHPA-A, WHPA-B, WHPA-E* and *IPZ-1* and *IPZ-2*. *WHPA-E* and *WHPA-F* are delineated for drinking water systems designated to be *groundwater under the direct influence of surface water* (*GUDI*).

Table 7-3 Threat Level Determination

Risk Score	Threat Level
80 or more	Significant
60 or greater, but less than 80	Moderate
Greater than 40, but less than 60	Low
40 or less than 40	No threat

Another approach to identifying drinking water quality threats is the events based approach. According to Technical Rule 130 and the MECP Technical Bulletin on groundwater quality analysis (July 2009), if modeling can show that activities in a vulnerable area cause a deterioration of the water source for purposes of drinking, then those activities are *significant threats* to the drinking water source.

As mentioned earlier, the *vulnerable areas* are *IPZ, WHPA, and HVA*. As there are no surface water intakes in the Upper Thames River SPA, there are no *IPZ*s. According to the *Technical Rules: Assessment Report*, vulnerability scores for *WHPA* range from 2 to 10 (depending on whether it is for *WHPA-A, WHPA-B, WHPA-C, WHPA-D, WHPA-E* or *WHPA-F*). Through the vulnerability scoring approach, an *activity* can only be identified as a *threat* if it is occurring in a *vulnerable area* and the vulnerability score of the area is greater than 4. In an area where the vulnerability score is 8 or greater, the *threat* may be *significant* (dependent on the *circumstances* associated with the *activity*). *WHPA-A*, *WHPA-B, WHPA-C, WHPA-E* and *WHPA-F* can have vulnerability scores of 8 or greater. As a result, it is possible to have *significant threats* in *WHPA-A, WHPA-B, WHPA-C, WHPA-E* and *WHPA-F*, dependent upon the assigned vulnerability score. As discussed in Section 4.3.4, *WHPA-F* was not required to be delineated. *HVA* are assigned a vulnerability score of 6 while *SGRA* are not assigned a vulnerability score. Hence there can be no *threats* in *SGRA,* and no *significant threats* in *HVA*, through the vulnerability scoring approach.

In order to assess the *risks* due to the *prescribed* drinking water quality *threats*, the Ministry of Environment, Conservation and Parks (*MECP*) has developed '*Tables of Drinking Water Threats (2013)* ' based on the 21 *prescribed threats*. The *MECP tables of drinking water threats* (2013) include the results of the *risk* score calculation and identify the *threat* level associated with an *activity* based on the vulnerability score of the area in which the *activity* is being undertaken. The *MECP tables of drinking water threats* (2013) provide the *circumstances* under which an *activity* may be categorized as a low, moderate or *significant threat*. Hence, the *circumstances* of the *activity* are considered to determine the level of *risk* associated with a water *threat*. The *circumstances* to be considered include the type of material, the quantity of material and whether it might be released to surface water or groundwater. Each combination of *circumstances* for an *activity* is assigned a hazard score. The hazard score ranges between 4.1 to 10 for chemical *threats*, 5 to 10 for *pathogens*, and 8.3 to 10 for *DNAPLs*. There are two separate tables in the *tables of drinking water threats* (2013/2017) for *activities* related to chemicals and for *activities* related to pathogens. The *MECP tables of drinking water threats* (2013/2017) are available at:
http://www.ontario.ca/environment-and-energy/tables-drinking-water-threats

The MECP tables of circumstances are not currently available on a single page on the MECP website however they may be searched individually from the following page by searching “provincial table” on the MECP website at:
https://www.ontario.ca/environment-and-energy/provincial-tables-circumstances.

See Maps 7-3-1 to 7-3-23 for activities related to chemicals, *DNAPLs* and pathogens that are low, moderate or *significant threats*. These maps also contain tables indicating the possible level of threat dependent on the *WHPA* zone and the vulnerability score. Refer to Appendix 10 for detailed lists of low, moderate or *significant threats* and the *circumstances* under which they occur.

Chemicals

Chemicals include, but are not limited to, nitrogen and phosphorus (related to the prescribed drinking water threat of application of commercial fertilizers, and *agricultural source material and non-agricultural source material* to land), atrazine, dicamba, glyphosate (related to the application of pesticide on land), *BTEX*, certain petroleum hydrocarbons (related to the handling and storage of fuel), chloroform (related to the handling and storage of organic solvent), sodium and copper (related to the storage of snow). In the *tables of drinking water threats (2013/2017)*, *dense non-aqueous phase liquids* (*DNAPLs*) such as trichloroethylene and vinyl chloride are considered as chemicals but only in *WHPA-D*, *WHPA-E* and *WHPA-F*. The consideration of *DNAPLs* in *WHPA-A, WHPA-B* and *WHPA- C* is described below.

Dense Non-Aqueous Phase Liquids

Dense non-aqueous phase liquids (*DNAPLs*) are considered separately from other chemical related *activities* in *WHPA-A, WHPA-B* and *WHPA-C*. *DNAPLs* are heavier than water and do not mix with water. They are of concern in groundwater since they sink into the ground, settle at the bottom of and contaminate an aquifer. Examples of *activities* or products containing *DNAPLs* include: dry cleaning, wood preservation, asphalt operations, machining, pesticides, brake cleaners, glues, varnishes, production and repair of automobiles, aviation equipment (source of information: http://www.ec.gc.ca/eau-water/default.asp?lang=En&n=6A7FB7B2-1#sub3). The *activities* related to the handling and storage of *Dense Non-Aqueous Phase Liquids* (*DNAPLs*) are deemed *significant threats* in *WHPA-A*, *WHPA-B* and *WHPA-C*, regardless of the vulnerability score. In *WHPA-D*, *WHPA-E* and *WHPA-F*, *dense non-aqueous phase liquids* (*DNAPLs*) are considered under chemical *threats*.

Pathogens

Pathogens are disease-causing microorganisms. In the *tables of drinking water threats (2013/2017)*, they are not limited to a specific list of types of pathogens. *Activities* that may cause the presence of pathogens include, but are not limited to, the application of *agricultural* *source material and non-agricultural source material* to land, livestock grazing, and sewage discharge. *Pathogens* are not viewed as *threats*, outside of *WHPA-A, WHPA-B, WHPA-E* and *IPZ-1* and *IPZ-2*.

Locations at which Significant Threats Occur

The Clean Water Act requires the enumeration of locations at which a *significant threat* is thought to occur. Also, a list of *activities* which are or 'would be' *threats* is to be included. Generally, this is addressed by including all *activities* listed in the *prescribed* lists even if they are not currently occurring in an area. *Activities* not currently occurring in the *vulnerable areas*, 'would be' *threats* if the *activity* was to occur in the future. The *circumstances* which result in *significant threats* must also be identified in the Assessment Reports.

Mapping of Impervious Area, Managed Lands and Livestock Density

As part of the identification of certain *prescribed* chemical drinking water *threats*, an intermediate step involving the creation of maps showing impervious area (see Maps 7-1-1 to 7-1-23), managed lands and livestock density (see Maps 7-2-1 to 7-2-23) is necessary. A determination of the percentage of impervious area is needed to determine the level of *threat* associated with the application of road salt. Also, the percentage of managed lands and the livestock density are required, as this is related to the level of *threat* for the application of *agricultural source material* (*ASM*), commercial fertilizer or *non-agricultural source material* (*NASM*).

Any pathogen *threats* associated with these *activities* (related to the application of *ASM* and *NASM*) are assessed separately using the pathogen table of the *tables of drinking water threats (2013/2017)*.

The calculations made to map the impervious area, managed lands and livestock density are described briefly below.

Impervious Area

For determining the *risk* level associated with the application of road salt, the percentage of impervious area must be determined. Impervious areas related to application of road salt include roads, parking areas and sidewalks. The percentage of impervious surface areas must be calculated within each square kilometre of *vulnerable areas* (Rule 16). The extent of each square kilometre is determined by overlaying a 1 kilometre by 1 kilometre grid over the *vulnerable area* with a node of the grid located at the centroid of the Source Protection Area. Geographic Information System (*GIS*) tools were used to undertake this calculation for each grid which touched a *vulnerable area*. Within the WHPAs, on-screen digitizing was performed using colour orthophotography from 2006 to delineate areas of paved road, parking lots, driveways and sidewalks. In the case of *HVA*s, the Southern Ontario Land Resource Information System (SOLRIS) land classification was used to delineate roads and, in conjunction with the orthophotography, was use to delineate parking lots, driveways and sidewalks. The area of paved surface within each of the grid cells described above was divided by the area of the *vulnerable area* within that same grid cell to determine the percentage of impervious surface area.

Managed Lands

In determining the percentage of managed lands, Source Protection committees must determine the areas where there may be application of *agricultural source material* (*ASM*), commercial fertilizer, or *non-agricultural source material* (*NASM*). These areas are expressed as percentages of the total area being evaluated. Managed lands can be broken into two types: agricultural managed land and non-agricultural managed land. Agricultural managed land includes areas of cropland, fallow and improved pasture that may receive nutrients. Non-agricultural managed lands include golf courses (turf), sports fields, lawns (turf) and other built-up grassed areas that may receive nutrients (primarily commercial fertilizer). Both managed land and agricultural managed lands are to be delineated within each of the *vulnerable areas* (individually for each *WHPA-A*, *WHPA-B*, *WHPA-C*, *WHPA-D*, *WHPA-E*, *WHPA-F*, well as for *HVA*). Mapping the percentage of managed lands is not required where the vulnerability score for an area is less than the vulnerability score necessary for the *activity* to be considered a *threat* in the Table of Drinking Water *Threats 2017*. Within the *WHPA*s, on-screen digitizing was performed using colour orthophotography from 2006 to delineate agricultural managed lands. In the case of *HVA*s, Municipal Property Assessment Corporation (MPAC) information and the SOLRIS land classification was used to delineate agricultural managed lands. Within the *WHPA*s, non-agricultural managed lands were determined using MPAC information and orthophotography to select areas of green from commercial, industrial and residential properties. In the case of *HVA*s, the SOLRIS land classification was used with orthophotography to select areas of green from commercial, industrial and residential properties.

The percentage of managed land area within a *vulnerable area* is the sum of agricultural managed land and non-agricultural managed land, divided by the total area of all land within a *vulnerable area*, multiplied by 100. This was undertaken for each part of the *WHPA* which has been delineated and for the *HVA*s as a whole. Where a parcel of managed land is partially within a *vulnerable area*, only the portion of the parcel within the *vulnerable area* is used in the calculations.

Livestock Density

Livestock density is used as a surrogate measure of the potential for generating and land applying *Agricultural Source Material* (*ASM*) as a source of nutrients within a defined area. The livestock density is expressed in nutrient units per acre. The calculation of livestock density in a specified area requires the following steps:

1. Estimate the number of each category of animals present within the specified area,
2. Convert the number of each category of poultry and livestock present into nutrient units (NU), to enable all livestock to be compared on an equivalent unit of measure in terms of the nutrients produced by each type,
3. Sum the total NU of all categories of poultry and livestock within the specified area and then divide this NU value by the area of agricultural managed land within the same specified area. The determination of the agricultural managed land is described above.

The NUs within a *vulnerable area* were determined using the MPAC data to screen for livestock operations, the orthophotography to determine livestock barn size and the table provided in a MECP Technical Bulletin to convert the barn area into NUs. For the Oxford well systems, in addition to air photo interpretation, notes and photos from windshield surveys were utilized to arrive at an estimation about the type of livestock housed in a particular structure.

Livestock density is to be calculated within each of the *vulnerable areas* (individually for each *WHPA-A*, *WHPA-B*, *WHPA-C*, *WHPA-D*, *WHPAE*, *WHPA-F*, as well as for *HVA* and *SGRA*). Mapping the livestock density is not required where the vulnerability score for an area is less than the vulnerability score necessary for the *activity* to be considered a *threat* in the Table of Drinking Water *Threats 2017*.

Risk Assessment using Managed Lands and Livestock Density

The percentage of managed land and the livestock density of an area are used together as a surrogate for representing the quantity of nutrients present as a result of nutrient generation and land application within an area. The *risk* assessment using managed lands and livestock density calculations is described below.

Chemical Threats Related to the Land Application of Nutrients

Table 1 of the *tables of drinking water threats* (2013/2017) requires that the maps for both percentage of managed lands and livestock density be considered when evaluating the *circumstances* with regard to each of the thresholds for land application of nutrients. Table 7-4 summarizes the chemical hazard scores for various combinations of percentage of managed lands and livestock densities. These are the consolidated hazard scores, incorporating the quantity, toxicity and fate scores. The highlighted combinations of percentage of managed land and NU/Acre give a hazard rating for land application of nutrients that, when combined with the area vulnerability scores of 9 or 10, would result in *significant risk* to source waters. To calculate *risk*, the hazard score is multiplied by the vulnerability score for the area.

Table 7-4 Chemical Hazard Scorings for Various Combinations of Percentage of Managed Lands and Livestock Densities

Percentage Managed Land of Total Land	Nutrient Units (NU) per Acre of Cropland		
	< 0.5 NU/acre	0.5 to 1.0 NU/acre	> 1.0 NU/acre
GROUNDWATER			
> 80%	8 Significant in areas of Vulnerability Score 10	8.4 Significant in areas of Vulnerability Score 10	8.4 Significant in Areas of Vulnerability Score 10
40 to 80%	6.8	7.6	8.4 Significant in areas of Vulnerability Score 10
< 40%	6	6.8	8 Significant in areas of Vulnerability Score 10
SURFACE WATER			
> 80%	8.8 Significant in areas of Vulnerability Score 10	9.2 Significant in areas of Vulnerability Score 10 or 9	9.2 Significant in areas of Vulnerability Score 10 or 9
40 to 80%	7.6	8.4 Significant in areas of Vulnerability Score 10	9.2 Significant in areas of Vulnerability Score 10 or 9
< 40%	6.8	7.6	8.8 Significant in areas of Vulnerability Score 10

Chemical Threats Related to the Use of Land for Livestock Grazing, Pasturing or Outdoor Confinement Area or Farm-Animal Yard

In general, the use of land as livestock grazing or pasture land will be a *significant* chemical *threat* in:

- *Vulnerable Areas* scoring 9 if the livestock density is sufficient to generate nutrients at an annual rate that is more than 1.0 Nutrient Units per acre (NU/acre); or
- *Vulnerable Areas* scoring 10 if the livestock density is sufficient to generate nutrients at an annual rate that is at least 0.5 NU/acre for surface water (in an *IPZ*) or more than 1.0 NU /acre for groundwater; and
- if the land use may result in the presence of Nitrogen or Phosphorus in surface water or Nitrogen in groundwater. The *tables of drinking water threats* (2013/2017) refer to Phosphorus in groundwater, but do not identify any *threats* associated with it in a *WHPA*.

The use of land as livestock outdoor confinement area or a farm-animal yard will be a *significant* chemical *threat* in:

- *Vulnerable Areas* scoring 10 if the number of animals confined in the area at any time is sufficient to generate nutrients at a rate of more than 300 nutrient units (NU) per hectare of the area annually for groundwater and at a rate of more than 120 NUs per hectare of the area annually for surface water (*IPZ*); or
- *Vulnerable Areas* scoring 9 if the number of animals confined in the area at any time is sufficient to generate nutrients at a rate of more than 120 NUs per hectare of the area annually for surface water (in an *IPZ*); and
- the land use may result in the presence of Nitrogen or Phosphorus in surface water or Nitrogen in groundwater. The *tables of drinking water threats (2013/2017)* refer to Phosphorus in groundwater, but do not identify any *threats* associated with it in a *WHPA*.

In determining chemical threats related to the use of land for livestock grazing, pasturing or outdoor confinement area or farm animal yard, a livestock density value is used. This value is calculated using the same methodology as described above, but is performed on an individual farm parcel rather than the whole of a *vulnerable area*.

Chemical Threats Related to Agricultural Source Material Storage

The *technical rules* and associated *tables of drinking water threats (2013/2017)* state that the use of land to store *Agricultural Source Material* (*ASM*) would be a *significant* chemical *threat* in *Vulnerable Areas* scoring 9 or 10 if the weight or volume of manure stored annually on a farm parcel is sufficient to annually land apply nutrients at a rate that is more than 1.0 Nutrient Units per Acre (NU/Acre) of the farm parcel. Under the Table of Drinking Water *Threats* (2013/2017) this is determined by the NU stored on farm parcel divided by the size of farm parcel. Furthermore, another *circumstance* for *ASM* storage is that a spill of the material or runoff from the area where the material is stored (i.e. a point source release) may result in the presence of Nitrogen or Phosphorus in groundwater (*WHPA*) or surface water (*IPZ*).

7.1.2 Other Activities

The Clean Water Act also allows the Source Protection Committee to include *activities* that they consider being drinking water *threats* but are not *prescribed* drinking water *threats*. These are called *other activities* (Rule 119). The Source Protection Committee can also identify additional *circumstances* (not already in the *tables of drinking water threats (2013/2017)*) under which they consider the *activity* to be a *prescribed* drinking water *threat*. The Source Protection Committee is considering a few such *other activities*, as discussed in Section 7.3. These include geothermal systems (harnessing underground temperature) and transportation corridors (shipping or road transport of materials).

Other activities may be listed as *threats* only if the Source Protection Committee identifies them as drinking water *threats*, and similar to the *prescribed threats*, if the hazard score is greater than 4 and the *risk* score calculated is greater than 40. The hazard score must be calculated based on certain criteria set out in the *technical rules*, and further must be agreed upon by the Director (*MECP*).

7.1.3 Threats Arising from Conditions

Conditions are a result of past *activities*. In general, *conditions* are the presence of:

- non-aqueous phase liquids in *WHPA*, *HVA*
- a single mass of more than 100 litres of *dense non-aqueous phase liquids* in surface water in an *IPZ*
- a contaminant in the groundwater of an *HVA* or *WHPA*, in surface soil of an *IPZ*, or in sediments in a *vulnerable area*, that exceeds a certain *MECP* 'criteria' for different land uses

The list above is only a summary of the types of situations that can be considered *conditions*. The actual list of situations are in Section 6 - Conditions Assessment of the Assessment Report, along with what the *MECP* 'criteria' are from *MECP* published tables of standards for soil, groundwater and sediments for land uses such as commercial, residential and industrial.

If *Conditions* (resulting from past *activities*) are identified, the hazard score is either 6 or 10 depending on certain factors (Rule 139). There are additional scenarios where, regardless of the *risk* score, a *condition* is a *significant threat*. These scenarios are when a *condition* is related to a drinking water quality *issue* (known to be partially or wholly due to anthropogenic causes; see Section 7.1.4 below) or an *IPZ-3*. For more information, refer to Section 6 – Conditions Assessment of this Assessment Report.

7.1.4 Threats Arising from Issues

A drinking water *issue* is a *parameter* (a substance) or *pathogen* (a disease-causing microorganism) which is shown to deteriorate, or trends towards a deterioration of raw (untreated) water quality for the purposes of drinking. The *issues* identified in the Upper Thames River Source Protection Area are summarized in Section 5 - Issues Evaluation of the Assessment Report.

According to Rules 114, 115, 131 and 141, *activities* or *conditions* that contribute to drinking water quality *issues* (known to be partially or wholly due to *anthropogenic* sources), are deemed *significant* drinking water *threats* regardless of assigned vulnerability scores. This applies to intake protection zones and wellhead protection areas only, for drinking water systems identified in the Source Protection Area Terms of Reference.

If an *issue* is identified, the *activities* that contribute to the identified *issue* and the areas where they occur (within *vulnerable areas*) must also be identified. A nitrate issue has been identified for the Woodstock rural wellfields (Thorton and Tabor) as described in Section 5. An Issue Contributing Area (ICA) has been delineated for the Tabor wellfield and the activities contributing to the issue have been identified and included in the numbers of locations of significant drinking water threats included in the following sections. For the Thorton wellfield, monitoring suggests that current and planned measures may be improving the nitrates in the drinking water source. A work plan is therefore included in Section 5 which suggests the issue be re-evaluated in a future update to the SPP. As such there are no additional significant drinking water threats contributing to the issue for the Thorton wellfield. For the *activities* or *conditions* contributing to *issues* that are deemed to be *significant threats* as described above, the *risks* the *activities* or *conditions* pose must be reduced through the source protection plan.

Further, *issues* in *HVAs* or those linked to a system not identified in the Terms of Reference may lead to the identification of moderate drinking water threats (not significant threats). Systems not identified in the Terms of Reference may be those included in the source protection planning process through municipal council resolution or by the Minister (MECP).

7.1.5 Local Guidance and Technical Studies

In the Thames-Sydenham and Region, a guidance document called the *Threats* and *Risk* Assessment Local Guidance Version 1.2 (September 9, 2009) was created. This guidance document provides clarification and local interpretation of the relevant sections in the Clean

Water Act, its regulations and the associated *technical rules* pertaining to the *threats* and *risk* assessment. It is provided in Appendix 10. In the Thames-Sydenham and Region, *threat* and *risk* assessment work was done according to the latest Technical Rules (amended November 16, 2009), the Clean Water Act (2006) and its regulations, as well as the *Threats* and *Risk* Assessment Local Guidance document.

For the *threats* analysis in the *WHPA-A to D*, an inventory of land use *activities* that may be associated with *prescribed* drinking water *threat* was conducted. The inventory was based on a review of multiple data sources including public records, data provided through questionnaires completed by municipal officials, previous contaminant/historical land use information, and data collected during windshield surveys. Very little site specific information was collected; therefore, all *prescribed* drinking water *threat activities* are considered potential rather than confirmed. In summary, evaluation followed a multi-step process including:

- assigning land use *activity*
- assigning vulnerability scores
- relating land use *activity* to *threat* category
- relating land use *activity* to *prescribed* drinking water *threat* and
- determining applicable *circumstances*.

Determining the applicable *circumstances* is based on a combination of site-specific knowledge of *activities* on the property, available information on local/regional characteristics, and on professional opinion. Where possible, site-specific data from information provided through available public records and interviews are considered. In many cases, selection of the relevant *circumstance* is based largely on professional opinion as to the likelihood of a *circumstance* being applicable, as site inspections have not been conducted to date.

Significant threats verification work was initiated in Perth and Middlesex Counties and the tables included in this assessment report are based on this updated information. Oxford County will undertake similar work as part of preparing for implementation and as such the information is not available for this update to the Assessment Report. The verification work was initiated in Perth and Middlesex to confirm previously identified threats, however it became apparent that it was also important to consider new threats which had become established since the previous inventory or which had been missed in previous inventories. This work was completed by CA staff using similar methodologies to the previous inventory work. It was generally completed as a desktop exorcise with drive-by inspections where appropriate. Managed land, livestock density and percent imperious data was considered where this information is included as a circumstance. Home heating fuel options and septic/sanitary servicing was also used to refine the threats inventory. Consistent linking to threats circumstances consistent with updated provincial data models was also undertaken to assist in the implementation of policies. Numbers of locations of significant drinking water threats provided in the tables in the following section are based on this updated inventory work. While this work is an improvement on the previous inventories it will be important that site inspection as part of routine compliance monitoring or threats verification be undertaken by Risk Management Inspectors as part of the implementation of the SPP

7.2 Drinking Water Quality Threats and Risk Assessment

From the *prescribed* list of *activities*, the drinking water *threats* and their *circumstances* are identified in *vulnerable areas* of each drinking water system. They are described further in this section and can also be found on the provinces' Table of Drinking Water Threats under the 2017 Techncial Rules website at https://www.ontario.ca/page/tables-drinking-water-threats or through the Threats Tool website at https://swpip.ca/.

The Source Protection Committee has not identified any '*other*' (not *prescribed*) *activities* or *circumstances* (not in the *tables of drinking water threats (2013/2017)*) at this point. However, the Source Protection Committee has expressed a concern to the *MECP* over the *risks* associated with the transportation of materials through pipelines or other corridors. The Source Protection Committee has also expressed a concern over the potential *risk* that geothermal systems pose to groundwater sources of drinking water. The Source Protection Committee will give further consideration to these *activities* and may include them in an amended Assessment Report if they cannot be adequately addressed through other means.
As part of the updates to the Table of Drinking Water Threats in 2017, "the establishment and operation of liquid hydrocarbon pipelines' has been identified as a new prescribed threat. TSR staff have reviewed these changes and determined that although there are pipelines extending

through some wellhead protection areas and Intake Protection Zones in the region, the vulnerability scores of those areas are such that the pipelines would only constitute a low or moderate threat. No new significant threats have been identified as a result of liquid hydrocarbon pipelines being added as a prescribed threat.

The investigation to determine if there are any *conditions* (*threats* resulting from past *activities*) is yet to be completed at the time of drafting this Assessment Report. However, a couple of potential *conditions* in the Upper Thames River Source Protection Area are being considered for further work. More studies will be undertaken on identifying and assessing *conditions* and the Assessment Report will be amended if necessary. These are discussed in Section 6 – Conditions Assessment.

Activities or *conditions* that contribute to drinking water quality *issues* (known to be partially or wholly due to *anthropogenic* sources), are deemed *significant* drinking water *threats* regardless of assigned vulnerability scores. This applies to *intake protection zones* and *wellhead protection areas* only, for drinking water systems identified in the Source Protection Area Terms of Reference. The area and *activities* contributing to a drinking water quality *issue* (known to be partially or wholly due to *anthropogenic* sources) must both be identified. An Issue Contributing Area (ICA) has been delineated for the Tabor wellfield and the activities contributing to the issue have been identified and included in the number of locations of significant drinking water threats included in the following sections. For the Thorton wellfield monitoring suggests that current and planned measures may be improving the nitrates in the drinking water source. A work plan is therefore included in section 5 which suggests the issue be re-evaluated in a future update to the SPP. As such there are no additional significant drinking water threats contributing to the issue for the Thorton wellfield.

The following subsections describe the findings of the *threats* identification through the vulnerability scoring approach, and results of the *risk* assessment for each drinking water system. This includes the identification of *significant threats*, number of locations at which *significant threats* are or would occur, and areas within *vulnerable areas* where low, moderate or *significant threats* could occur.

7.2.1 Threats Identified through Mapping of Impervious Surfaces, Managed Lands and Livestock Density

The maps indicating impervious surfaces (Maps 7-1-1 to 7-1-23), managed lands and livestock density (Maps 7-2-1 to 7-2-23) in the region are provided in Appendix 1 of this Assessment Report. The identification of the *threats* related to these mapped areas is completed. The *threats* related to these mapping products are the application of *agricultural source material and non-agricultural source material* to land, the application of commercial fertilizer to land, and the application of road salt. They are identified as chemical related threats in the description on each drinking water system below. Due to the vulnerability scoring of *WHPA-E*, *HVA*, the analysis will not result in the identification of any *significant threats* in these *vulnerable areas*.

7.2.2 Number of Locations of Significant Threats

Tables 7-5, 7-6, 7-7 and 7-8 provide the number of locations where *significant threats* are thought to occur, based on current land use, within the *vulnerable areas* of the Upper Thames River Source Protection Area. These numbers include *threats* due to chemical and pathogen-related *activities*. As can be seen from Tables 7-5, 7-6 and 7-7, there are no locations of *activities* that 'are or would be' *significant threats* within the *WHPA-E,* due to the vulnerability scores. As can be seen from Table 7-8, there are no locations of *activities* that 'are or would be' *significant threats* within the *HVA*. This is due to the range of vulnerability scores allowed for *HVA* as discussed in Section 7.1.1. There are however locations where *significant threats* 'are or would' occur in the *WHPA-A*, *WHPA-B* and *WHPA-C*. There are no surface water intakes in this Source Protection Area, therefore no *IPZ*s.

Table 7-5 Number of Locations of Significant Drinking Water Threats in Middlesex County

System - wellfield	Vulnerable Area	Vulnerability Score	Number of Locations of Significant Threats
Birr	WHPA - A	10	13
	WHPA - B	6	0
	WHPA - C	4	0
	WHPA - D	2	0
Melrose	WHPA - A	10	13
	WHPA - B	10	10
	WHPA - C	6, 8	0
	WHPA - D	2, 4, 6	0
Dorchester	WHPA - A	10	5
	WHPA - B	10	36

Table 7-5 Number of Locations of Significant Drinking Water Threats in Middlesex County

System - wellfield	Vulnerable Area	Vulnerability Score	Number of Locations of Significant Threats
	WHPA - B	6	0
	WHPA - C	4, 8	0
	WHPA - D	2, 6	0
	WHPA - E	6.3	0
Thorndale	WHPA - A	10	6
	WHPA - B	6	1
	WHPA - C	4	0
	WHPA - D	2	0

Table 7-6 Number of Locations of Significant Drinking Water Threats in Oxford County

System - wellfield	Vulnerable Area	Vulnerability Score	Number of Locations of Significant Threats
Beachville	WHPA - A	10	6
	WHPA - B	6, 8	0
	WHPA - C	4, 8	1
	WHPA - D	2, 4, 6	0
Embro	WHPA - A	10	4
	WHPA - B	6	3
	WHPA - C	4	0
	WHPA - D	2	0
Hickson	WHPA - A	10	10
	WHPA - B	8	0
	WHPA - C	4	0
	WHPA - D	2	0
Ingersoll	WHPA - A	10	21
	WHPA - B	6, 8, 10	22
	WHPA - C	2, 6	16
	WHPA - D	2, 4, 6	0
Innerkip	WHPA - A	10	2
	WHPA - B	8	0
	WHPA - C	6, 8	0
	WHPA - D	2, 4	0
Lakeside	WHPA - A	10	6
	WHPA - B	6	0
	WHPA - C	4	0
	WHPA - D	2	0
Mount Elgin	WHPA - A	10	17
	WHPA - B	6	0
	WHPA - C	4	0
	WHPA - D	2	0
Tavistock	WHPA - A	10	5
	WHPA - B	6	10
	WHPA - C	4	1

Table 7-6 Number of Locations of Significant Drinking Water Threats in Oxford County

System - wellfield	Vulnerable Area	Vulnerability Score	Number of Locations of Significant Threats
	WHPA - D	2	0
Thamesford	WHPA - A	10	6
	WHPA - B	6, 8, 10	6
	WHPA - C	4, 8, 10	0
	WHPA - D	2, 8	0
	WHPA - E	6.3	0
Woodstock – Urban Wells	WHPA - A	10	6
	WHPA - B	8, 6	20
	WHPA - C	6, 2	55
	WHPA - D	4, 2	0
Woodstock – Rural Wells	WHPA - A	10	20
	WHPA - B	10, 8	9
	WHPA - C	8, 6, 2	0
	WHPA - D	4, 2	0
	WHPA - E	7	0

Table 7-7 Number of Locations of Significant Drinking Water Threats in Perth County, City of Stratford and Town of St. Marys

System - wellfield	Vulnerable Area	Vulnerability Score	Number of Locations of Significant Threats
Mitchell	WHPA - A	10	16
	WHPA - B	6	2
	WHPA - C	4	0
	WHPA - D	2	0
Shakespeare	WHPA - A	10	1
	WHPA - B	6	0
	WHPA - C	4	0
	WHPA - D	2	0
Sebringville	WHPA - A	10	13
	WHPA - B	10	0
	WHPA - C	4	0
	WHPA - D	2	0
St. Pauls	WHPA - A	10	17
	WHPA - B	6	0
	WHPA - C	4	0
	WHPA - D	2	0
Stratford	WHPA - A	10	27
	WHPA - B	6	4
	WHPA - C	4	1
	WHPA - D	2	0
St. Marys	WHPA - A	10	31
	WHPA - B	6, 8, 10	21
	WHPA - C	4, 6	0
	WHPA - D	2, 4, 6	0
	WHPA - E	7.2	0

Table 7-8 Number of Locations of Significant Drinking Water Threats in HVA and SGRA

System - wellfield	Vulnerable Area	Vulnerability Score	Number of Locations of Significant Threats
(Not applicable)	HVA	6.0	0
(Not applicable)	SGRA	Not applicable	0

7.2.3 Threats in Birr Wellhead Protection Areas

Table 7-9 indicates the number of locations where *significant threats* could occur in the Birr *WHPA* of the Upper Thames River Source Protection Area based on current land use. The *significant threats* occur in *WHPA-A.* The land use within the Birr *WHPA* is mainly agricultural, residential and commercial. Map 7-3-1 shows areas in the Birr *WHPA* where *activities* 'are or would be' low, moderate or *significant threats*. The level of *threat* is dependent upon the *vulnerable area* (*WHPA-A, WHPA-B, WHPA-C* or *WHPA-D*) where the *activity* is occurring, the vulnerability score and the *circumstances* associated with the *activity*. Refer to Appendix 10 for detailed lists of low, moderate or *significant threats* and the *circumstances* under which they occur.

Table 7-9 Significant Threats in the Birr WHPA

Prescribed Drinking Water Threat	Type (Chemical, Pathogen or DNAPL)	WHPA
The establishment, operation or maintenance of a system that collects, stores, transmits, treats or disposes of sewage	Pathogen	A
The application of agricultural source material to land	Pathogen	A
Application Of Non-Agricultural Source Material (NASM)	Pathogen	A
The application of commercial fertilizer to land.	Chemical	A
The application of pesticide to land.	Chemical	A
Number of occurrences of significant prescribed drinking water threats		13
Total number of locations of significant prescribed drinking water threats		13*

*some parcels may have more than one activity occurring

7.2.4 Threats in Dorchester Wellhead Protection Areas

Table 7-10 indicates the number of locations where *significant threats* could occur in the Dorchester *WHPA* of the Upper Thames River Source Protection Area based on current land use. The *significant threats* occur in *WHPA-A* and *WHPA-B*. The land use within the Dorchester *WHPA* is mainly residential, agricultural, commercial and park/open space. The Dorchester Swamp is a natural feature that spans the *WHPA*. Map 7-3-2 and Map 7-3-2a show areas in the Dorchester *WHPA* where *activities* 'are or would be' low, moderate or *significant threats*. The level of *threat* is dependent upon the *vulnerable area* (*WHPA-A, WHPA-B, WHPA-C, WHPA-D or WHPA-E*) where the *activity* is occurring, the vulnerability score and the *circumstances* associated with the *activity*. Refer to Appendix 10 for detailed lists of low, moderate or *significant threats* and the *circumstances* under which they occur.

Table 7-10 Significant Threats in the Dorchester WHPA

Prescribed Drinking Water Threat	Type (Chemical, Pathogen or DNAPL)	WHPA
The establishment, operation or maintenance of a system that collects, stores, transmits, treats or disposes of sewage	Chemical, Pathogen	A, B
The application of agricultural source material to land	Pathogen	A, B
The storage of agricultural source material	Pathogen	A, B
The application of non-agricultural source material to land	Pathogen	A, B
The handling and storage of commercial fertilizer	Chemical	A, B
The application of pesticide to land	Chemical	A, B
The handling and storage of pesticide	Chemical	B
The handling and storage of fuel	Chemical	A, B
The handling and storage of an organic solvent.	Chemical	A,B
The use of land as livestock grazing or pasturing land, an outdoor confinement area or a farm-animal yard	Pathogen	A, B
The handling and storage of a dense non-aqueous phase liquid	Chemical	A,B,C
Number of occurrences of significant prescribed drinking water threats		103
Total number of locations of significant prescribed drinking water threats		41*

*some parcels may have more than one activity occurring

7.2.5 Threats in Kilworth-Komoka Wellhead Protection Areas – WELLS DECOMMISSIONED

The Kilworth-Komoka wells were decommissioned in October 2010, as per information from Municipality of Middlesex Centre. Information on the wells is therefore removed from this Assessment Report. Komoka/Kilworth is now supplied by the Lake Huron Primary Water Supply System.

Table 7-11 Significant Threats in the Kilworth-Komoka WHPA - WELLS DECOMMISSIONED

Prescribed Drinking Water Threat	Type (Chemical, Pathogen or DNAPL)	WHPA
Not Applicable* (NA)	NA	NA

*The Kilworth-Komoka wells were decommissioned in October 2010 and are therefore information on the wells is removed from this Assessment Report

7.2.6 Threats in City of London Wellhead Protection Areas – WELLS DECOMMISSIONED

The City of London wells were decommissioned in the fall of 2019, as per information from the City of London. Information on the wells is therefore removed from this Assessment Report. The City of London is now supplied entirely by the Lake Huron Primary Water Supply System and the Elgin Area Primary Water Supply System.

Table 7-12 Significant Threats in the City of London-Fanshawe WHPA – WELLS DECOMMISSIONED

Prescribed Drinking Water Threat	Type (Chemical, Pathogen or DNAPL)	WHPA
Not Applicable* (NA)	NA	NA

*The London-Fanshawe wells were decommissioned in the fall of 2019 and therefore information on the wells is removed from this Assessment Report

Table 7-13 Significant Threats in the City of London-Hyde Park WHPA – WELLS DECOMMISSIONED

Prescribed Drinking Water Threat	Type (Chemical, Pathogen or DNAPL)	WHPA
Not Applicable* (NA)	NA	NA

*The London-Hyde Park wells were decommissioned in the fall of 2019 and therefore information on the wells is removed from this Assessment Report

7.2.7 Threats in Melrose Wellhead Protection Areas

Table 7-14 indicates the number of locations where *significant threats* could occur in the Melrose *WHPA* of the Upper Thames River Source Protection Area based on current land use. The *significant threats* occur in *WHPA-A* and *WHPA-B*. The land use within the Melrose *WHPA* is mainly residential and agricultural. Map 7-3-6 shows areas in the Melrose *WHPA* where *activities* 'are or would be' low, moderate or *significant threats*. The level of *threat* is dependent upon the *vulnerable area* (*WHPA-A, WHPA-B, WHPA-C* or *WHPA-D*) where the *activity* is occurring, the vulnerability score and the *circumstances* associated with the *activity*. Refer to Appendix 10 for detailed lists of low, moderate or *significant threats* and the *circumstances* under which they occur.

Table 7-14 Significant Threats in the Melrose WHPA

Prescribed Drinking Water Threat	Type (Chemical, Pathogen or DNAPL)	WHPA
The establishment, operation or maintenance of a system that collects, stores, transmits, treats or disposes of sewage	Pathogen	A, B
The application of agricultural source material to land	Pathogen, Chemical	B
The application of non-agricultural source material to land	Pathogen, Chemical	B
The application of commercial fertilizer to land	Chemical	B
The application of pesticide to land.	Chemical	B
The handling and storage of fuel	Chemical	A, B
The handling and storage of a dense non-aqueous phase liquid	DNAPL	A,B,C
Number of occurrences of significant prescribed drinking water threats		33
Total number of locations of significant prescribed drinking water threats		23*

*some parcels may have more than one activity occurring

7.2.8 Threats in Thorndale Wellhead Protection Areas

Table 7-15 indicates the number of locations where *significant threats* could occur in the Thorndale *WHPA* of the Upper Thames River Source Protection Area based on current land use. The *significant threats* occur in *WHPA-A* and *WHPA-B*. The land use within the Thorndale *WHPA* is mainly agricultural, residential and industrial. Map 7-3-7 shows areas in the Thorndale *WHPA* where *activities* 'are or would be' low, moderate or *significant threats*. The level of *threat* is dependent upon the *vulnerable area* (*WHPA-A, WHPA-B, WHPA-C* or *WHPA-D*) where the *activity* is occurring, the vulnerability score and the *circumstances* associated with the *activity*. Refer to Appendix 10 for detailed lists of low, moderate or *significant threats* and the *circumstances* under which they occur.

Table 7-15 Significant Threats in the Thorndale WHPA

Prescribed Drinking Water Threat	Type (Chemical, Pathogen or DNAPL)	WHPA
The establishment, operation or maintenance of a system that collects, stores, transmits, treats or disposes of sewage	Pathogen	A
The application of agricultural source material to land	Chemical, Pathogen	A
The application of non-agricultural source material to land	Chemical, Pathogen	A
The handling and storage of commercial fertilizer	Chemical	A
The application of pesticide to land	Chemical	A
The handling and storage of pesticide	Chemical	A

The handling and storage of fuel.	Chemical	B
The handling and storage of a dense non-aqueous phase liquid	DNAPL	A,B,C
Number of occurrences of significant prescribed drinking water threats		18
Total number of locations of significant prescribed drinking water threats		7*

*some parcels may have more than one activity occurring

7.2.9 Threats in Beachville Wellhead Protection Areas

Table 7-16 indicates the number of locations where *significant threats* could occur in the Beachville *WHPA* of the Upper Thames River Source Protection Area based on current land use. The *significant threats* occur in *WHPA-A* and *WHPA-C*. The land use within the Beachville *WHPA* is mainly agricultural, residential and industrial. Map 7-3-8 shows areas in the Beachville *WHPA* where *activities* 'are or would be' low, moderate or *significant threats*. The level of *threat* is dependent upon the *vulnerable area* (*WHPA-A, WHPA-B, WHPA-C* or *WHPA-D*) where the *activity* is occurring, the vulnerability score and the *circumstances* associated with the *activity*. Refer to Appendix 10 for detailed lists of low, moderate or *significant threats* and the *circumstances* under which they occur.

Table 7-16 Significant Threats in the Beachville WHPA

Prescribed Drinking Water Threat	Type (Chemical, Pathogen or DNAPL)	WHPA
The establishment, operation or maintenance of a system that collects, stores, transmits, treats or disposes of sewage	Pathogen	A
The handling and storage of a dense non-aqueous phase liquid	DNAPL	C
Number of occurrences of significant prescribed drinking water threats		7
Total number of locations of significant prescribed drinking water threats		7*

*some parcels may have more than one activity occurring

7.2.10 Threats in Embro Wellhead Protection Areas

Table 7-17 indicates the number of locations where *significant threats* could occur in the Embro *WHPA* of the Upper Thames River Source Protection Area based on current land use. The *significant threats* occur in *WHPA-A* and *WHPA-B*. The land use within the Embro *WHPA* is mainly agricultural, residential and commercial. Map 7-3-9 shows areas in the Embro *WHPA* where *activities* 'are or would be' low, moderate or *significant threats*. The level of *threat* is dependent upon the *vulnerable area* (*WHPA-A, WHPA-B, WHPA-C* or *WHPA-D*) where the *activity* is occurring, the vulnerability score and the *circumstances* associated with the *activity*. Refer to Appendix 10 for detailed lists of low, moderate or *significant threats* and the *circumstances* under which they occur.

Table 7-17 Significant Threats in the Embro WHPA

Prescribed Drinking Water Threat	Type (Chemical, Pathogen or DNAPL)	WHPA
The establishment, operation or maintenance of a system that collects, stores, transmits, treats or disposes of sewage	Pathogen	A
The application of agricultural source material to land	Pathogen	A
The use of land as livestock grazing or pasturing land, an outdoor confinement area or a farm-animal yard	Pathogen	A
The handling and storage of fuel	Chemical	A
The handling and storage of a dense non-aqueous phase liquid	DNAPL	A, B
Number of occurrences of significant prescribed drinking water threats		9
Total number of locations of significant prescribed drinking water threats		7*

*some parcels may have more than one activity occurring

7.2.11 Threats in Hickson Wellhead Protection Areas

Table 7-18 indicates the number of locations where *significant threats* could occur in the Hickson *WHPA* of the Upper Thames River Source Protection Area based on current land use. The *significant threats* occur in *WHPA-A*. The land use within the Hickson *WHPA* is mainly agricultural and residential. Map 7-3-10 shows areas in the Hickson *WHPA* where *activities* 'are or would be' low, moderate or *significant threats*. The level of *threat* is dependent upon the *vulnerable area* (*WHPA-A, WHPA-B, WHPA-C* or *WHPA-D*) where the *activity* is occurring, the vulnerability score and the *circumstances* associated with the *activity*. Refer to Appendix 10 for detailed lists of low, moderate or *significant threats* and the *circumstances* under which they occur.

Table 7-18 Significant Threats in the Hickson WHPA

Prescribed Drinking Water Threat	Type (Chemical, Pathogen or DNAPL)	WHPA
The establishment, operation or maintenance of a system that collects, stores, transmits, treats or disposes of sewage	Pathogen	A
The application of agricultural source material to land	Pathogen	A

The application of agricultural source material to land	Chemical	A
The application of commercial fertilizer	Chemical	A
The application of pesticide to land	Chemical	A
Number of occurrences of significant prescribed drinking water threats		21
Total number of locations of significant prescribed drinking water threats		10*

*some parcels may have more than one activity occurring

7.2.12 Threats in Ingersoll Wellhead Protection Areas

Table 7-19 indicates the number of locations where *significant threats* could occur in the Ingersoll *WHPA* of the Upper Thames River Source Protection Area based on current land use. The *significant threats* occur in *WHPA-A*, *WHPA-B* and *WHPA-C*. The land use within the Ingersoll *WHPA* is mainly agricultural, industrial, park/open space and commercial. Map 7-3-11 shows areas in the Ingersoll *WHPA* where *activities* 'are or would be' low, moderate or *significant threats*. The level of *threat* is dependent upon the *vulnerable area* (*WHPA-A, WHPA-B, WHPA-C* or *WHPA-D*) where the *activity* is occurring, the vulnerability score and the *circumstances* associated with the *activity*. Refer to Appendix 10 for detailed lists of low, moderate or *significant threats* and the *circumstances* under which they occur.

Table 7-19 Significant Threats in the Ingersoll WHPA

Prescribed Drinking Water Threat	Type (Chemical, Pathogen or DNAPL)	WHPA
The establishment, operation or maintenance of a waste disposal site within the meaning of Part V of the Environmental Protection Act	Chemical	A
The establishment, operation or maintenance of a system that collects, stores, transmits, treats or disposes of sewage	Pathogen	A, B
The application of agricultural source material to land	Chemical, Pathogen	A, B
The storage of agricultural source material	Chemical, Pathogen	B
The application of commercial fertilizer to land	Chemical	A, B
The application of pesticide to land	Chemical	B
The handling and storage of pesticide	Chemical	A, B
The handling and storage of fuel	Chemical	A, B
The handling and storage of a dense non-aqueous phase liquid	DNAPL	A, B, C
The handling and storage of an organic solvent	Chemical	A
The use of land as livestock grazing or pasturing land, an outdoor confinement area or a farm-animal yard	Chemical, Pathogen	A

Number of occurences of significant prescribed drinking water threats	61
Total number of locations of significant prescribed drinking water threats	40*

*some parcels may have more than one activity occurring

7.2.13 Threats in Innerkip Wellhead Protection Areas

Table 7-20 indicates the number of locations where *significant threats* could occur in the Innerkip *WHPA* of the Upper Thames River Source Protection Area based on current land use. The *significant threats* occur in *WHPA-A*. The land use within the Innerkip *WHPA* is mainly agricultural, residential and park/open space. Map 7-3-12 shows areas in the Innerkip *WHPA* where *activities* 'are or would be' low, moderate or *significant threats*. The level of *threat* is dependent upon the *vulnerable area* (*WHPA-A, WHPA-B, WHPA-C* or *WHPA-D*) where the *activity* is occurring, the vulnerability score and the *circumstances* associated with the *activity*. Refer to Appendix 10 for detailed lists of low, moderate or *significant threats* and the *circumstances* under which they occur.

Table 7-20 Significant Threats in the Innerkip WHPA

Prescribed Drinking Water Threat	Type (Chemical, Pathogen or DNAPL)	WHPA
The application of agricultural source material to land	Pathogen	A
The application of pesticide to land	Chemical	A
Number of occurrences of significant prescribed drinking water threats		3
Total number of locations of significant prescribed drinking water threats		2*

*some parcels may have more than one activity occurring

7.2.14 Threats in Lakeside Wellhead Protection Areas

Table 7-21 indicates the number of locations where *significant threats* could occur in the Lakeside *WHPA* of the Upper Thames River Source Protection Area based on current land use. The *significant threats* occur in *WHPA-A*. The land use within the Lakeside *WHPA* is mainly agricultural with some residential and industrial use. Map 7-3-13 shows areas in the Lakeside *WHPA* where *activities* 'are or would be' low, moderate or *significant threats*. The level of *threat* is dependent upon the *vulnerable area* (*WHPA-A, WHPA-B, WHPA-C* or *WHPA-D*) where the *activity* is occurring, the vulnerability score and the *circumstances* associated with the *activity*.

Refer to Appendix 10 for detailed lists of low, moderate or *significant threats* and the *circumstances* under which they occur.

Table 7-21 Significant Threats in the Lakeside WHPA

Prescribed Drinking Water Threat	Type (Chemical, Pathogen or DNAPL)	WHPA
The establishment, operation or maintenance of a system that collects, stores, transmits, treats or disposes of sewage	Pathogen	A
The application of agricultural source material to land	Chemical, Pathogen	A
The application of commercial fertilizer to land	Chemical	A
The application of pesticide to land	Chemical	A
Number of occurrences of significant prescribed drinking water threats		13
Total number of locations of significant prescribed drinking water threats		6*

*some parcels may have more than one activity occurring

7.2.15 Threats in Mount Elgin Wellhead Protection Areas

Table 7-22 indicates the number of locations where *significant threats* could occur in the Mount Elgin*WHPA* of the Upper Thames River Source Protection Area based on current land use. The *significant threats* occur in *WHPA-A*. The land use within the Mount Elgin *WHPA* is mainly agricultural, residential and institutional. Map 7-3-14 shows areas in the Mount Elgin *WHPA* where *activities* 'are or would be' low, moderate or *significant threats*. The level of *threat* is dependent upon the *vulnerable area* (*WHPA-A, WHPA-B, WHPA-C* or *WHPA-D*) where the *activity* is occurring, the vulnerability score and the *circumstances* associated with the *activity*. Refer to Appendix 10 for detailed lists of low, moderate or *significant threats* and the *circumstances* under which they occur.

Table 7-22 Significant Threats in the Mount Elgin WHPA

Prescribed Drinking Water Threat	Type (Chemical, Pathogen or DNAPL)	WHPA
The establishment, operation or maintenance of a waste disposal site within the meaning of Part V of the Environmental Protection Act	Pathogen	A
The establishment, operation or maintenance of a system that collects, stores, transmits, treats or disposes of sewage	Pathogen	A
The application of agricultural source material to land	Pathogen	A

The application of pesticide to land	Chemical	A
The handling and storage of fuel	Chemical	A
The handling and storage of a dense non-aqueous phase liquid	DNAPL	A
The use of land as livestock grazing or pasturing land, an outdoor confinement area or a farm-animal yard	Pathogen	A
Number of occurrences of significant prescribed drinking water threats		34
Total number of locations of significant prescribed drinking water threats		17*

*some parcels may have more than one activity occurring

7.2.16 Threats in Tavistock Wellhead Protection Areas

Table 7-23 indicates the number of locations where *significant threats* could occur in the Tavistock *WHPA* of the Upper Thames River Source Protection Area based on current land use. The *significant threats* occur in *WHPA-A*, *WHPA-B* and *WHPA-C*. The land use within the Tavistock *WHPA* is mainly agricultural, residential and institutional. Map 7-3-15 shows areas in the Tavistock *WHPA* where *activities* 'are or would be' low, moderate or *significant threats*. The level of *threat* is dependent upon the *vulnerable area* (*WHPA-A, WHPA-B, WHPA-C* or *WHPA-D*) where the *activity* is occurring, the vulnerability score and the *circumstances* associated with the *activity*. Refer to Appendix 10 for detailed lists of low, moderate or *significant threats* and the *circumstances* under which they occur.

Table 7-23 Significant Threats in the Tavistock WHPA

Prescribed Drinking Water Threat	Type (Chemical, Pathogen or DNAPL)	WHPA
The establishment, operation or maintenance of a system that collects, stores, transmits, treats or disposes of sewage	Pathogen	A
The handling and storage of fuel	Chemical	A
The handling and storage of a dense non-aqueous phase liquid	DNAPL	A, B, C
The handling and storage of an organic solvent	Chemical	A
Total number of occurrences of significant threats		19
Total number of locations of significant threats		15*

*some parcels may have more than one activity occurring

7.2.17 Threats in Thamesford Wellhead Protection Areas

Table 7-24 indicates the number of locations where *significant threats* could occur in the Thamesford *WHPA* of the Upper Thames River Source Protection Area based on current land use. The *significant threats* occur in *WHPA-A* and *WHPA-B*. The land use within the Thamesford *WHPA* is mainly agricultural and residential with some industrial use. Map 7-3-16 and Map 7-3-16a show areas in the Thamesford *WHPA* where *activities* 'are or would be' low, moderate or *significant threats*. The level of *threat* is dependent upon the *vulnerable area* (*WHPA-A, WHPA-B, WHPA-C, WHPA-D* or *WHPA-E*) where the *activity* is occurring, the vulnerability score and the *circumstances* associated with the *activity*. Refer to Appendix 10 for detailed lists of low, moderate or *significant threats* and the *circumstances* under which they occur.

Table 7-24 Significant Threats in the Thamesford WHPA

Prescribed Drinking Water Threat	Type (Chemical, Pathogen or DNAPL)	WHPA
The establishment, operation or maintenance of a system that collects, stores, transmits, treats or disposes of sewage	Pathogen	A, B
The application of agricultural source material to land	Pathogen	A, B
The handling and storage of a dense non-aqueous phase liquid	DNAPL	A, B
The application of pesticide to land	Chemical	A
Number of occurrences of significant prescribed drinking water threats		10
Total number of locations of significant prescribed drinking water threats		8*

*some parcels may have more than one activity occurring

7.2.18 Threats in Woodstock Wellhead Protection Areas

Table 7-25 and Table 7-26 indicate the number of locations where *significant threats* could occur in the Woodstock *WHPA* of the Upper Thames River Source Protection Area based on current land use. The *significant threats* occur in *WHPA-A*, *WHPA-B* and *WHPA-C*. The land use within the Woodstock *WHPA* is mainly agricultural, residential, industrial and commercial. Map 7-3-17 and Map 7-3-17a shows areas in the Woodstock *WHPA* where *activities* 'are or would be' low, moderate or *significant threats*. The level of *threat* is dependent upon the *vulnerable area* (*WHPA-A, WHPA-B, WHPA-C, WHPA-D* or *WHPA-E*) where the *activity* is occurring, the vulnerability score and the *circumstances* associated with the *activity*. Refer to Appendix 10 for detailed lists of low, moderate or *significant threats* and the *circumstances* under which they occur.

Table 7-27 indicates the number of locations where significant threats could occur in the Woodstock ICA of the Upper Thames River Source Protection Area based on current land use. The land use within the Woodstock WHPA is mainly agricultural. Map 7-3-17b shows areas in the Woodstock WHPA where activities 'are or would be' low, moderate or significant threats which contribute to an Issue. The level of threat is significant, regardless of the vulnerability score and the circumstances associated with the activity provided the circumstances identify the activity as a threat due to nitrate (identified as an Issue).

Table 7-25 Significant Threats in the Woodstock WHPA (Urban well system)

Prescribed Drinking Water Threat	Type (Chemical, Pathogen or DNAPL)	WHPA
The establishment, operation or maintenance of a waste disposal site within the meaning of Part V of the Environmental Protection Act	Chemical	A
The establishment, operation or maintenance of a system that collects, stores, transmits, treats or disposes of sewage	Pathogen	A
The handling and storage of fuel	Chemical	A
The handling and storage of a dense non-aqueous phase liquid	DNAPL	A, B, C
Number of occurrences of significant prescribed drinking water threats		71
Total number of locations of significant prescribed drinking water threats		68*

*some parcels may have more than one activity occurring

Table 7-26 Significant Threats in the Woodstock WHPA (Rural well system)

Prescribed Drinking Water Threat	Type (Chemical, Pathogen or DNAPL)	WHPA
The establishment, operation or maintenance of a system that collects, stores, transmits, treats or disposes of sewage	Pathogen	A, B
The application of agricultural source material to land	Chemical, Pathogen	A, B
The application of commercial fertilizer to land	Chemical	A
The application of pesticide to land	Chemical	A, B
The handling and storage of pesticides	Chemical	A, B
The handling and storage of fuel	Chemical	A, B
The handling and storage of a dense non-aqueous phase liquid	DNAPL	B
The use of land as livestock grazing or pasturing land, an outdoor confinement area or a farm-animal yard	Chemical, Pathogen	B

Number of occurrences of significant prescribed drinking water threats	57
Total number of locations of significant prescribed drinking water threats	29*

*some parcels may have more than one activity occurring

Table 7-27 Significant Threats in the Woodstock ICA

Prescribed Drinking Water Threat	Type (Chemical, Pathogen or DNAPL)
The establishment, operation or maintenance of a system that collects, stores, transmits, treats or disposes of sewage	Chemical
The application of agricultural source material to land	Chemical
The storage of agricultural source material	Chemical
The application of commercial fertilizer	Chemical
The handling and storage of commercial fertilizer	Chemical
The use of land as livestock grazing or pasturing land, an outdoor confinement area or a farm-animal yard	Chemical
Number of occurrences of significant prescribed drinking water threats	75
Total number of locations of significant prescribed drinking water threats	31

*some parcels may have more than one activity occurring. The activities identified in this table may also be identified as chemical threats in 7-26.

7.2.19 Threats in Mitchell Wellhead Protection Areas

Table 7-28 indicates the number of locations where *significant threats* could occur in the Mitchell *WHPA* of the Upper Thames River Source Protection Area based on current land use. The *significant threats* occur in *WHPA-A* and *WHPA-B*. The land use within the Mitchell *WHPA* is mainly agrcultural, industrial, commercial and residential. Map 7-3-18 shows areas in the Mitchell *WHPA* where *activities* 'are or would be' low, moderate or *significant threats*. The level of *threat* is dependent upon the *vulnerable area* (*WHPA-A, WHPA-B, WHPA-C* or *WHPA-D*) where the *activity* is occurring, the vulnerability score and the *circumstances* associated with the *activity*. Refer to Appendix 10 for detailed lists of low, moderate or *significant threats* and the *circumstances* under which they occur.

Table 7-28 Significant Threats in the Mitchell WHPA

Prescribed Drinking Water Threat	Type (Chemical, Pathogen or DNAPL)	WHPA
The establishment, operation or maintenance of a system that collects, stores, transmits, treats or disposes of sewage	Chemical, Pathogen	A
The handling and storage of fuel	Chemical	A, B
The establishment, operation or maintenance of a waste disposal site within the meaning of Part V of the Environmental Protection Act.	Chemical	A, B
The application of commercial fertilizer to land.	Chemical	A, B
The application of non-agricultural source material to land.	Chemical, Pathogen	A, B
The application of pesticide to land.	Chemical	A, B
The application of agricultural source material to land.	Pathogen	A, B
The use of land as livestock grazing or pasturing land, an outdoor confinement area or a farm-animal yard. O. Reg. 385/08, s. 3.	Pathogen	A, B
The handling and storage of a dense non-aqueous phase liquid	DNAPL	A, B, C
Number of occurrences of significant prescribed drinking water threats		45
Total number of locations of significant prescribed drinking water threats		16*

*some parcels may have more than one activity occurring

7.2.20 Threats in Sebringville Wellhead Protection Areas

Table 7-29 indicates the number of locations where *significant threats* could occur in the Sebringville *WHPA* of the Upper Thames River Source Protection Area based on current land use. No *significant threats* occur in the Sebringville *WHPA*. Map 7-3-19 shows areas in the Sebringville *WHPA* where *activities* 'are or would be' low, moderate or *significant threats*. The level of *threat* is dependent upon the *vulnerable area* (*WHPA-A, WHPA-B, WHPA-C* or *WHPA-D*) where the *activity* is occurring, the vulnerability score and the *circumstances* associated with the *activity*. Refer to Appendix 10 for detailed lists of low, moderate or *significant threats* and the *circumstances* under which they occur.

Table 7-29 Significant Threats in the Sebringville WHPA

Prescribed Drinking Water Threat	Type (Chemical, Pathogen or DNAPL)	WHPA
The establishment, operation or maintenance of a system that collects, stores, transmits, treats or disposes of sewage	Pathogen	A
Number of occurrences of significant prescribed drinking water threats		13

Total number of locations of significant prescribed drinking water threats	13

7.2.21 Threats in Shakespeare Wellhead Protection Areas

Table 7-30 indicates the number of locations where *significant threats* could occur in the Shakespeare *WHPA* of the Upper Thames River Source Protection Area based on current land use. The *significant threats* occur in *WHPA-A*. The land use within the Shakespeare *WHPA* is mainly agricultural, industrial and residential. Map 7-3-20 shows areas in the Shakespeare *WHPA* where *activities* 'are or would be' low, moderate or *significant threats*. The level of *threat* is dependent upon the *vulnerable area* (*WHPA-A, WHPA-B, WHPA-C* or *WHPA-D*) where the *activity* is occurring, the vulnerability score and the *circumstances* associated with the *activity*. Refer to Appendix 10 for detailed lists of low, moderate or *significant threats* and the *circumstances* under which they occur.

Table 7-30 Significant Threats in the Shakespeare WHPA

Prescribed Drinking Water Threat	Type (Chemical, Pathogen or DNAPL)	WHPA
The establishment, operation or maintenance of a system that collects, stores, transmits, treats or disposes of sewage	Chemical, Pathogen	A
Number of occurrences of significant prescribed drinking water threats		1
Total number of locations of significant prescribed drinking water threats		1

*some parcels may have more than one activity occurring

7.2.22 Threats in St. Marys Wellhead Protection Areas

Table 7-31 indicates the number of locations where *significant threats* could occur in the St. Marys *WHPA* of the Upper Thames River Source Protection Area based on current land use. The *significant threats* occur in *WHPA-A* and *WHPA-B* . The land use within the St. Marys *WHPA* is mainly industrial, commercial and agricultural. Map 7-3-21 and Map 7-3-21a show areas in the St. Marys *WHPA* where *activities* 'are or would be' low, moderate or *significant threats*. The level of *threat* is dependent upon the *vulnerable area* (*WHPA-A, WHPA-B, WHPA-C, WHPA-D* or *WHPA-E*) where the *activity* is occurring, the vulnerability score and the *circumstances* associated with the *activity*. Refer to Appendix 10 for detailed lists of low, moderate or *significant threats* and the *circumstances* under which they occur.

Table 7-31 Significant Threats in the St. Marys WHPA

Prescribed Drinking Water Threat	Type (Chemical, Pathogen or DNAPL)	WHPA
The application of agricultural source material to land	Chemical, Pathogen	B
The storage of agricultural source material	Pathogen	B
The application of commercial fertilizer to land	Chemical	B
The handling and storage of commercial fertilizer	Chemical	B
The application of pesticide to land	Chemical	B
The handling and storage of fuel	Chemical	B
The establishment, operation or maintenance of a system that collects, stores, transmits, treats or disposes of sewage	Chemical, Pathogen	A, B
The establishment, operation or maintenance of a waste disposal site within the meaning of Part V of the Environmental Protection Act	Chemical	B
The handling and storage of a dense non-aqueous phase liquid	DNAPL	A, B
The handling and storage of an organic solvent	Chemical	A, B
The use of land as livestock grazing or pasturing land, an outdoor confinement area or a farm-animal yard	Pathogen	B
Total number of occurances of significant threats		151
Total number of locations of significant threats		52*

*some parcels may have more than one activity occurring

7.2.23 Threats in St. Pauls Wellhead Protection Areas

Table 7-32 indicates the number of locations where *significant threats* could occur in the St. Pauls *WHPA* of the Upper Thames River Source Protection Area based on current land use. The *significant threat* occurs in *WHPA-A*. The land use within the St. Pauls *WHPA* is mainly agricultural and residential. Map 7-3-22 shows areas in the St. Pauls *WHPA* where *activities* 'are or would be' low, moderate or *significant threats*. The level of *threat* is dependent upon the *vulnerable area* (*WHPA-A, WHPA-B, WHPA-C* or *WHPA-D*) where the *activity* is occurring, the vulnerability score and the *circumstances* associated with the *activity*. Refer to Appendix 10 for detailed lists of low, moderate or *significant threats* and the *circumstances* under which they occur.

Table 7-32 Significant Threats in the St. Pauls WHPA

Prescribed Drinking Water Threat	Type (Chemical, Pathogen or DNAPL)	WHPA
The establishment, operation or maintenance of a system that collects, stores, transmits, treats or disposes of sewage	Chemical, Pathogen	A
The application of agricultural source material to land	Chemical, Pathogen	A
The application of non-agricultural source material to land.	Chemical, Pathogen	
The application of commercial fertilizer to land	Chemical	A
The application of pesticide to land	Chemical	A
The handling and storage of fuel.	Chemical	
The use of land as livestock grazing or pasturing land, an outdoor confinement area or a farm-animal yard	Chemical, Pathogen	A
The handling and storage of an organic solvent.	Chemical	A,B
The handling and storage of a dense non-aqueous phase liquid	DNAPL	A,B,C
Number of occurrences of significant prescribed drinking water threats		38
Total number of locations of significant prescribed drinking water threats		17*

*some parcels may have more than one activity occurring

7.2.24 Threats in Stratford Wellhead Protection Areas

Table 7-33 indicates the number of locations where *significant threats* could occur in the Stratford *WHPA* of the Upper Thames River Source Protection Area based on current land use. The *significant threats* occur in *WHPA-A, WHPA-B* and *WHPA-C*. The land use within the Stratford *WHPA* is mainly agricultural, commercial, industrial and residential. Map 7-3-23 shows areas in the Stratford *WHPA* where *activities* 'are or would be' low, moderate or *significant threats*. The level of *threat* is dependent upon the *vulnerable area* (*WHPA-A, WHPA-B, WHPA-C* or *WHPA-D*) where the *activity* is occurring, the vulnerability score and the *circumstances* associated with the *activity*. Refer to Appendix 10 for detailed lists of low, moderate or *significant threats* and the *circumstances* under which they occur.

Table 7-33 Significant Threats in the Stratford WHPA

Prescribed Drinking Water Threat	Type (Chemical, Pathogen or DNAPL)	WHPA
The establishment, operation or maintenance of a system	Chemical, Pathogen	A

that collects, stores, transmits, treats or disposes of sewage		
The handling and storage of a dense non-aqueous phase liquid	DNAPL	A, B, C
The establishment, operation or maintenance of a waste disposal site within the meaning of Part V of the Environmental Protection Act.		A
The application of commercial fertilizer to land	Chemical	A
The handling and storage of commercial fertilizer	Chemical	A
The application of pesticide to land	Chemical	A
The handling and storage of pesticide	Chemical	A
The handling and storage of fuel.	Chemical	A
The handling and storage of an organic solvent.	Chemical	A
The handling and storage of a dense non-aqueous phase liquid	DNAPL	A,B,C
Number of occurrences of significant prescribed drinking water threats		37
Total number of locations of significant prescribed drinking water threats		27*

*some parcels may have more than one activity occurring

7.2.25 Threats in HVA

Table 7-5 to Table 7-8 indicate the number of locations where *significant threats* could occur in the *vulnerable areas* of the Upper Thames River Source Protection Area based on current land use. Due to the low to moderate vulnerability scoring of the *HVA*, it is not possible to have *significant threats* in these *vulnerable areas*. It is possible however to have low and moderate levels of chemical *threats*, including *dense non-aqueous phase liquids* (*DNAPLs*), for a vulnerability score of 6 in *HVA*.

Map 4-3-2 shows the *HVA* delineation in the Upper Thames River Source Protection Area. Table 7-34 shows the levels of *threats* that could occur in *HVA*. Refer to Appendix 10 for detailed lists of moderate or low *threats* and the *circumstances* under which they occur.

Table 7-34 Levels of Threats Related to Pathogens, Chemicals and DNAPLs in HVAs

Vulnerable Area	Vulnerability Score	Level of Threat for Activities Related to Pathogens			Level of Threat for Activities Related to Chemicals			Level of Threat for Activities Related to DNAPLs		
		Significant	Moderate	Low	Significant	Moderate	Low	Significant	Moderate	Low
HVA	6	No	No	No	No	Yes	Yes	No	Yes	Yes

7.3 Site Specific Risk Assessment

A site-specific risk assessment to confirm the existence of significant threats will be necessary as part of implementation. Although additional efforts have been made to verify significant threats, this has not included on site verification of the threat. Although this level of effort was considered as part of the threats verification, it would still be necessary during implementation. Further it will also be necessary as part of compliance monitoring for Part IV implementation in both locations where significant threats have been identified and those where threats have not been identified. This is due in part to the potential for activities and circumstance to change at any location without any regulatory approval process. As part of the consultation on this assessment report, those who are believed to be engaging in a *significant threat* will be notified.

7.4 Data Gaps

A preliminary investigation has been completed to determine if there are any *conditions*. A couple of potential *conditions* in the Upper Thames River Source Protection Area are being considered. If more information becomes available to the SPC to identify and assess *conditions* for potential *threats*, this work would be part of a subsequent Assessment Report.

If a drinking water quality *issue* is identified at a well or intake as per Rule 114 and is known to be partially or wholly due to *anthropogenic* causes, the area and the activity contributing to a drinking water quality *issue* must also be identified as per Rule 115. In the Upper Thames River SPA, some of the *issues* are naturally occurring and are therefore understood to not be subject to Rule 115.

Nitrates have been identified as partially or wholly anthropogenic for the Woodstock rural well fields. An ICA has been identified for the Tabor Well field and the threats contributing to the issue have been identified. For the Thorton well field a workplan has been developed which continues to monitor the results from implementation of current management measures. The results from this monitoring will be used to determine if an ICA needs to be delineated to address the issue at Thorton. This will need to be reassessed in subsequent updates to the Assessment Report.

The sources or causes of the rest of the potentially anthropogenic issues are yet to be determined. If more information becomes available to the SPC it may be possible to determine the source or cause of those issues. If it is determined necessary to conduct the work (to identify the area and activities contributing to the *issue*, as per Rules 114 and 115), that work would be included in a subsequent Assessment Report.

8.0 Great Lakes

The Clean Water Act (2006) requires that the Great Lakes Agreements be considered in an Assessment Report and *Source Protection Plans*, if a Source Protection Area (*SPA*) contains water that flows into a Great Lake (Section 14). The *Technical Rules: Assessment Report* also requires that a description be provided on how the Great Lakes Agreements were considered in work undertaken (Rule 9) towards the Assessment Report.

The Upper Thames River Source Protection Area (*UTRSPA*) is one of the three *SPA*s that the Thames-Sydenham and Region Source Protection Region (*SPR*) is comprised of, the other two being the Lower Thames Valley Source Protection Area (*LTVSPA*), and the St. Clair Region Source Protection Area (*SCRSPA*).

The *UTRSPA* is based on the Upper Thames River Conservation Authority (CA) jurisdiction. Conservation Authorities are established on a watershed basis. The *UTRSPA* is landlocked and has no Great Lakes shoreline. It is surrounded by the Ausable Bayfield Maitland Valley *SPR* and Lake Erie *SPR*, as well as the *LTVSPA*. The Thames River originates in the *UTRSPA* and continues to flow through the *LTVSPA* where it outlets into Lake St. Clair, which in turn outlets into Lake Erie through the Detroit River.

Lake St. Clair is not a Great Lake but it is included while considering Great Lakes in the source protection planning process. For source water protection purposes, the Lake Erie basin is considered to be comprised of Lake St. Clair, the Detroit River and Lake Erie.

In the *UTRSPA*, most communities receive their drinking water from groundwater sources. However the City of London and a few neighbouring communities receive water from Lake Huron and Lake Erie, through municipal water treatment plants located outside of this *SPA.* Map

1-3 shows the watershed boundary of the *UTRSPA*, and the location of the groundwater systems and surface water intakes that serve communities in the watershed.

8.1 Impact of Considering Great Lakes

The Clean Water Act requires *Source Protection Plans* to consider policies that relate to the Great Lakes. The Ministry of Environment, Conservation and Parks (*MECP*) document 'A Discussion Paper on Requirements for the Content and Preparation of Source Protection Plans' (June 2009) provides some details on how Great Lakes policies may be included in the Source Protection Plan. Those details are reproduced below.

The Clean Water Act gives the Minister of the Environment the authority to set targets for the Great Lakes or any part thereof, to address any water quality or quantity issue related to the use of the Great Lakes as a source of drinking water (Section 85). Targets are anticipated to direct and coordinate action on a drinking water source protection issue or an emerging Great Lakes problem. The Minister also has the option of establishing a Great Lakes target for a group of source protection areas. If a target applies to multiple source protection areas, the Minister may direct the source protection authorities to decide jointly on what the relative target should be for each individual source protection area, to contribute to the overall target.

The Clean Water Act also provides that the source protection plan may identify one or more Great Lakes target policies as a “designated Great Lakes policy” (Section 22). Where a *source protection plan* does not designate any of the Great Lakes policies, the Minister may direct a source protection authority to do so during the process of reviewing and approving the *source protection plan*.

Also, policies that govern monitoring to assist in implementing and in determining the effectiveness of a Great Lakes target policy may be established. It may be possible that Great Lakes targets are set up through other *SPR source protection plans* but include the *UTRSPA*, in which case the *SPA* will be involved in discussions with other *SPA*s on achieving those targets.

8.2 Great Lakes Agreements

Under the Clean Water Act, the Great Lakes Agreements to be considered (Section 14) are listed below:

1. The Great Lakes Water Quality Agreement of 1978 between Canada and the United States of America, signed at Ottawa on November 22, 1978, including any amendments made before or after this section comes into force.
2. The Great Lakes Charter signed by the premiers of Ontario and Quebec and the governors of Illinois, Indiana, Michigan, Minnesota, New York, Ohio, Pennsylvania and Wisconsin on February 11, 1985, including any amendments made before or after this section comes into force.
3. The Canada-Ontario Agreement Respecting the Great Lakes Basin Ecosystem 2002 entered into between Her Majesty the Queen in Right of Canada and Her Majesty the Queen in Right of Ontario, effective March 22, 2002, including any amendments made before or after this section comes into force.
4. The Great Lakes-St. Lawrence River Basin Sustainable Water Resources Agreement.
5. 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.

The first four Agreements are discussed below. At the time of drafting of this report, the Source Protection Committee is not aware of any other Agreement, signed by the Government of Ontario or the Government of Canada, related to the Great Lakes and prescribed by the regulations.

8.2.1 Great Lakes Water Quality Agreement

Negotiations to amend the GLWQA were launched in early 2010. On February 12, 2013, the Governments of Canada and the United States ratified the Great Lakes Water Quality Agreement of 2012. The Agreement facilitates binational action on threats to water quality and ecosystem health. Under the Great Lakes Water Quality Agreement, the governments of Canada and the United States agreed “to restore and maintain the chemical, physical, and biological integrity of the waters of the Great Lakes Basin Ecosystem”. This is accomplished in part through the development and implementation of binational Lakewide Management and

Action Plans (LAMPs) for each lake. Through the development of issue related strategies, the LAMP will identify actions required to restore and protect the lakes and evaluate the effectiveness of those actions.

The Thames-Sydenham and Region Source Protection Region is straddled by Lakes Erie and Huron. Lake Erie's ecosystem and economy are threatened by algal blooms that have become a regular occurrence throughout the Western basin of the lake during summer months, leading to poor aesthetics, recreational beach closures and reduced tourism revenue. The blooms are attributed primarily to excessive nutrient inputs from urban and rural land uses. In addition, Lake Erie water quality is affected by habitat loss and degradation and the introduction of non-native aquatic and terrestrial plant species. The top priority for Lake Erie Lakewide Action and Management Plan (LAMP) partners is to address excess algal blooms by reducing nutrient inputs to the lake. The Lake Erie LAMP is coordinated by a committee of water quality and natural resource managers from both Canada and the United States, with participation from federal, provincial, state and local governments that have a role in implementation.

Although no formal Lakewide Management Plan exists for Lake Huron, the Lake Huron Binational Partnership was formed in 2002 to meet commitments in the Canada-United States Great Lakes Water Quality Agreement for lakewide management. The Partnership facilitates information sharing, sets priorities, and coordinates binational environmental protection and restoration activities. The U.S. Environmental Protection Agency, Environment Canada, Michigan Departments of Natural Resources and Environmental Quality, and the Ontario Ministries of Environment and Natural Resources form the core of the Partnership. The Lake Huron Binational Partnership focuses on key priorities and on the ground actions that help to improve and protect the overall quality of Lake Huron including controlling non-point source pollution and improving fish spawning and nursery habitat.

As mentioned before, the Thames River originates in the *UTRSPA* and continues to flow through the *LTVSPA* where it outlets into Lake St. Clair, which in turn outlets into Lake Erie. The Great Lakes Water Quality Agreement (*GLWQA*) has been considered in the Lower Thames Valley Source Protection Area Assessment Report. Under the Great Lakes Water Quality Agreement, the Four Agency Management Committee established a framework for binational coordination of environmental issues on Lake St. Clair (U.S. Environmental Protection Agency, Environment Canada, Ontario Ministry of Environment, Conservation and Parks, Michigan Department of Environmental Quality. 2004). It is called the Lake St. Clair Management Plan. Lake St. Clair intakes in the Essex Region SPA supply some communities in the Lower Thames Valley Source Protection Area.

Areas of Concern (AOC) are locations within the Great Lakes identified as having experienced high levels of environmental harm. Under the 1987 Great Lakes Water Quality Agreement between Canada and the United States, 43 such areas were identified, 12 of which were Canadian and 5 of which were shared binationally. The 2012 Great Lakes Water Quality Agreement reaffirms both countries' commitments to restoring water quality and ecosystem health in Great Lakes Areas of Concern. The St. Clair River, a binational AOC is located within the Thames-Sydenham and Region Source Protection Region.

In order to improve the environmental conditions of the AOC, a Remedial Action Plan (RAP) has been developed for the St. Clair River. The St. Clair River RAP is a partnership between Canadian and U.S. federal governments, provincial (Ontario) and state (Michigan) governments, with cooperation from the public and stakeholders through the St. Clair Binational Public Advisory Committee. Environment Canada and the Ontario Ministry of the Environment, Conservation and Parks are the lead government agencies for the Canadian side of the St. Clair River Remedial Action Plan. The St. Clair Region Conservation Authority is working with these agencies to assist in the local implementation of the plan. At the time of writing of this report, it is understood that the Lake Huron Bi-national Partnership Action Plan is not prescribed by the Regulations.

8.2.2 The Canada-Ontario Agreement Respecting the Great Lakes Basin Ecosystem

Information on this Agreement is reproduced from the Ministry of Environment, Conservation and Parks website (https://www.ontario.ca/page/canada-ontario-agreement-coa-respecting-great-lakes-basin-ecosystem). The governments of Canada and Ontario have signed an agreement to protect the Great Lakes that includes cleaning up 15 Areas of Concern on the Great Lakes or its connecting channels where the natural environment has been severely degraded, reducing harmful pollutants, and improving water quality. The Agreement also aims to conserve fish and wildlife species and habitats, lessen the threat of aquatic invasive species and improve land management practices within the Great Lakes Basin. The Agreement, which is valid until 2011, contains new areas of cooperation such as protecting sources of drinking water, understanding the impacts of climate change and encouraging sustainable use of land, water and other natural resources. The implementation of this Agreement helps fulfill the obligations of the Great Lakes Water Quality Agreement.

This Agreement is not considered to be relevant to the current Assessment Report, as there are no Areas of Concern in the *UTRSPA*. However as mentioned earlier, the Assessment Report notes the participation of the Upper Thames River CA in organizations that promote watershed based programs that aim at improving Great Lakes water quality.

8.2.3 The Great Lakes Charter and the Great Lakes-St. Lawrence River Basin Sustainable Water Resources Agreement

The Great Lakes Charter contains agreements between the eight Great Lakes states in the United States and the Provinces of Ontario and Quebec. 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" (http://www.cglg.org/pub/charter/index.html).

The Great Lakes Charter was supplemented in 2001 by the Great Lakes Charter Annex, and its implementing agreements, including the Great Lakes-St. Lawrence River Basin Sustainable Water Resources Agreement, pertaining to the watershed of the Great Lakes and the St. Lawrence River upstream from Trois-Rivières, Québec within the jurisdiction of eight states in the United States and the Provinces of Ontario and Quebec (http://www.mnr.gov.on.ca/en/Business/Water/2ColumnSubPage/STEL02_164560.html).

The Upper Thames River *SPA* is supplied with groundwater from wells within the *SPA*, as well as Lake Huron and Lake Erie water from intakes located in other *SPRs*. The Water Budget and Water Quantity Stress Assessment included in this Assessment Report consider supply and *demand* within the watersheds of the Thames-Sydenham and Region. Great Lakes water budgeting must be undertaken on a much larger scale. The information developed through the Water Budget work in the Thames-Sydenham and Region, along with those developed in the other Source Protection Regions, can be used by others when considering the larger scale Great Lakes basin water budgets. This work is beyond the scope of the Assessment Report and *Source Protection Plan* in the Thames-Sydenham and Region.

8.3 Proposed Working Groups

The formation of a Lake Erie Basin working group was discussed in October 2009. This group could bring together interested parties within the Source Protection Regions (*SPRs*) that have intakes which rely on water from the Lake Erie basin as their source of drinking water. This working group would provide a forum to discuss drinking water specific matters relevant to the Clean Water Act. The Lake Erie Basin is comprised of Lake Erie, Lake St. Clair and the Detroit River. The proposed working group members would include system operator, Conservation Authority and Source Protection Committee representation from the Niagara Peninsula *SPR*, Lake Erie *SPR,* Thames-Sydenham and Region *SPR* and the Essex Region Source Protection Area. In the *UTRSPA*, the City of London and a few other communities receive water from municipal intakes located outside the source protection region, on Lake Erie and Lake Huron. At the preliminary meeting held in October 2009 at Woodstock, discussions took place on lake-wide and local water quality issues identified through draft Assessment Report work. General source water quality concerns were also discussed. From preliminary information being compiled through the Assessment Reports, turbidity, aluminium, algal growth and nutrients appear to be common to many of the intakes in the southwestern part of Lake Erie. At the time the meeting was held, the drinking water quality issue identification (as per the Clean Water Act and *technical rules*) was not complete. Once the *issues* identification process has been completed and *issues* contributing areas and activities have been identified it will be possible to consider whether issues are lake-wide or due to local activities at a subwatershed scale. In the Thames-Sydenham and Region the *issues* contributing areas and activities would be determined as part of an amended Assessment Report. The relevance of existing Great Lakes groups and agreements to the requirements of the Clean Water Act was also discussed. The formation of a more formal working group was considered. At this time, however, it was decided to correspond with neighbouring Source Protection Regions as needed and to hold another meeting in 2010, after the submission of Assessment Reports. This plan would help bring forward for discussion the findings of each Source Protection Authority's Assessment Report, especially as they pertain to *issues*.

A similar working group for Lake Huron has been discussed by the SPC Chairs and Project Managers. At the time of discussion, there were very few *issues* which might warrant such a working group for Lake Huron. While the Upper Thames River SPA does not contain surface water intakes, a large portion of the population of this SPA is supplied Lake Huron and Lake Erie water, as mentioned earlier. Further, a part of the St. Clair Region SPA is supplied with Lake Huron water. Since the time of the discussion on the formation of a working group for Lake Huron, the St. Clair Region SPA Proposed Assessment Report has been submitted to the province, and there are no *issues* identified for the Lake Huron intake in that SPA. If however, other regions feel there are lake-wide issues that should be discussed, a working group could be considered for Lake Huron.

The Thames-Sydenham and Region (TSR) Source Protection Committee has expressed interest in participation in the Lake Huron and Lake Erie working groups if they are formed. There was some concern as to whether Lake St. Clair *issues* could be adequately considered in the Lake Erie working group. It is however important to realize that Lake St. Clair is bounded by Essex Region SPA and the Thames-Sydenham and Region. As such it is expected that *issues* identified with the Essex Region intakes in Lake St. Clair could be dealt with through collaboration between the two SPCs. The SPAs within the TSR will continue to work with the Essex Region SPA on projects and *issues* related to Lake St. Clair.

8.4 Next Steps for Great Lakes

The Thames-Sydenham and Region will continue to be involved in the Lake Erie Basin working group if formed. Dealing with lake-wide issues, investigating local activities, and formation of Great Lakes related policies will be discussed with other members of the working group. If the *MECP* identifies Great Lakes targets, policies specific to those targets will need to be developed under the Source Protection Plan. Further, if the *MECP* identifies targets that apply across several Source Protection Regions and Source Protection Areas, working groups such as the

Lake Erie working group may provide an opportunity to work together to satisfy shared regulatory requirements.

9.0 Data Gaps and Next Steps

The development of Assessment Reports is required by the Clean Water Act, the related regulations and the *Technical Rules: Assessment Report*. Together these documents outline the materials which are required in the Assessment Reports. The Clean Water Act and the regulations also outline the process for developing, consulting on, submitting, and revising the Assessment Reports.

Through information from various technical studies, the Assessment Report must identify and assess *vulnerable areas*, evaluate drinking water quality *issues*, and identify and assess *threats* to the sources of drinking water. This section of the Assessment Report describes the known data gaps in the technical studies conducted, the plans to fill the gaps and the next steps in the *Source Protection Planning* process.

9.1 Data Gaps

The different types of data gaps summarized in this section relate to the availability of information and the timing of Provincial guidance updates, such as the *Technical Rules*.

The *Technical Rules: Assessment Report* identifies many of the requirements of the Assessment Report. For some of these requirements, the *technical rules* allow for the submission of a work plan if the information necessary to complete the item is not available. These items include work related to threats contributing to *issues*, Tier 3 Water Budget, *Wellhead Protection Area-E* (*WHPA-E*) and *WHPA-F* associated with *Groundwater Under Direct Influence* (*GUDI*) of surface water systems and *Intake Protection Zone-3* (*IPZ-3*).

Other gaps identified in the Assessment Report are a result of information not being available, or not available in time, to be included in the Assessment Report.

Several of the gaps identified in the Amended Proposed Assessment Report are now filled. These include the Tier 3 water budget and the delineation of Woodstock ICA.

Table 9-1 provides the work plan to fill the remaining few gaps in the Upper Thames River Source Protection Area Assessment Report. This Table identifies the gap, provides a description of the gap and its current status, lists the steps to be undertaken in the work plan to fill the gap, and provides the anticipated work plan completion date.

9-1 Plan to fill Data and Analysis Gaps

Gap	Description	Work Plan	Planned Completion Schedule
Edge-matching of HVA and SGRA with neighbour-ing regions	▪ Edge-matching of HVA and SGRA with neighbouring regions is to be completed in order to form seamless mapping between source protection regions	▪ This work will be considered when neighbouring regions' HVA and SGRA maps are complete ▪ Methodologies will be determined in consultation with the neighbouring regions once the extent of the challenges are known.	Dependent on when neighbouring regions complete HVA and SGRA maps
Impact of Climate Change	▪ Work undertaken in Upper Thames River Source Protection Area although focused more on flooding and infrastructure than on water supply ▪ Requires an understanding of the local climatic conditions resulting from global climate change which is not yet available ▪ Impact on source water protection is unknown	▪ Examine data available for the Upper Thames River Source Protection Area and assess relevancy to source protection ▪ Consider local climactic conditions when information becomes available ▪ Prepare draft section on climate change if data allows ▪ Update Assessment Report if warranted	To be determined
Improved understand--ing of water use	▪ Use actual water use data in water budget work	▪ Obtain actual water use data from all significant water users through the PTTW reporting system ▪ Requires reassessment after sufficient data has been reported, perhaps when Assessment Report requires future update ▪ Where Tier 3 assessment will be undertaken, updated PTTW will be considered to the extent that the data is available	Subsequent Assessment Report, dependent on other programs
Compare Capture zones with those from Tier 3 Model	▪ Tier 3 Water Budget model has improved the level of understanding in some of the capture zones in the UTRSPA ▪ An assessment of the impact of that improved understanding on the capture zones should be undertaken	▪ Compare conceptual models used for WHPA delineation with those used for T3WB ▪ Determine the likely impacts on capture zone delineation ▪ If appropriate run models to delineate revised WHPA	Subsequent Assessment Report dependent on available resources

9-1 Plan to fill Data and Analysis Gaps

Gap	Description	Work Plan	Planned Completion Schedule
Woodstock ICA	▪ An assessment of nitrate levels in 2014 suggests that levels may be decreasing in the Tabor wells. Additional sampling is needed to confirm the trend and assess whether Nitrate is still an Issue at the Thorton wellfield.	▪ Continue with enhanced nutrient management plans on County owned farmland within the wellfield ▪ U. of Waterloo to monitor nitrate migration across landscape to improve conceptual understanding and refine model ▪ Monitor nitrate levels at each well ▪ Prioritize negotiation of RMP associated with nitrate application within the wellfield ▪ Retain consultant to analyze data and provide recommendation regarding nitrate issue designation ▪ If necessary delineate ICA using T3WB model and U of Waterloo conceptual understanding of nitrate movement through the aquifer, identify associated significant drinking water threats and amend AR as appropriate.	Subsequent Assessment Report

*Dependent upon submission of the updated Assessment Report and/or approved funding

If further information becomes available to the SPC to identify conditions and the sources of water quality issues, the associated work would be included in a subsequent Assessment Report. As mentioned in Section 5.6, the sources or causes of some of the *issues* are yet to be determined. This is an information gap. Filling of this data gap, as more information becomes available to the SPC, may help identify *issues* as per Rule 114, and possibly lead to identifying the area and activity contributing to those *issues* as required by Rule 115. As described in Section 6.3, the Source Protection Committee would review information, which becomes available to it, that helps identify *conditions*.

Also, as described in Section 7.3, a site-specific *risk* assessment to confirm the number of locations at which *significant threats* occur would be undertaken as municipalities prepare for the implementation of Source Protection Plans Site specific risk assessment is an important part of compliance monitoring of activities within vulnerable areas where significant drinking water threats may occur. The site specific assessment involves the examination of *activities* and the *circumstances* under which they occur through site visits and discussions with the landowners.

The outcome of the site specific *risk* assessment will be part of annual reports to provide ongoing assessment of the number of locations of significant drinking water threats.

9.2 Next Steps

Prior to the submission of an Assessment Report to the Director, the Clean Water Act identifies consultation requirements. The required consultation is part of a more comprehensive consultation plan being conducted in the Thames-Sydenham and Region involving local and regional consultation on the draft proposed, proposed Assessment Report, and Updated Assessment as well as the technical work that has informed it. See Section 1 - Introduction and Background for more information on the Assessment Report consultation process. Once consultation is complete and the Source Protection Committee has considered input received through the consultation, the Assessment Report is submitted to the Director (Ministry of Environment) for approval. The Director can approve the Assessment Report or request amendments to it. Amendments which the Director requests will not require consultation.

Following submission of the Assessment Report, work will continue on filling the data and analysis gaps discussed above. That work will require updates to the Assessment Report which will also be consulted on. The updated Assessment Report will then be submitted to the Director for approval.

The Source Protection Committee has identified that the Assessment Report is, in fact, a living document which will require periodic amendments and updates. Review and update of the Assessment Report will be required as identified in the Clean Water Act. The period of the review will be determined by the Director in the approval of the Assessment Report. Aside from the required review of the Assessment Report, the Source Protection Committee has the ability to amend the Assessment Report at such time when it becomes aware that the material in the Assessment Report has an effect on the *Source Protection Plan* developed. Any amendments to the Assessment Report will require consultation of those affected by the amendments.