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REGION

Kettle Creek Source Protection Area

ASSESSMENT REPORT

Prepared on behalf of:
Lake Erie Region Source Protection Committee

Under the *Clean Water Act, 2006*
(Ontario Regulation 287/07)

Version 2.1
August 15, 2024

This project has received funding from the Government of Ontario.

Note: Please refer to Volume I of the Kettle Creek Source Protection Plan for a list of version numbering and a high-level summary of amendments that have been made since original approval in 2014.

EXECUTIVE SUMMARY

The Kettle Creek Source Protection Area Assessment Report was submitted to the Ministry of the Environment, Conservation and Parks on May 7, 2010, and received approval on October 7, 2010. Additional updates have been made to the assessment report following the October 2010 approval. These recent amendments are included in the Kettle Creek Assessment Report which was posted for a 35-day public consultation period form April 5 to May 9, 2023. No comments were received during the most recent public consultation period. Detailed public consultation comments and how they were addressed for previous iterations of the Kettle Creek Assessment Report are available upon request.

The Assessment Report summarizes the technical studies undertaken in the Kettle Creek Source Protection Area (watershed) to delineate areas around municipal drinking water sources that are most vulnerable to contamination and overuse. Within these vulnerable areas, historical, existing and possible future land use activities were identified that could pose a threat to municipal water sources. Technical studies include a characterization of the human and physical geography of the watershed, a water budget and water quantity stress assessment, an assessment of groundwater and surface water vulnerability, a land use activity inventory, and an evaluation of existing water quality contamination Issues.

The Assessment Report provides an introduction to the Source Protection Planning process, and the roles and responsibilities of the Lake Erie Region Source Protection Committee, municipalities and conservation authorities. Section 2 of the Assessment Report provides a summary of the human and physical geography of the Kettle Creek watershed, while Section 3 summarizes the water budget and stress assessment findings. Section 4 summarizes both surface water and groundwater vulnerability, including Intake Protection Zones, Highly Vulnerable Aquifers, Significant Recharge Areas and Wellhead Protection Areas. Section 4 also provides a summary of the threats enumeration and Issues evaluation undertaken in each vulnerable area.

Sections 5 and 6 provide information on how climate change in the area may affect the results of the Assessment Report and how Great Lakes agreements were considered as part of the work undertaken. Section 7 summarizes the findings in the Assessment Report and provides an outline of the next steps in developing a source protection plan for the Kettle Creek Source Protection Area.

Kettle Creek watershed contains two municipal drinking water systems. The village of Belmont draws water from two groundwater wells operated by the Municipality of Central Elgin. The system serves approximately 1,900 people. The wells are located in an area of low vulnerability, which results in medium to low vulnerability scores in most of the wellhead protection area, and an area of high vulnerability within the 100-metre area around the wells. To date, no significant drinking water threat has been identified in the wellhead protection area surrounding the Belmont wells. No drinking water Issues have been identified to date.

The Elgin Area Water Board operates a municipal surface water intake in Lake Erie near the town of Port Stanley. The Elgin Area Water Supply System serves approximately 100,000 people in several municipalities in the area. The vulnerability of the surface water within Intake Protection Zones 1, 2 is considered to be low; therefore, no significant drinking water threats have been identified using the threats based approach. No Issues have been identified in the Intake Protection Zones (IPZs) to date.

Additional studies were undertaken in 2010 and 2012 to gather more detailed information on the Elgin Area Water Supply intake. The results of the events based threats investigations include the identification of the handling and storage of 5,000 m^3 or more of commercial fertilizer and of 6,000 Litres or more of fuel have been identified as potential significant drinking water threats. In recent years, the bulk storage tanks of fertilizer have been removed and the lands are being rezoned as part of the Secondary Plan for the Port Stanley Harbour area. The Events Based Area and associated IPZ-3 for the Urea Ammonium Nitrate (UAN) fertilizer threat have been removed as part of the 2024 assessment report update.

The findings of the water budget and stress assessment studies indicate that the groundwater subwatershed within which the Belmont wells are located has a low potential for stress. As such, no water quantity threats have been identified.

The results of the technical studies were used to develop policies to protect sources of municipal drinking water. Policies have been developed by municipalities, conservation authorities, property and business owners, farmers, industry, health officials, community groups and others working together to develop a fair, practical and implementable Source Protection Plan. Public input and consultation have played a significant role throughout the process.

In 2024, updates were approved for the watershed characterization section, water quality risk assessment, and the state of climate change research in Lake Erie Region. The Assessment Report also includes minor administrative and editorial updates.

The public could submit comments on the draft Assessment Report by email or by regular mail.

Any comments received during this comment period were considered prior to the submission of the assessment report to the Ministry of the Environment, Conservation and Parks for review and approval.

Note: New and former names of Provincial Ministries are used within this document. Name changes are documented as follows:

Ministry of Environment, Conservation and Parks (MECP)

Date	**Name**
Pre-2014	Ministry of the Environment (MOE)
2014	Ministry of Environment and Climate Change (MOECC)
2018	Ministry of the Environment, Conservation and Parks (MECP)

Ministry of Natural Resources (MNR)

Date	**Name**
Pre-2014	Ministry of Natural Resources (MNR)
2014	Ministry of Natural Resources and Forestry (MNRF)
2021	Ministry of Northern Development, Mines, Natural Resources and Forestry (NDMNRF)
2022	Ministry of Natural Resources and Forestry (MNRF)
2024	Ministry of Natural Resources (MNR)

Ministry of Agriculture, Food and Agribusiness (OMAFA) and Ministry of Rural Affairs (OMRA)

Date	**Name**
Pre-2024	Ministry of Agriculture, Food and Rural Affairs (OMAFRA)
2024	Ministry of Agriculture, Food and Agribusiness (OMAFA) and Ministry of Rural Affairs (OMRA)

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1.0 INTRODUCTION

Following the public inquiry into the Walkerton drinking water crisis in May 2000, Justice Dennis O'Connor released a report in 2002 containing 121 recommendations for the protection of drinking water in Ontario. Since the release of the recommendations, the Government of Ontario has introduced legislation to safeguard drinking water from the source to the tap, including the *Clean Water Act*, 2006. The Act provides a framework for the development and implementation of local, watershed-based source protection plans, and is intended to implement the drinking water source protection recommendations made by Justice Dennis O'Connor in Part II of the Walkerton Inquiry Report. The Act came into effect in July 2007, along with the first five associated regulations.

The intent of the *Clean Water Act,* 2006 is to ensure that communities are able to protect their municipal drinking water supplies now and in the future from overuse and contamination. It sets out a risk-based process on a watershed basis to identify vulnerable areas and associated drinking water threats and Issues. It requires the development of policies and programs to reduce or eliminate the risk posed by significant threats to sources of municipal drinking water through science-based source protection plans.

Source Protection Committees are working in partnership with municipalities, Conservation Authorities, water users, property owners, the Ministry of Environment, Conservation and Parks (MECP) and the Ministry of Natural Resources and Forestry (MNRF), and other stakeholders to facilitate the development of local, science based source protection plans.

The *Clean Water Act*, 2006 and Drinking Water Source Protection are one component of a multi-barrier approach to protecting drinking water supplies in Ontario. The five steps in the multi-barrier approach include:

- Source water protection
- Adequate treatment
- Secure distribution system
- Monitoring and warning systems
- Well thought-out responses to adverse conditions.

After the Walkerton Inquiry, the Government of Ontario enacted the Safe Drinking Water Act, which provides new requirements and rules for the treatment, distribution and testing of municipal drinking water supplies. Together, the *Clean Water Act*, 2006 and Safe Drinking Water Act, along with their associated regulations, provide the legislative and regulatory framework to implement the multi-barrier approach to municipal drinking water protection in Ontario.

The protection of municipal drinking water supplies through the *Clean Water Act*, 2006 is one piece of a much broader environmental protection framework in Ontario. Water resources in Ontario are protected directly and indirectly through the federal and provincial governments, municipalities, conservation authorities and public health units. These agencies are responsible for protecting and improving water quality, water quantity and aquatic habitats, providing land use planning and development rules to ensure that water resources are not negatively affected, providing flood management and responses to low water availability, and many others.

1.1 Source Protection Planning Process

The key objectives of this process are the completion of science-based Assessment Reports that identify the risks to municipal drinking water sources, and locally-developed Source Protection Plans that put policies in place to reduce the risks to protect current and future sources of drinking water.

Since 2005, municipalities and conservation authorities have been undertaking studies to delineate areas around municipal drinking water sources that are most vulnerable to contamination and overuse. Within these vulnerable areas, technical studies have identified historical, existing and possible future land use activities that are or could pose a threat to municipal water sources. This Assessment Report is a compilation of the findings of the technical studies undertaken in the Kettle Creek Source Protection Area (watershed area).

The draft Kettle Creek Assessment Report was the first version of the report made available for public consultation in 2010. The Kettle Creek Assessment Report was approved by the Ministry of the Environment, Conservation and Parks on October 7, 2010 and is available on the Lake Erie Source Protection Region website.

Additional technical work has been completed since the latest approval of the Kettle Creek Assessment Report and the Source Protection Plan in 2014. The public consultation period for the Kettle Creek Assessment Report and Source Protection Plan update was held from April 5 to May 9, 2023. This consultation period provided an opportunity for stakeholders and the public to view and provide comment on the Kettle Creek Assessment Report and Source Protection Plan.

All comments received during this comment period will be forwarded to the Ontario Ministry of the Environment, Conservation and Parks with the submission of the Kettle Creek Source Protection Plan.

The Assessment Report provides the technical foundation for the Source Protection Plan. The Source Protection Plan is a document that contains policies to protect sources of drinking water against threats identified in the Assessment Report. The Plan sets out:

- how the risks posed by drinking water threats will be reduced or eliminated;
- policy, threat and Issues monitoring programs;

- who is responsible for taking action;
- timelines for implementing the policies and programs; and
- how progress will be measured.

After approval of the Source Protection Plan, annual monitoring and progress reports on implementation will be required. Implementation of the Source Protection Plan, once it has been approved by the Minister, will be led by municipalities in most cases. In some cases, conservation authorities, public health units, or other organizations may be involved in implementing policies in the Source Protection Plans. The implementers will be able to use a range of voluntary and regulatory programs and tools, including outreach and education; incentive programs; land use planning (zoning by-laws, and Official Plans); new or amended provincial instruments; risk management plans; and prohibition. Actions to reduce the risk posed by current activities found to be significant threats will be mandatory, since the *Clean Water Act*, 2006 requires that all existing significant threats cease to be significant.

1.2 Source Protection Authorities and Regions

The province has organized the Source Protection Program using watershed boundaries, rather than municipal or other jurisdictions. The watershed boundary is the most appropriate scale for water management, since both groundwater and surface water flow across political boundaries. For Source Protection planning purposes, the watershed is referred to as a Source Protection Area under the *Clean Water Act*, 2006. The Kettle Creek watershed is called the Kettle Creek Source Protection Area. Similarly, conservation authorities are referred to as Source Protection Authorities under the *Clean Water Act,* 2006 and are responsible for facilitating and supporting the development of source protection plans.

For the purposes of source protection, the Kettle Creek Source Protection Authority is partnered with the Catfish Creek Source Protection Authority, Grand River Source Protection Authority and Long Point Region Source Protection Authority to create the Lake Erie Source Protection Region. The Lake Erie Source Protection Region is one of 19 regions established across the province. The Grand River Source Protection Authority acts as the lead Source Protection Authority in the Lake Erie Region.

1.3 Source Protection Committee

In the Kettle Creek Source Protection Area, the Source Protection Planning process is led by a steering committee called the Lake Erie Region Source Protection Committee. The Committee was formed in November 2007, and has met monthly in the first five years for the development of the Assessment Report and Source Protection Plan. Since then the committee met on a quarterly basis. The Committee has been responsible for directing the development of the Assessment Reports and Source Protection Plans for each of the four Source Protection Areas in the Lake Erie Region. The list of current and past members is published on the Lake Erie Source Protection Region website.

Message from the Committee

The overall objective of the Lake Erie Region Source Protection Committee, in partnership with local communities and the Ontario government, is to direct the development of source protection plans that protect the quality and quantity of present and future sources of municipal drinking water in the Lake Erie Source Protection Region. We will work with others to gather technical and traditional (local and Indigenous) knowledge on which well-informed, consensus-based decisions can be made in an open and consultative manner. In developing the Source Protection Plan, the Lake Erie Region Source Protection Committee intends to propose policies that are environmentally protective, effective, economical, and fair to local communities.

The committee will strive to develop policies that are practical and implementable, and that focus limited resources on areas that net the greatest benefit, while recognizing that the plan must address significant threats so that they cease to be significant. Where possible, the committee will strive to develop policies and programs that also provide a benefit to broader protection of water quality and quantity. The process to assess drinking water threats and Issues will be based on the best available science, and where there is uncertainty, we will strive to follow the precautionary approach.

In December 2008, the Committee submitted to the Minister of the Environment their Terms of Reference for the Kettle Creek Source Protection Area Assessment Report and Source Protection Plan. The Terms of Reference sets out the work plan for completing both the Assessment Report and Source Protection Plan and received Ministerial approval on May 11, 2009. A copy of the Kettle Creek Region Source Protection Area Terms of Reference can be found on the Lake Erie Source Protection website.

1.4 Framework of the Assessment Report

The Kettle Creek Source Protection Area Assessment Report was completed in compliance with Ontario Regulation 287/07 (General) under the *Clean Water Act*, 2006, which sets out the minimum requirements for Assessment Reports. In addition, the technical work summarized in this Assessment Report was completed in conformance with the Technical Rules: Assessment Report under O. Reg. 287/07. The technical work was undertaken by local municipalities and conservation authorities. Funding to complete the technical studies for the Assessment Report was provided by the Province of Ontario.

Within the Kettle Creek Source Protection Area (SPA), there are two municipal drinking water sources: The Belmont Water System serving the Village of Belmont in the Municipality of Central Elgin; and the Elgin Area Water Supply System serving several communities in Elgin County and the City of London. The Belmont drinking water supply draws water from two groundwater wells. The Elgin Area Water Supply draws water from a surface water intake in Lake Erie located offshore of the town of Port Stanley in the Kettle Creek SPA.

The *Clean Water Act*, 2006 focuses on the protection of municipal drinking water supplies; however, the Act allows for other water systems to be considered, including clusters of private wells, communal systems, and other non-municipal supplies. Only municipalities within which the supplies are located or the Minister of the Environment, Conservation and Parks have the power to add additional non-municipal systems. To date, no municipalities in the Kettle Creek Source Protection Area have designated non-municipal drinking water supplies under the *Clean Water Act*, 2006.

The technical studies summarized in this Assessment Report start with information at the watershed scale, and then move to the municipal drinking water system scale. The document is organized into the following sections: Watershed Characterization; Water Budget and Water Quantity Stress Assessment; Water Quality Risk Assessment; and Conclusions.

The descriptions of the technical work provided in the Assessment Report are summaries of more detailed technical reports. In order to find more detail on any of the components of the Assessment Report, the reader is encouraged to view the technical studies and background reports available on the Lake Erie Source Protection Region website.

1.5 Continuous Improvement

The findings of this Assessment Report are based on the best available information. It is recognized that new information that informs the findings of this Assessment Report will become available in the future. Beyond the completion of this Assessment Report, Municipalities and Conservation Authorities will continue to refine and improve the findings and attempt to address the data gaps documented in the Report. As new or improved information becomes available, the relevant components of the Assessment Report will be amended as required. Opportunities for input and review of amended Assessment Reports will be made available to those affected by the proposed changes.

1.6 Public Consultation

Updates to the assessment report require one formal round of consultation with the public and stakeholders.

During each period of public consultation, members of the public, municipalities or other interested bodies were able to submit comments to the Source Protection Committee. The Committee in turn considers these comments following each period of public consultation.

The Kettle Creek Assessment Report was posted for a 35-day public consultation period between April 5 and May 9, 2023. The public was invited to review the assessment report online, at the Central Elgin municipal office, or at the Kettle Creek Conservation Authority (KCCA) where hard copies were made available.

The public could submit comments on the Assessment Report by email (comments@sourcewater.ca) or by regular mail.

All comments received during this comment period will be forwarded to the Ontario Ministry of the Environment, Conservation and Parks with the submission of the Kettle Creek Assessment Report and Source Protection Plan.

No comments were received during the most recent public consultation period**.** Detailed public consultation comments and how they were addressed for previous iterations of the Kettle Creek Assessment Report are available upon request.

1.7 Overview of Source Protection Risk Assessment Process

Source Protection Area Assessment Reports are summaries of technical studies that identify:

- The vulnerable areas around municipal-residential drinking water sources
- How “vulnerable” the vulnerable areas are
- Where potential threats to water quality and quantity can be found in each vulnerable area
- The activities that pose the biggest threat to human health
- How significant the risk of the threat is of contaminating or depleting the water supply

1.7.1 Vulnerable Areas

What are vulnerable areas?

The *Clean Water Act*, 2006 identifies four types of vulnerable areas related to drinking water sources:

- Highly Vulnerable Aquifer (HVA) areas
- Significant Groundwater Recharge Areas (SGRA)
- Wellhead Protection Areas (WHPA)
- Intake Protection Zones (IPZ)

The first three vulnerable areas are associated with groundwater, while intake protection zones are associated with surface water (rivers and lakes). The Highly Vulnerable Aquifer areas, Significant Groundwater Recharge Areas and Wellhead Protection Areas are determined through complex modelling of the geology and groundwater flow in an area, as well as the permeability of surface material above the groundwater (aquifers). The Intake Protection Zones are determined by assessing the flow of surface water in the river or lake.

Wellhead Protection Areas and Intake Protection Zones are developed specifically around municipal water supplies (around groundwater wells or surface water intakes). Highly Vulnerable Aquifers and Significant Groundwater Recharge Areas are assessed at the watershed scale and are not necessarily associated with any existing groundwater municipal drinking water systems.

Groundwater

Within the source protection program, all groundwater-based municipal supplies have completed an assessment of vulnerability of the system to quality-related threats and have enumerated and classified threats within WHPAs as having a significant, moderate, or low potential for risk to the quality of the municipal drinking water supply. Following the completion of the threats assessment, it is each municipalities' goal to manage threats and reduce the number of significant threats to the drinking water system through policies identified in the source protection plan.

The following sections outline the methods used to map WHPAs, determine vulnerability scoring and enumerate and classify quality-related threats to the municipal supply.

Wellhead Protection Areas

A WHPA is a planning term used to describe scientifically based capture zones delineated for water supply wells. The Technical Rules (MECP, 2021) require that WHPAs for water quality be delineated for each municipal drinking water supply well. A WHPA consists of four zones which are based on the time it takes for groundwater to travel from the water table surface to the municipal well. The zones are defined as follows:

- WHPA-A: 100 m radius around the municipal well
- WHPA-B: Time of travel to the municipal well is 2 years or less
- WHPA-C: Time of travel to the municipal well is equal to or less than 5 years and greater than 2 years
- WHPA-D: Time of travel to the municipal well is equal to or less than 25 years and greater than 5 years

A WHPA-E can be delineated for groundwater wells when there is an interaction between the surface water and ground water supply that may impact the water quality at the well.

Methodology for WHPA Delineation

Within the Kettle Creek watershed, calibrated, numerical groundwater flow models were used to delineate capture zones. A groundwater flow model is a simplified representation of a complex physical, hydrologic and hydrogeologic system where natural and anthropogenic processes affect the rates and direction of groundwater flow.

Using the groundwater flow models, capture zones in the Kettle Creek watershed were delineated through time of travel assessments using backward and forward particle tracking. Virtual particles were released in the groundwater flow model and either tracked forward in time towards the municipal well or backward (particles released at the municipal and tracked backward) in time through the aquifer for specified time intervals. The resulting paths that the particles take were then projected to ground surface and plotted on a plan view. Time-of-travel capture zones were subsequently created by drawing polygons around the wells and the particles path lines at specific times. As such, capture zones represent the land areas beneath which groundwater and associated contaminants may migrate toward a well within a specified period.

Aquifer Vulnerability

Municipal wells draw their water from aquifers located beneath the ground surface. Aquifers are replenished when surface water infiltrates into the groundwater system. Sometimes, the water infiltrating from the ground surface can carry pollutants such as road salt, nitrate from fertilizers, or industrial chemicals into the groundwater system.

The vulnerability of an aquifer is its susceptibility to impacts from land use activities such as the application of road salt, manure, or fertilizers. Vulnerability is assessed based on the travel time from ground surface to the municipal aquifer.

An aquifer vulnerability analysis is a physically-based evaluation of the geologic and hydrogeologic character of the sediments and bedrock overlying the municipal aquifer. The resulting calculations provide a rating of the intrinsic vulnerability for the aquifer of interest. The calculated vulnerability is highly dependent upon a number of factors which include the geologic structure, the hydraulic character of the sediments, the vertical hydraulic gradient, and the hydraulic connection between the surficial recharge water and the aquifer of interest. The results from the aquifer vulnerability assessment are classified to map areas of high, medium and low intrinsic vulnerability.

Vulnerability Scoring within WHPAs

To obtain the vulnerability score within a WHPA, a scoring matrix is applied which intersects the WHPA zones with the aquifer vulnerability classification. The scores applied, as shown in **Table 1-1** and **Table 1-2** below, are dependent on the method used for the vulnerability analysis.

Table 1-1: Wellhead Protection Area Vulnerability Scores – ISI/AVI

Groundwater Vulnerability Category for the Area	WHPA-A	WHPA-B	WHPA-C	WHPA-D
High	10	10	8	6
Medium	10	8	6	4
Low	10	6	4	2

Table 1-2: Wellhead Protection Area Vulnerability Scores – SAAT/SWAT

Groundwater Vulnerability Category for the Area	WHPA-A	WHPA-B	WHPA-C	WHPA-D
High	10	10	8	6
Medium	10	8	6	4
Low	10	6	2	2

Vulnerability within WHPA-Es is assessed relevant to how an IPZ-2 is assigned vulnerability scores. The area vulnerability factor for IPZ-2 is assigned by a value ranging between 7 and 9 using professional judgement, where 9 is the highest vulnerability score (Technical Rule 89).

Transport Pathways

A constructed transport pathway is a shortcut, which can make it easier for a contaminant to be transported to a drinking water source. The vulnerability of the municipal aquifers accounts only for the natural protection provided by the materials overlying the aquifers of interest; however, anthropogenic activities can bypass this natural physical protection thereby increasing the vulnerability. Examples of transport pathways includes private water wells, unused or improperly decommissioned water wells, construction of underground services, subsurface excavations, pits and quarries.

The vulnerability of the aquifer may be increased by any land use activity or feature that disturbs the surface above the aquifer, or which artificially enhances flow to that aquifer. In areas where transport pathways exist, the vulnerability can be increased to reflect the higher vulnerability caused by the constructed pathway (i.e., from low to moderate or high, and moderate to high). In some cases, the intrinsic vulnerability index is already high and cannot be further increased.

The vulnerability of the aquifer is only increased to account for a transport pathway where there is sufficient confidence in the available data to justify the increase in vulnerability.

Uncertainty Assessment

An analysis of the uncertainty, characterized by “high” or “low”, is made on the vulnerability of each delineated WHPA (Technical Rules 13 and 14) (MECP, 2021). The uncertainty rating should consider the following:

1. The distribution, variability, quality and relevance of data used in the preparation of the assessment report.
2. The ability of the methods and models used to accurately reflect the flow processes in the hydrological system.
3. The quality assurance and quality control procedures applied.

4. The extent and level of calibration and validation achieved for models used or calculations or general assessments completed.
5. The accuracy to which the groundwater vulnerability categories effectively assess the relative vulnerability of the underlying hydrogeological features.
6. The accuracy to which the area vulnerability factor and the source vulnerability factor effectively assesses the relative vulnerability of the hydrological features.

Surface Water

Some municipalities rely on surface water to supply drinking water to their residents. Surface water is transported through an intake pipe directly from the lake or river into a water treatment system. Protecting the area around a surface water intake means protecting the surrounding water and, in most cases, the land that surrounds the water. This area of water and land is known as an intake protection zone, or IPZ.

Intake Protection Zone

The IPZ is the primary vulnerable area to be delineated to ensure the protection of the municipal surface water supply. For each drinking water system, an IPZ-1, IPZ-2 and IPZ-3 can be delineated.

Intake Protection Zone 1 (IPZ-1) is the area immediately adjacent to the intake. This zone is considered the most vulnerable area for surface water intakes due to its proximity to the intake. Contaminants of concern entering this area would experience little to no dilution before reaching the intake.

Intake Protection Zone 2 (IPZ-2) acts as a secondary protective zone that generally extends upstream of the IPZ-1. The IPZ-2 is defined as the area within and around the surface water body that may contribute water to an intake within a 2 hour time of travel.

Intake Protection Zone 3 (IPZ-3) includes parts of the watershed that may be impacted by extreme events such as storms, strong winds, or high waves. The IPZ-3 includes the area within each surface water body that may contribute water to the intake and where this area abuts land. The IPZ-3 also includes the portion of land within the Conservation Authority Regulation Limit or 120 m, whichever is greater. Additionally, IPZ-3s are delineated to capture all water courses / bodies that contribute water to the sources.

The Technical Rules classify surface water intakes according to their location, with slightly different rules for delineating the Intake Protection Zone and Vulnerability Score for the four different classifications.

The four classifications are:

- Type A: Intakes or the planned intake is or would be located in a Great Lake;
- Type B: Intake or the planned intake is or would be located in a connecting channel;

- Type C: Intake or the planned intake is or would be located in a river and neither the direction nor velocity of the flow of the water at the intake is affected by a water impoundment structure; or
- Type D: If the intake is not a Type A, B or C.

With the written consent of the Director, the Source Protection Authority may reclassify the intake or planned intake and shall include in the assessment report a rationale and evidence to support the reclassification (Technical Rule 55.1, 2021).

Delineation of Intake Protection Zones

For each of the four surface water intake types, three IPZs are identified. The methodologies for delineation of the vulnerable areas around a surface water intake are detailed below.

IPZ-1 is a fixed distance from the intake based on the sensitivity analysis of a massive sudden spill in the vicinity of the intake. Intake types A and D are defined by a 1 km radius centered on the crib of the intake. Intake type B is defined by a semi-circle that has a radius of 1 km extending upstream from the crib of the intake and a rectangle with a length of 2 km centred on the crib of the intake and a width of 100 metres extending downstream from the crib of the intake. Intake type C is defined by a semi-circle that has a radius of 200 metres extending upstream from the crib of the intake and a rectangle with a length of 400 metres centred on the crib of the intake and a width of 10 metres downstream of the intake.

IPZ-2 represents the operator response time to shut down the drinking water system in case of a spill. Intake types A, B, C and D are defined as the area that may contribute water to the intake where the time of travel to the intake is equal to or less than the time that is sufficient to allow the operator of the system to respond to an adverse condition in the quality of the surface water. The Technical Rules indicate that a minimum 2-hour time of travel should be used to delineate the IPZ-2 (excluding IPZ-1).

IPZ-3 is an area beyond the IPZ-1 and 2 and is delineated differently based on the intake type. For intake types A, B, C and D, the IPZ-3 is defined as the area of the water and land that may lead to contaminants reaching an intake during an extreme event such as a one in one hundred year rainfall as determined through modeling or other methods (contaminant transport, boundary approach, combined approach). Significant threats are then identified if it can be shown through modeling that a release of a contaminant during an extreme event may be transported to the intake. For intake types C and D not located in Lake Nipissing, Lake Simcoe, Lake St. Clair, or the Ottawa River, the IPZ-3 is defined as the area within each surface water body that may contribute water to the intake within the watershed boundary.

For all intake types where the IPZ-1, IPZ-2 and IPZ-3 abuts land, a setback of less than or equal to 120m or the Conservation Authority Regulation limit is included, whichever, is greater. The set-back is measured from the high water mark of the surface water body that encompasses the area where overland flow drains into the surface water body and the areas of the Conservation Authority Regulation limit along the abutted land.

According to Technical Rule 72 and 73 (MECP, 2021), where an area that is an IPZ-2 or IPZ-3 includes a setback from a surface waterbody delineated with sub rules 65(1), 68(2), 70(2) the area may be extended to include an area that contributes water to the IPZ-2 or IPZ-3, through a natural or anthropogenic transport pathway. The following factors shall be considered when determining the extended area:

- The hydrological conditions of the area where the transport pathway is located.
- Where a transport pathway is anthropogenic in origin, the type and design of the pathway.
- In respect of an IPZ-2, the time of travel for water to enter into and pass through the transport pathway.

Vulnerability Scoring of Intake Protection Zones

The vulnerability score (V) is a numerical expression of the susceptibility of the intake to contamination. Vulnerability scores are assigned for each type of intake for IPZ-1 and IPZ-2 and for type C and type D intakes for IPZ-3. The vulnerability scores are based on the attributes of the intakes (e.g. length and depth), type of source water body, and the physical characteristics of the environment it is situated in. The vulnerability score (V) is a unitless factor and is calculated by multiplying area vulnerability factor (B) by the source vulnerability factor (C).

The area vulnerability factor (B) is unique for each IPZ and relates to features and processes in the local environment that may impact the intake. The area vulnerability factor was prescribed by the Technical Rules for all IPZ-1s, which receive a score of 10, regardless of the type of intake. Typical factors that may dictate the area vulnerability factor for IPZ-2s include percentage of the area of the IPZ-2 that is composed of land, land cover, soil type, permeability and slope and hydrological conditions in the area that contribute water to the area via transport pathways. The area vulnerability factor for IPZ-3s must be based upon the above listed factors as well as proximity to the intake. The source vulnerability factor (C) relates to the type of water body, intake characteristics (length, depth) and number of recorded drinking water issues.

The IPZ-3 related to type A intake or type B intake is not assigned a vulnerability score, while areas within an IPZ-3 related to type C intake and type D intake are. According to Technical Rule 91, the area vulnerability factor for the IPZ-3, or an area within it, cannot be greater than the area vulnerability factor for IPZ-2.

Uncertainty Assessment

An analysis of the uncertainty, characterized by “high” or “low”, is made on the vulnerability of each delineated IPZ (Technical Rules 13 and 14) (MECP, 2021). The uncertainty rating should consider the following:

1. The distribution, variability, quality and relevance of data used in the preparation of the assessment report.
2. The ability of the methods and models used to accurately reflect the flow processes in the hydrological system.

3. The quality assurance and quality control procedures applied.
4. The extent and level of calibration and validation achieved for models used or calculations or general assessments completed.
5. The accuracy to which the groundwater vulnerability categories effectively assess the relative vulnerability of the underlying hydrogeological features.
6. The accuracy to which the area vulnerability factor and the source vulnerability factor effectively assesses the relative vulnerability of the hydrological features.

1.7.2 Drinking Water Threats Assessment – Water Quality

The Ontario *Clean Water Act*, 2006, defines a Drinking Water Threat as “an activity or condition that adversely affects or has the potential to adversely affect the quality or quantity of any water that is or may be used as a source of drinking water, and includes an activity or condition that is prescribed by the regulation as a drinking water threat.”

The Technical Rules (MECP, 2021) list five ways in which to identify a drinking water threat:

a) Through an activity prescribed by the Act as a Prescribed Drinking Water Threat;
b) Through an activity identified by the Source Water Protection Committee as an activity that may be a threat and (in the opinion of the Director) a hazard assessment confirms that the activity is a threat;
c) Through a condition that has resulted from past activities that could affect the quality of drinking water;
d) Through an activity associated with a drinking water Issue; and
e) Through an activity identified through the events based approach.

Threats from Activities

The Province has identified 22 activities where, if present in vulnerable areas, now or in the future, could pose a threat to drinking water quality or quantity (listed in Section 1.1 of O. Reg. 287/07). Twenty of these activities are relevant to drinking water quality threats, while two are relevant to drinking water quantity threats (Threats 19 and 20).

Table 1-3 lists the activities that are prescribed drinking water threats. Listed beside the prescribed drinking water threats are the typical land use activities that are associated with the threat.

Table 1-3: Drinking Water Threats

Threat Number	Prescribed Drinking Water Threat	Land Use / Activity
1	The establishment, operation or maintenance of a waste disposal site within the meaning of Part V of the Environmental Protection Act.	Landfills – Active, Closed Hazardous Waste Disposal Liquid Industrial Waste
2	The establishment, operation or maintenance of a system that collects, stores, transmits, treats or disposes of sewage.	Sewage Infrastructures, Septic Systems, etc.
3	The application of agricultural source material to land.	e.g., manure, organic soil conditioners, anaerobic digestion output, etc.
4	The storage of agricultural source material.	e.g., manure, organic soil conditioners, anaerobic digestion output, etc.
5	The management of agricultural source material.	aquaculture
6	The application of non-agricultural source material to land.	e.g., organic waste matter derived from the production of biodiesel, organic soil conditioners, pulp, paper and sewage biosolids
7	The handling and storage of non-agricultural source material.	e.g., organic waste matter derived from the production of biodiesel, organic soil conditioners, pulp, paper and sewage biosolids
8	The application of commercial fertilizer to land.	Agriculture Fertilizer
9	The handling and storage of commercial fertilizer.	General Fertilizer Storage
10	The application of pesticide to land.	Pesticides
11	The handling and storage of pesticide.	General Pesticide Storage
12	The application of road salt.	Road Salt Application
13	The handling and storage of road salt.	Road Salt Storage
14	The storage of snow.	Snow Dumps
15	The handling and storage of fuel.	Petroleum Hydrocarbons
16	The handling and storage of a dense non-aqueous phase liquid.	DNAPLs
17	The handling and storage of an organic solvent	Organic Solvents
18	The management of runoff that contains chemicals used in the de-icing of aircraft.	De-icing

Threat Number	Prescribed Drinking Water Threat	Land Use / Activity
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.	Private water taking
20	An activity that reduces the recharge of an aquifer.	Impervious Surfaces
21	The use of land as livestock grazing or pasturing land, an outdoor confinement area or a farm-animal yard.	Agricultural Operations
22	The establishment and operation of a liquid hydrocarbon pipeline. O. Reg. 385/08, s. 3; O. Reg. 206/18, s. 1.	Liquid Hydrocarbon Pipelines

Threats from Conditions

Conditions relate to past or historic activities. Conditions must fall into one of the statements below which are listed in the MECP 2021 Technical Rule (126). If the source protection committee is aware of one of the following conditions that results from a past activity, the committee shall list it as a drinking water threat.

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

- 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.

Threats from Issues and Issue Contributing Areas

A drinking water Issue is defined as the presence of a parameter, listed in Schedules 1, 2, or 3 (listed below) of O. Reg 170/03, or Table 4 of the Technical Support Document for the Ontario Drinking Water Quality Standards (ODWQS) Objectives and Guidelines, at a concentration or a trend of increasing concentration, that may result in the deterioration of the quality of water for use as a source of drinking water. Pathogens are also considered an Issue if they are present at concentrations or a trend of increasing concentrations that may result in the deterioration of the quality of water for use as a source of drinking water. In addition to these parameters, the SPC may identify other parameters for the Issues evaluation.

Schedule 1 Parameters: These include two indicator microorganisms namely E. coli and total coliform. These microorganisms are present in fecal matter (e.g., sewage effluents) and their presence indicates the presence of harmful pathogens, such as Giardia and Cryptosporidium.

Schedule 2 Parameters*:* Schedule 2 parameters include chemical parameters (e.g. metals, inorganics, pesticides and neurotoxins). These parameters are potentially toxic and may adversely affect human health at or above certain concentrations in drinking water. Some of these parameters occur naturally in the environment, while others are results of human activities.

Schedule 3 Parameters*:* These parameters include radio-active materials such as uranium-235. These parameters are potentially toxic and may adversely affect human health at or above certain concentrations in drinking water.

Schedule 4 Parameters*:* These consist mostly of parameters that may impair the taste, odour or colour of the water. These parameters may adversely impact the treatment, disinfection and the distribution of the treated water. The ODWQS identifies either aesthetic objectives (AOs) or operational guidelines for the parameters.

Where a drinking water Issue is identified, the objective is to identify all sources and threats that may contribute to the Issue within an Issue Contributing Area (WHPA-ICA or IPZ-ICA) and manage these threats appropriately. All threats related to a particular Issue within the WHPA-ICA or an IPZ-ICA are classified as significant drinking water threats, regardless of the vulnerability.

Assessing Threats from Activities

Once lists of threats have been compiled, the next step is to determine circumstances under which the threats may be low, moderate, or significant for each vulnerable area.

The Source Water Protection Threats Tool show the threat for circumstances under which a given activity is classified as a low, moderate, or significant threat. These tables list specific descriptions of situations where chemicals and pathogens pose threats to sources of drinking water. The information from these tables is used with the vulnerability scores to help determine where certain activities are significant, moderate and low drinking water threats. Additionally, the Ministry's tables of drinking water quality threats can be used for accuracy.

The enumeration of land use activities that may be associated with prescribed drinking water threats is based on a review of multiple data sources, including public records, data provided by municipal officials, previous contaminant/historical land use information, and data collected during windshield surveys. When available, site specific information is collected to confirm the presence of drinking water threats and the level of management determined.

The method for determining when an activity is a threat is based on a semi-quantitative risk assessment. The assessment considers both the nature of the activity or condition (the hazard rating) and the vulnerability of the affected area (WHPA-A to E, IPZ-1, IPZ-2 and IPZ-3). Both the vulnerability and calculated hazard scores are used to determine a risk score.

All significant threats must be addressed in the Source Protection Plan. The LESPR SPC may choose to develop policies.

2.0 WATERSHED CHARACTERIZATION

Understanding the human and physical characteristics of the watershed is important to protecting and managing water. Interactions between surface water, groundwater and potential sources of contamination require an understanding of the physical characteristics of the bedrock and surficial geology, physiographic regions, climate and significant natural features within the watershed. Additionally, how the people of the watershed interact with these physical characteristics plays an ever-increasing role in determining overall health of the ecosystem. The following sections are intended to provide information on the physical and human characteristics of the Kettle Creek watershed.

2.1 Lake Erie Source Protection Region

In an effort to share knowledge and resources for the purposes of developing source protection plans, a partnership was formed in 2004 between the Grand River, Long Point Region, Catfish Creek and Kettle Creek Conservation Authorities to form the Lake Erie Source Protection Region. The partnership was formalized in 2007 by Ontario Regulation 284/07 (Source Protection Areas and Regions) under the *Clean Water Act*, 2006. The Grand River Conservation Authority, referred to in the regulation as the Grand River Source Protection Authority, acts as the lead source protection authority for the region. **Map 2-1** shows the territory covered by the Lake Erie Region, including municipal boundaries and main rivers and tributaries. The four Source Protection Authorities agreed to jointly undertake research, public education, and watershed planning and management for the advancement of drinking water source protection for the respective watersheds. The watersheds have a long history of partnership and cooperation, and have a natural association by containing the majority of inland rivers and streams flowing from Ontario directly into Lake Erie.

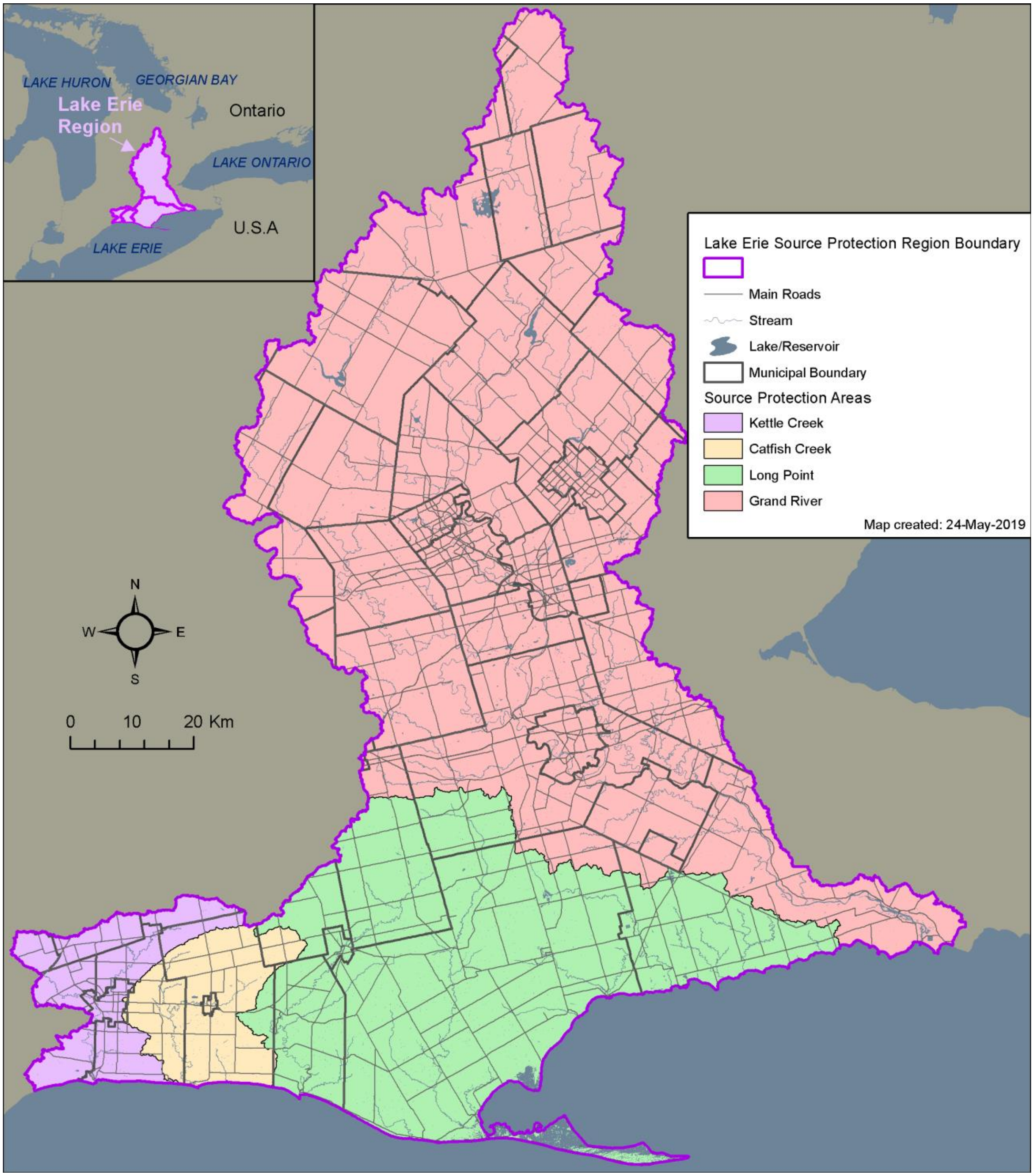
Combined, the Source Protection Region represents a diverse area, ranging from intense agricultural production to large, and rapidly expanding urban areas. The region spans an area from the City of St. Thomas in the west, to Halton Hills on the east, and as far north as Dundalk. The area includes, in whole or in part, 49 upper, lower and single tier municipalities, as well as two First Nations communities.

2.2 Kettle Creek Source Protection Area

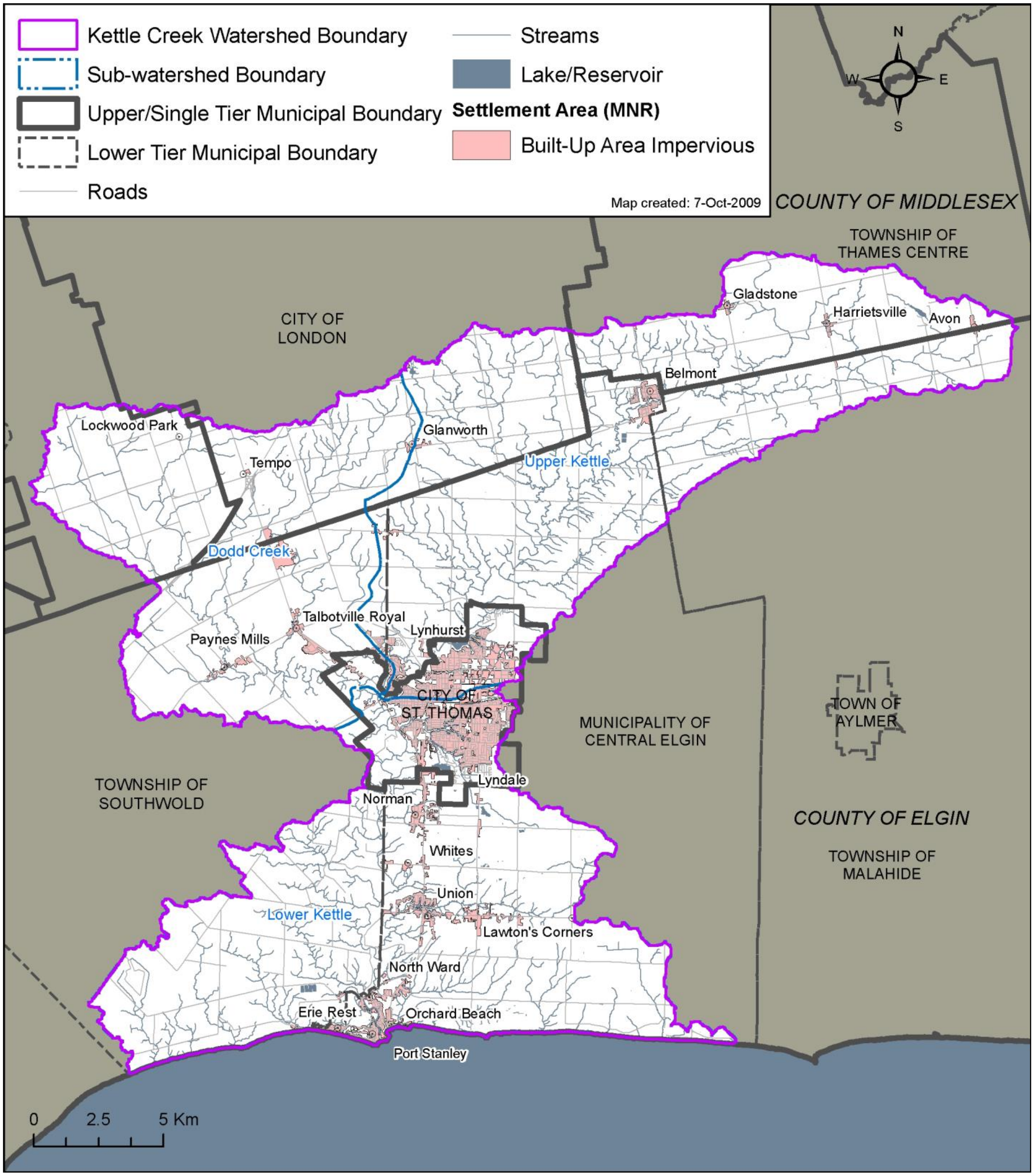
The Kettle Creek Watershed is situated in the heart of the Carolinian Life Zone on the north shore of Lake Erie. As shown on **Map 2-2**, the watershed area is hourglass in shape and drains 520 km^2 of land, which includes the south-central portion of Middlesex County/City of London and the central portion of Elgin County, including the City of St. Thomas. There are four upper-tier and single-tier municipalities in the Kettle Creek Source Protection Area: Elgin County, City of St. Thomas, County of Middlesex, and City of London. Elgin County has three lower-tier municipalities: Townships of Southwold, Malahide and Municipality of Central Elgin; County of Middlesex has two lower-tier municipalities: Townships of Middlesex Centre and Thames Centre.

The tributaries to Kettle Creek include Dodd Creek, Upper Kettle Creek and Lower Kettle Creek. Kettle Creek originates at Lake Whittaker, a kettle lake in the northeastern portion of the watershed. The upper portion of Kettle Creek flows in a southwesterly direction to the City of St. Thomas where it is joined by Dodd Creek, a major tributary flowing from the northwest part of the watershed: Kettle Creek then flows predominately southward towards Lake Erie being joined by the tributaries of Beaver and Mill Creeks before emptying into Lake Erie at Port Stanley. The total drainage area of Kettle Creek at the outlet to Lake Erie is about 440 km^2. Numerous small watercourses bordering Kettle Creek along the Lake Erie shoreline drain directly into Lake Erie. They drain a total area of approximately 80 km^2 with the largest draining 11.5 km^2 (KCCA, 2008). The primary agricultural land use is cash crop, and a moderate amount of specialty cropping also exists. According to the Kettle Creek Conservation Authority (2021), the population of the Kettle Creek Source Protection Area is approximately 83,595 people.

Map 2-1: Lake Erie Source Protection Region Boundary



Map 2-2: Kettle Creek Watershed Boundary



2.3 Physiography

The physiographic features (as mapped by Chapman and Putnam, 1984) within the Kettle Creek Watershed are presented in **Map 2-3**. These landforms were shaped by glacial processes occurring during the Late Wisconsinan glaciation. This occurred 10,000 to 25,000 years ago when glaciers and glacial lobes extended into southern Ontario and as far south as Michigan, Indiana, Illinois and Ohio (Barnett, 1992).

The main physiographic regions within the Kettle Creek Watershed are the Mount Elgin Ridges, the Ekfrid Clay Plain, and the Norfolk Sand Plain.

2.3.1 Mount Elgin Ridges

Located between the Thames River Valley and the sand plains of Norfolk and Elgin counties, the Mount Elgin Ridges cover approximately 270 square kilometres in the northern third of the Kettle Creek watershed (Chapman and Putnam, 1984). This distinct physiographic region is made up of two prominent topographic features, the St. Thomas and Westminster Moraines. (**Map 2-4**).

The St. Thomas Moraine was built by a submerged ice front. It is the strongest moraine of the series, varying in width of up to five kilometres between London and Tillsonburg and is prominent as far as Wallacetown (Barnes, 1967).

The Westminster moraine trends east to west and is approximately five kilometres wide. It passes about 12 kilometres south of the City of London's centre and is flanked on the north by the parallel Ingersoll Moraine. To the south, the Westminster Moraine is flanked by the parallel St. Thomas Moraine. Like most temperate lacustrine moraines, the Westminster Moraine consists of heavy clay deposited over coarser materials such as sand, gravel and extensive boulder beds (Dewdney and Dewdney, 2000). The succession of ridges and valleys in the Mount Elgin Ridges is characterized by clay or silty clay ridges and valleys with alluvium of gravel, sand or silt.

The divides between the Thames River and the several smaller rivers that run south to Lake Erie are found in this region. The broad "Belmont Vale" is occupied by the main branch of the Kettle Creek which, working headward from Lake Erie, has entrenched itself deeply into the till.

2.3.2 Ekfrid Clay Plain

The Ekfrid Clay Plain comprises a fairly large area in the Lake Erie region and approximately 110 square kilometres in the central portion of the Kettle Creek watershed. The flat lying area is characterized by clay and silt deposits providing little relief and poor drainage.

2.3.3 Norfolk Sand Plain

The Norfolk Sand Plain is an extensive 120 square kilometres and encompasses the southern third of the Kettle Creek watershed and extends to the Lake Erie shoreline. It is wedge shaped with a broad curved base along the shore of Lake Erie tapering northward to a point at Brantford on the Grand River. The sands and silts of this region were deposited as a delta in glacial Lake Whittlesey and Warren. The great discharge of meltwater from the Grand River area entered the lake between the ice front and the moraines to the north-west, building the delta from west to east as the glacier withdrew. Thus it covered most of the area west of the Galt Moraine. From observations in exposed river valleys and along the very steep bluffs of Lake Erie there are records of sand beds up to 23 metres deep, but usually silt or clay strata or beds of boulder clay occur within nine metres of the surface (Barnes, 1967).

2.4 Ground Surface Topography

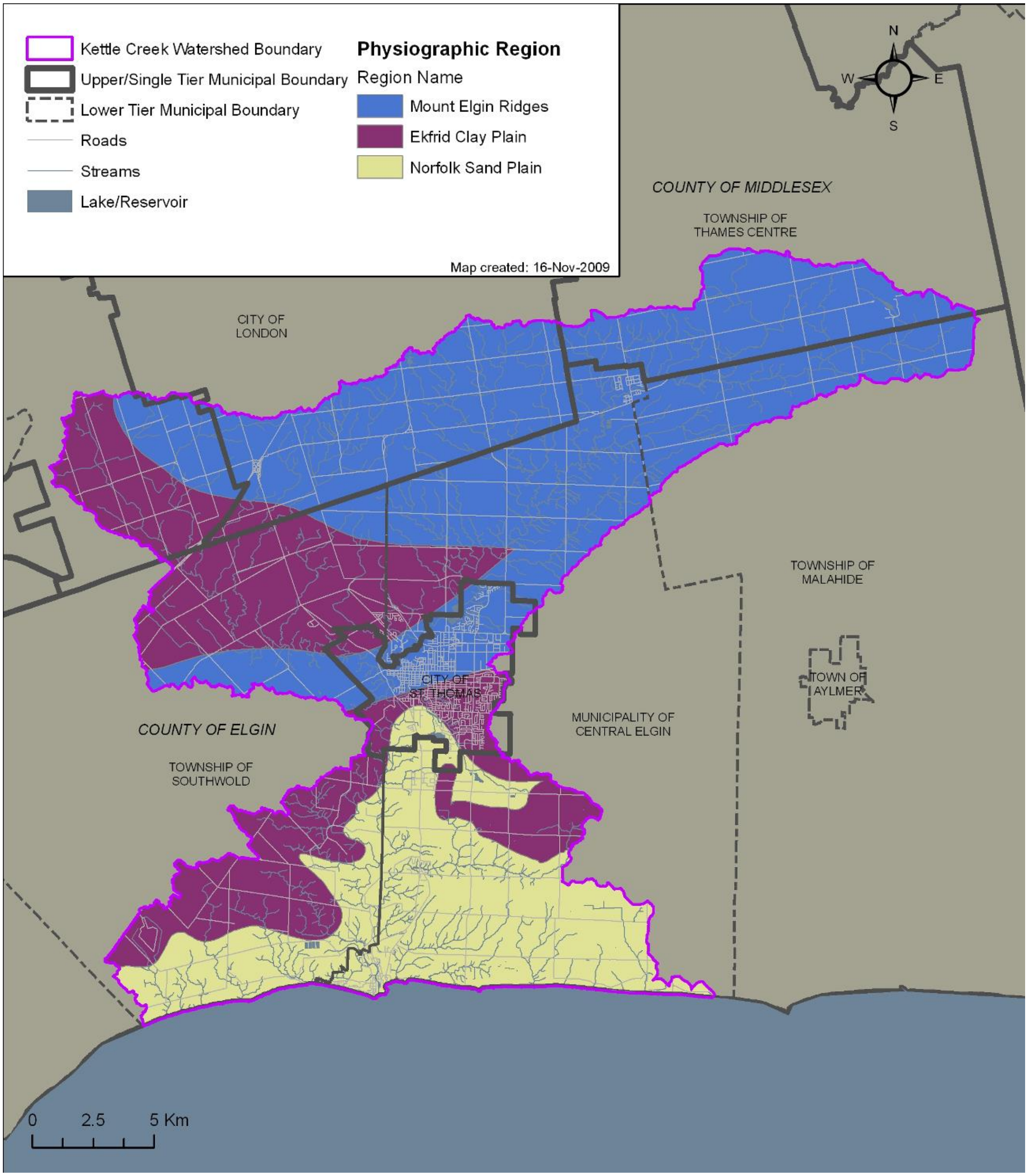
The topography of the Kettle Creek watershed was initially shaped during the regression of the last glaciation and is continuing to be reshaped by current fluvial processes that are taking place in the watershed on a daily basis. **Map 2-5** shows the topography of the Kettle Creek watershed. The topographic heights that exist within the watershed can be identified as the northerly St. Thomas and Westminster Moraines and the southerly Sparta Moraine. The topographic lows in the watershed occur as incised river valleys, created by glaciofluvial processes and continue to evolve as a result of current stream morphology (Dillon and Golder, 2004).

The Kettle Creek watershed drains 520 square kilometres of land situated in the heart of Elgin County and southern Middlesex County. The watershed is characterized by deeply incised valley systems and a steep descent of watercourses from headwater areas to Kettle Creek’s outlet at Port Stanley. Kettle Creek and its tributaries decrease in elevation at an average of 1.75 metres per kilometre of watercourse. Given the predominance of moderately impermeable clay soils found throughout the watershed, rainfall and snowmelt quickly runs-off to nearby drains and streams. Accordingly, the watershed’s primary natural resource management issues include: low base flows, ‘flash’ flooding and run-off, erosion and sedimentation, and degrading quality and quantity of water resources.

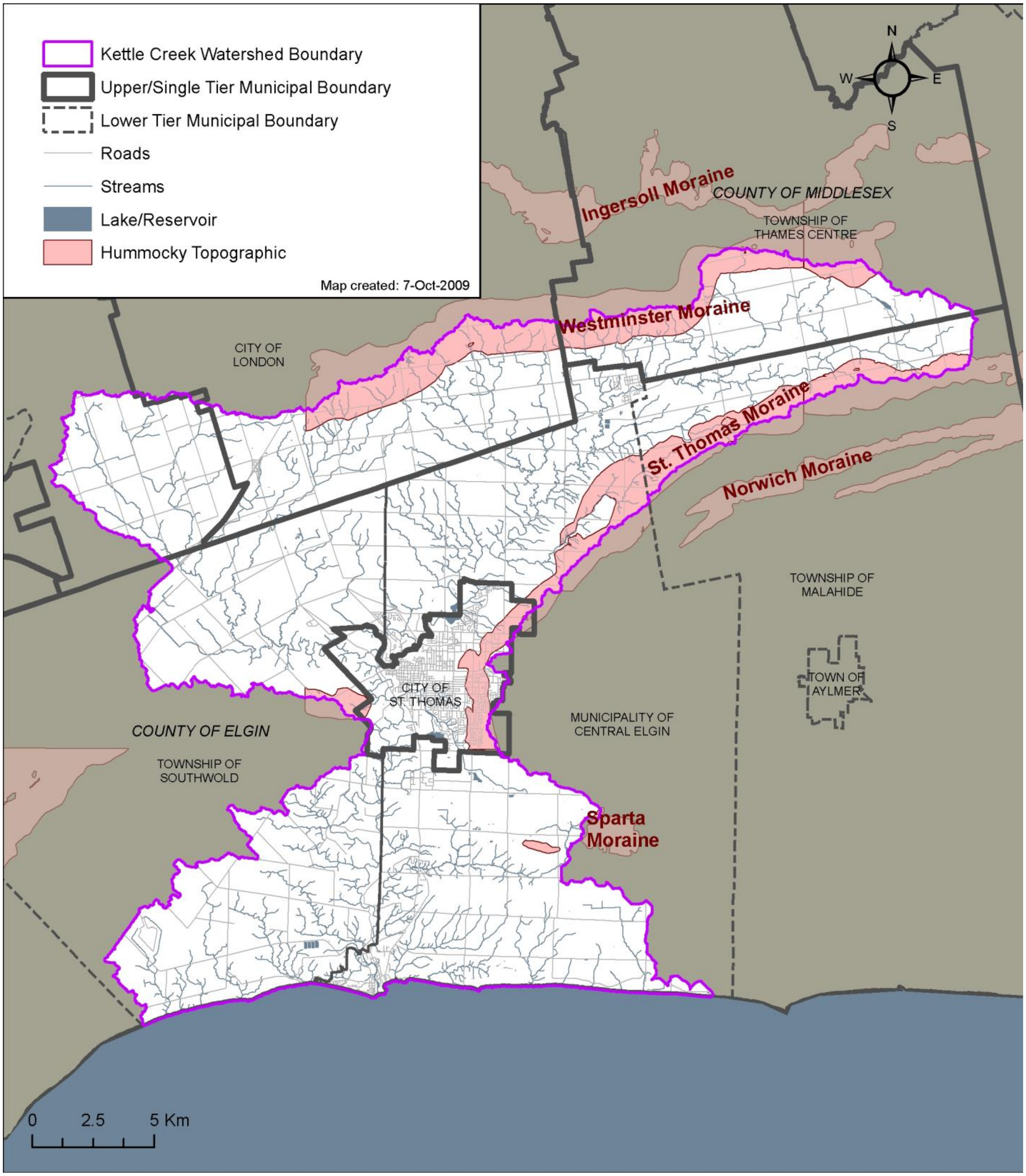
2.4.1 Bedrock Topography

In Ontario, there was an extensive period of time between the final deposition of the Paleozoic sedimentary rocks (approximately 350 million years ago) and the earliest record of glacial deposition during the Late Wisconsinan Glaciation approximately 115,000 years ago. During this period, the exposed bedrock surface was likely subjected to glacial and fluvial erosion and weathering that shaped the underlying bedrock surface. Much of the bedrock surface’s irregular topography is attributed to fluvial erosion whereby paleo-drainage was focused along the bedrock for extensive periods of time. This led to the erosion of river valleys in the bedrock, which in some places were subsequently infilled with sediment. Generally, bedrock topography slopes from the north towards the south. **Map 2-6** illustrates bedrock topography across the Kettle Creek watershed.

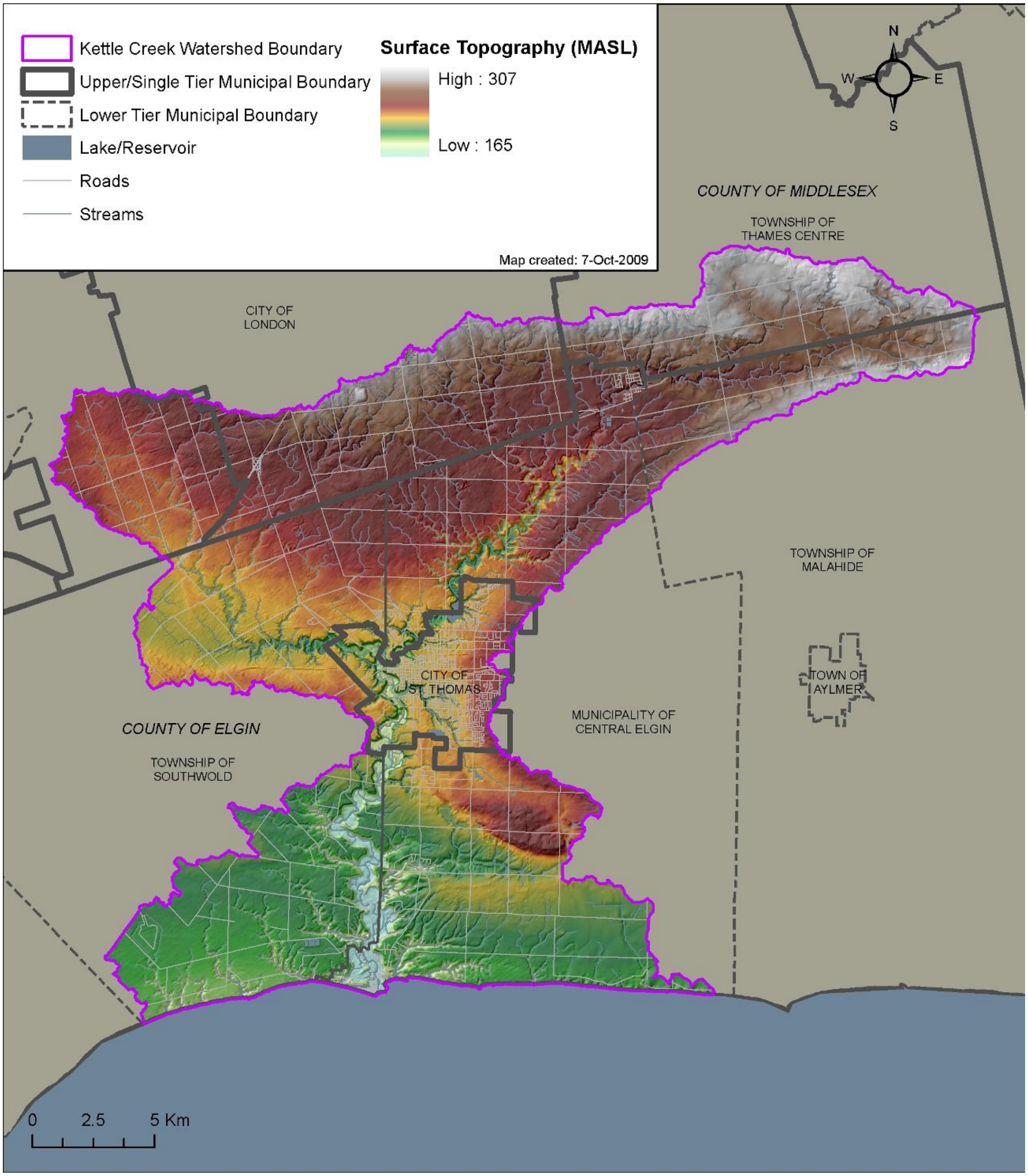
Map 2-3: Physiography of Kettle Creek Watershed



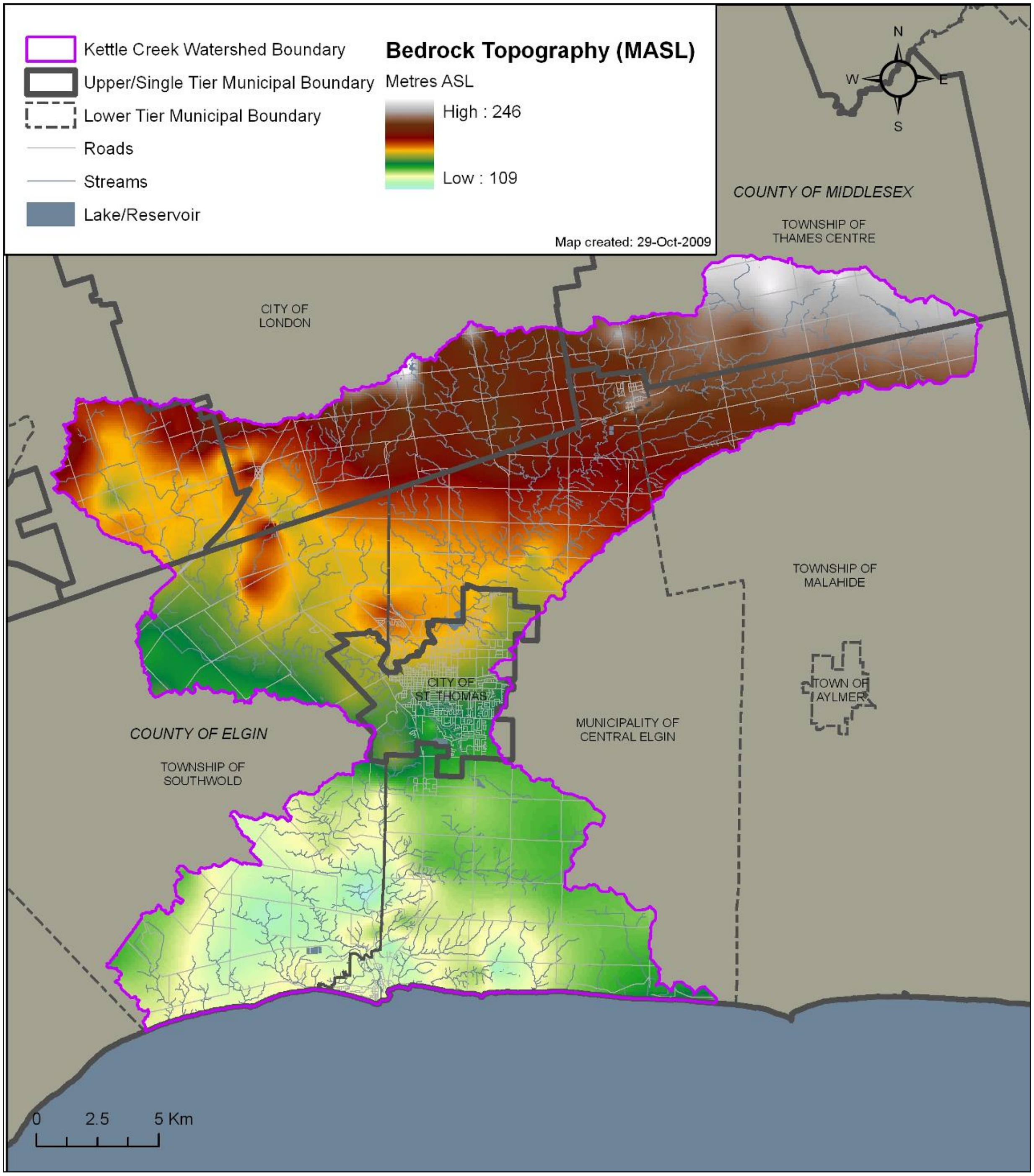
Map 2-4: Hummocky Topography of Kettle Creek Watershed



Map 2-5: Ground Surface Topography of Kettle Creek Watershed



Map 2-6: Bedrock Topography of Kettle Creek Watershed



2.5 Geology

The watershed is underlain by a series of gently dipping Paleozoic sedimentary rocks consisting of deep-water shales interbedded with shallow water carbonates and sandstone. These rocks are overlain by unconsolidated Quaternary-aged sediments of variable thickness that were laid down after the last glaciation. Dundee Formation dolostone and limestone underlie the northern portion of the watershed, with Marcellus Formation shales situated throughout the south of the watershed along the north shore of Lake Erie.

2.5.1 Bedrock Geology

The bedrock geology within the watershed consists of Middle Devonian Michigan Basin (Dundee Formation) and Appalachian Basin (Marcellus Formation) sedimentary rocks. Bedrock is not exposed at surface as a thick layer of Quaternary sediment (30 metres to 140 metres) covers the entire watershed. The bedrock geology presented in **Map 2-7** was assembled by the Ontario Geological Survey (OGS) in 2001.

The Dundee Formation is the oldest bedrock unit in the watershed and subcrops throughout most of the northern portions of the watershed. The formation is characterized as a fossiliferous limestone with bituminous partings and chert nodules (Johnson et al., 1992). In Ontario, the average thickness of the Dundee Formation ranges from 35 to 45 metres. Both Singer et al. (2003) and MacRitchie et al. (1994) identified the Dundee Formation as a major hydrogeologic unit stretching across Ontario. As a regional aquifer, well yields depend on secondary permeability, created through enhanced porosity resulting from features such as fracturing, dissolution, and dolomitization. Relatively high well yields observed in the top 1.5 metres of the Dundee Formation suggest that flow is confined to joint and fracture zones developed as a result of differential glacial stresses (Schwartz, 1974).

The Marcellus Formation, which conformably overlays the Dundee Formation, subcrops throughout the southern portion of the watershed between the town of Aylmer and the Lake Erie shoreline. The Marcellus Formation within southwestern Ontario has been characterized as a black, organic-rich shale with grey shale interbeds and sparse fossils. The Formation was deposited in a marine environment with a stratified water column and can range up to 12 metres in thickness (Dillon and Golder, 2004; Johnson et al., 1992).

2.5.2 Quaternary Geology

Quaternary-aged overburden sediments within the watershed provide a detailed record of glacial and interglacial events that took place throughout the most recent Wisconsinan Glaciation. During the Late Wisconsinan stage, glacial ice advanced and retreated into the lower Great Lakes region. The three primary advances (stades) were the Nissouri, Port Bruce, and Port Huron Stades. These stades were separated by two periods of temporary ice retreat (interstades; the Erie and Mackinaw Interstades).

Table 2-1 presents a list of the Quaternary sediments identified in the watershed, their distribution, and the general time period in which the deposits were laid down. **Map 2-8,** shows the spatial distribution of these units at surface across the watersheds.

Table 2-1: Quaternary Deposits Located Within the Kettle Creek Source Protection Study Area

Age (Y.B.P)*	Glacial Stage	Substage	Glacial Stade/ Interstade	Associated Deposits
5000-11,500	Wisconsinan	Late Wisconsinan	Holocene/ Recent	Modern alluvium, organic deposits, Long Point spit, Eolian sand dunes
11,500-12,000	Wisconsinan	Late Wisconsinan	Twocreekean Interstade	Shoreline Formation Glaciolacustrine Deposition
12,000-13,200	Wisconsinan	Late Wisconsinan	Port Huron Stade	Wentworth Till, Norfolk Sand Plain, Haldimand Clay Plain
13,200-14,000	Wisconsinan	Late Wisconsinan	Mackinaw Interstade	Paris/ Galt Moraines
14,000-15,500	Wisconsinan	Late Wisconsinan	Port Bruce Stade	Port Stanley Till, Glaciolacustrine Deposits
15,500-18,000	Wisconsinan	Late Wisconsinan	Erie Interstade	Glaciolacustrine Deposits
18,000-25,000	Wisconsinan	Late Wisconsinan	Nissouri Stade	Catfish Creek Till
25,000-53,000	Middle Wisconsinan	Middle Wisconsinan	Undifferentiated tills and deposits	Undifferentiated tills and deposits

* Y.B.P. represents number of years before present

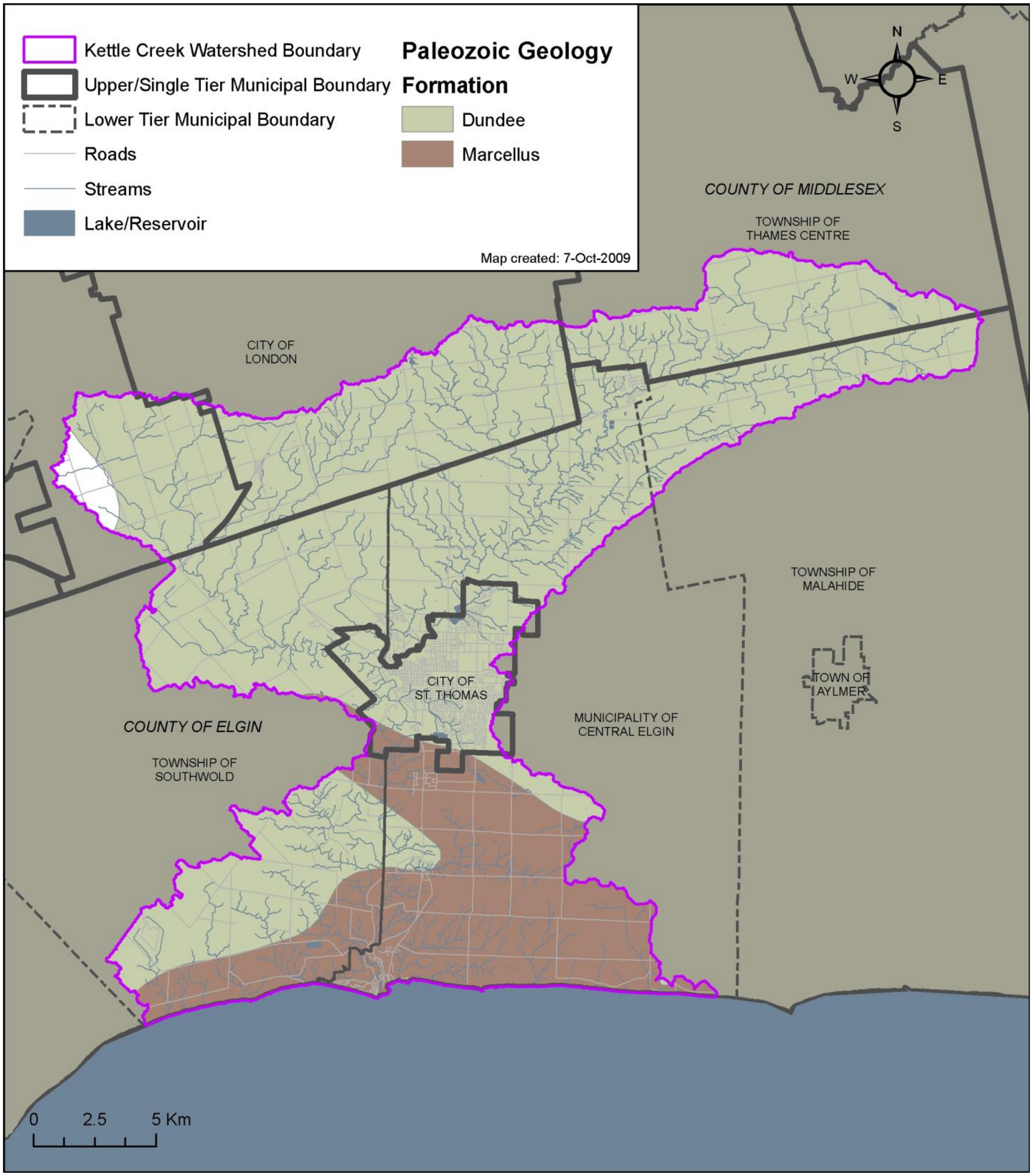
The most extensive subglacial till sheet in southern Ontario is the Catfish Creek Till (deVries and Dreimanis, 1960; Barnett, 1978; 1992; 1993). The till is composed of stacked layers of subglacial lodgement till as well as stratified glaciofluvial and glaciolacustrine sediments and supraglacial till layers and lenses (Dreimanis, 1982;

Barnett, 1992). The till is described as a highly calcareous, gritty, sandy silt till. It is often described as hardpan in water well drillers' records because of its stoniness and hardness (Barnett, 1978; 1982; 1992). The till occurs primarily as a buried till plain across the Kettle Creek watershed, but it outcrops near the community of Sparta and within the Lake Erie bluffs near Port Talbot.

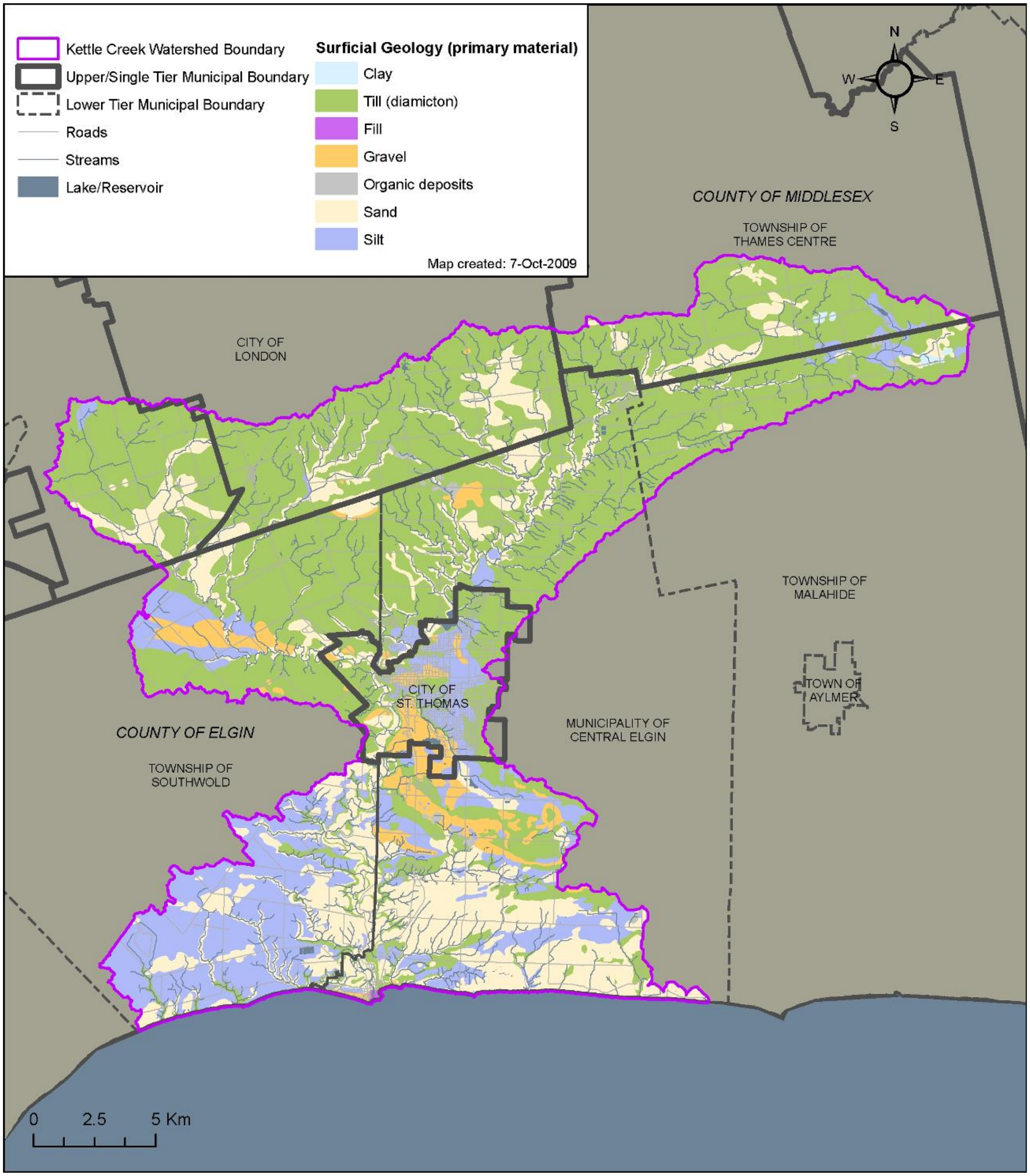
Catfish Creek Till and the overlying Port Stanley Till are separated by a discontinuous layer of glaciolacustrine sediments that are up to 4 m thick and texturally vary from well-sorted sand to clay (Schwartz, 1974). The Port Stanley Till is described as a silt to clayey silt till with few clasts (Barnett, 1982). Within the watershed, the `till complex' consists of up to 5 layers of subglacial till separated by glaciolacustrine sediments resulting from glacial lake level fluctuations within the Lake Erie basin (Barnett, 1982; 1992). Within the northern portions of the Kettle Creek watershed, the Port Stanley Till is the prevailing surficial unit. The younger overlying till units were deposited during retreat cycles of the Erie ice lobe. This generated a depositional environment of subaquatic flow in glaciolacustrine conditions and produced lacustrine silt and sand interbeds within the Port Stanley Till (Dillon and Golder, 2004).

The Wentworth Till is the youngest till within the watershed, and is commonly buried beneath glaciolacustrine sediments (Barnett, 1982). Glacial Lake Whittlesey followed by Glacial Lake Warren, each flooded a large portion of the watershed throughout the Port Huron Stade (Barnett, 1992). The Ekfrid Clay Plain was laid down under calm conditions where the fine-grained suspended sediment settled out onto the floor of glacial Lakes Whittlesey and Warren.

Map 2-7: Bedrock Geology of Kettle Creek Watershed



Map 2-8: Quaternary Geology of Kettle Creek Watershed



The Norfolk Sand Plain lies across the watershed and forms an extensive surficial feature deposited when the sediment laden Grand River (historic alignment) emptied into the deep glacial lake. The Grand River deposited a deltaic sequence of sands and silts throughout the western portion of the region at the front of the eastward retreating ice front (Chapman and Putnam, 1984). Norfolk Sand Plain sands are described as fine to medium-grained, ranging in thickness from less than 1 metre, to roughly 27 metres (although this estimate may include deeper, and older sands; Barnett, 1982). Within the Kettle Creek Watershed, the Norfolk Sand Plain is located across the southern portions of the watershed and forms an important aquifer across the area which is used for private groundwater supply.

2.5.3 Overburden Thickness

Overburden thickness is an important feature as it provides an indication of the relative protection of buried overburden and bedrock aquifers. Overburden thickness and grain size distribution of those sediments control the infiltration rate of precipitation, as well as the rate of movement of surface contamination into these aquifers.

Overburden thickness was derived by subtracting the bedrock topographic surface (see above) from the ground surface digital elevation model (DEM). **Map 2-9** shows the distribution of overburden throughout the watershed, and illustrates the presence of moraines and incised river valleys.

Overburden thickness ranges from zero along some river valleys, to over 115 metres in areas where the end moraines overlie thick till deposits. The thickest overburden materials are found in the southern regions of the watershed along the Lake Erie shoreline. In addition, the thicknesses of the St. Thomas, Sparta, Norwich, Tillsonburg and Paris Moraines located are also readily identifiable on this map.

2.6 Groundwater

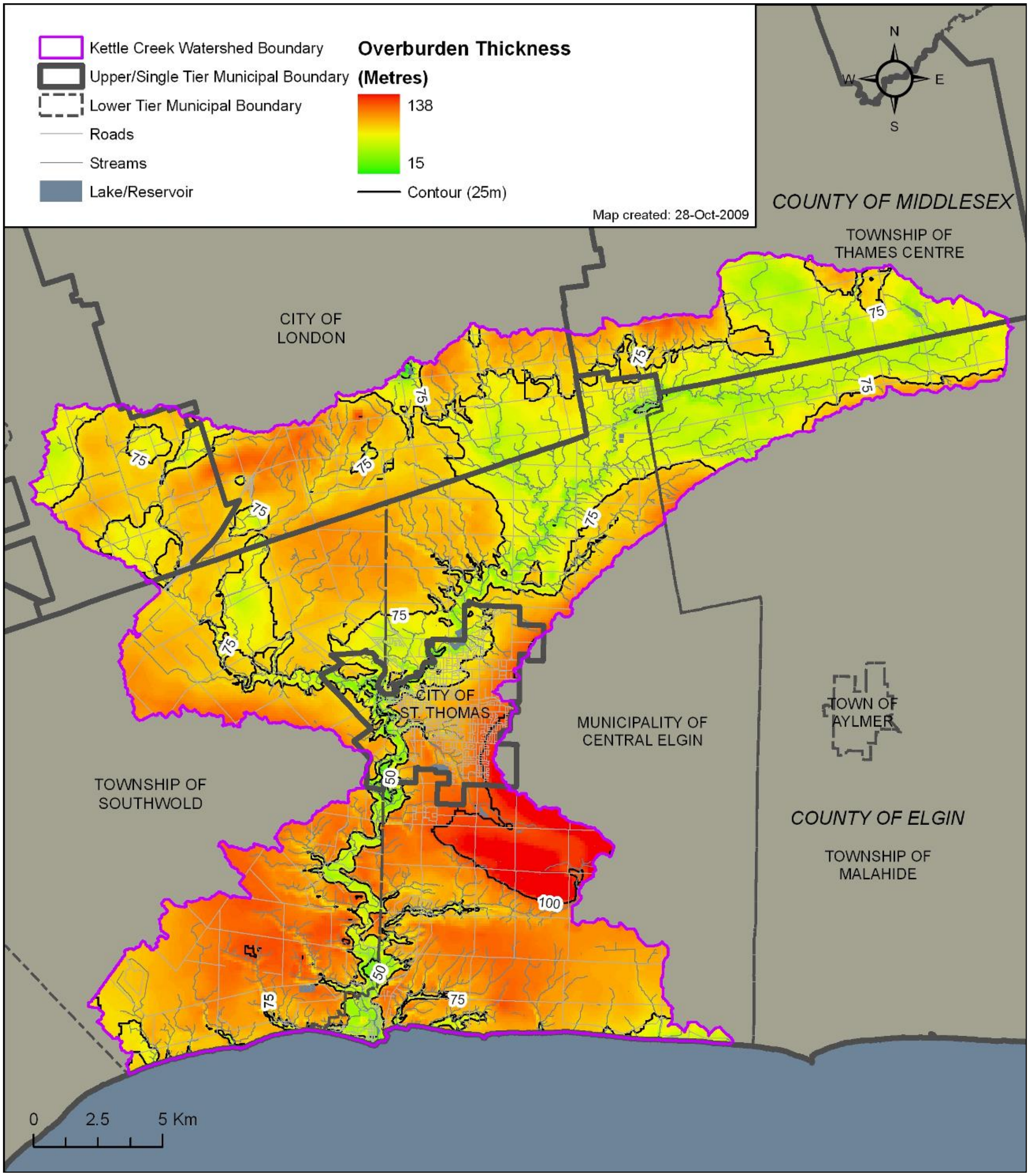
Within the Kettle Creek watershed, the location and spatial distribution of aquifers, has largely been based upon geologic and hydrogeologic information held within the MECP’s Water Well Information System (WWIS), in combination with the knowledge of the glacial history of the area. Cross-sections through the subsurface have been drawn across much of the watershed for various water supply or groundwater related studies.

An assessment of water well records within the Kettle Creek watershed indicates that approximately 90 percent of the water wells are completed within the overburden sediments. This is not unexpected as the overburden cover within the watershed is quite thick, ranging between approximately 40 metres near Kettle Creek to 120 metres near the community of Sparta.

2.6.1 Aquifer Units

Aquifers within the Kettle Creek Watershed can be characterized as three aquifer units. The primary aquifer complex is comprised of broad unconfined shallow sand and gravel units located between St. Thomas and Lake Erie. Smaller sand and gravel aquifers occur in the City of London in the northeastern extents of the watershed. Deeper confined overburden aquifers, generally located at depths of greater than 20 metres, are found within the central parts of the watershed as discontinuous sand and gravel lenses within the Port Stanley Till. The Dundee Formation forms the bedrock aquifer in the watershed; however, it is largely untapped as a result of adequate groundwater resources within the overburden. These hydrostratigraphic units were defined through work completed by Strynatka et al. (2006), Dillon and Golder (2004), and Waterloo Hydrogeologic Inc. et al. (2003).

Map 2-9: Overburden Thickness of Kettle Creek Watershed



2.6.2 Shallow Overburden Aquifer

A water table surface represents groundwater conditions within the shallow aquifer under unconfined conditions. Within the Kettle Creek Watershed, the water table was generated using the static water level elevations of overburden wells completed less than 20 m below ground surface (**Map 2-10**).

Map 2-10 indicates that shallow wells are generally associated with the surficial sand deposits located throughout the Kettle Creek Watershed, particularly between St. Thomas and Lake Erie. There are few shallow wells in the central portion of the watershed and along the boundary with the Catfish Creek Watershed to the east as the upper primary aquifer is absent.

Water table elevations vary from approximately 280 metres asl across the north of the watershed to 180 metres asl along Kettle Creek and the Lake Erie shoreline. Shallow groundwater flow is predominantly from the north, flowing south towards Lake Erie. Flow is influenced by Kettle Creek with local shallow groundwater flow directed towards the main branch of the creek.

2.6.3 Deeper Overburden Aquifer

Static groundwater elevations within the deep overburden sediments were used to generate a potentiometric surface for the deep overburden aquifer unit. **Map 2-11** illustrates the position of the deeper overburden potentiometric surface. The deep overburden unit is semi-confined to confined and consists of thin (less than five metres) discontinuous sand and gravel lenses within the Port Stanley and underlying Catfish Creek Tills. Groundwater flow directions in this deep unit are similar to the water table surface with groundwater flow occurring primarily from the north to the south towards Lake Erie. Groundwater flow within the southern portions of the watershed is locally influenced by Kettle Creek. The overburden potentiometric surface varies from 290 masl across the north of the watershed to 150 masl along Kettle Creek and the Lake Erie shoreline.

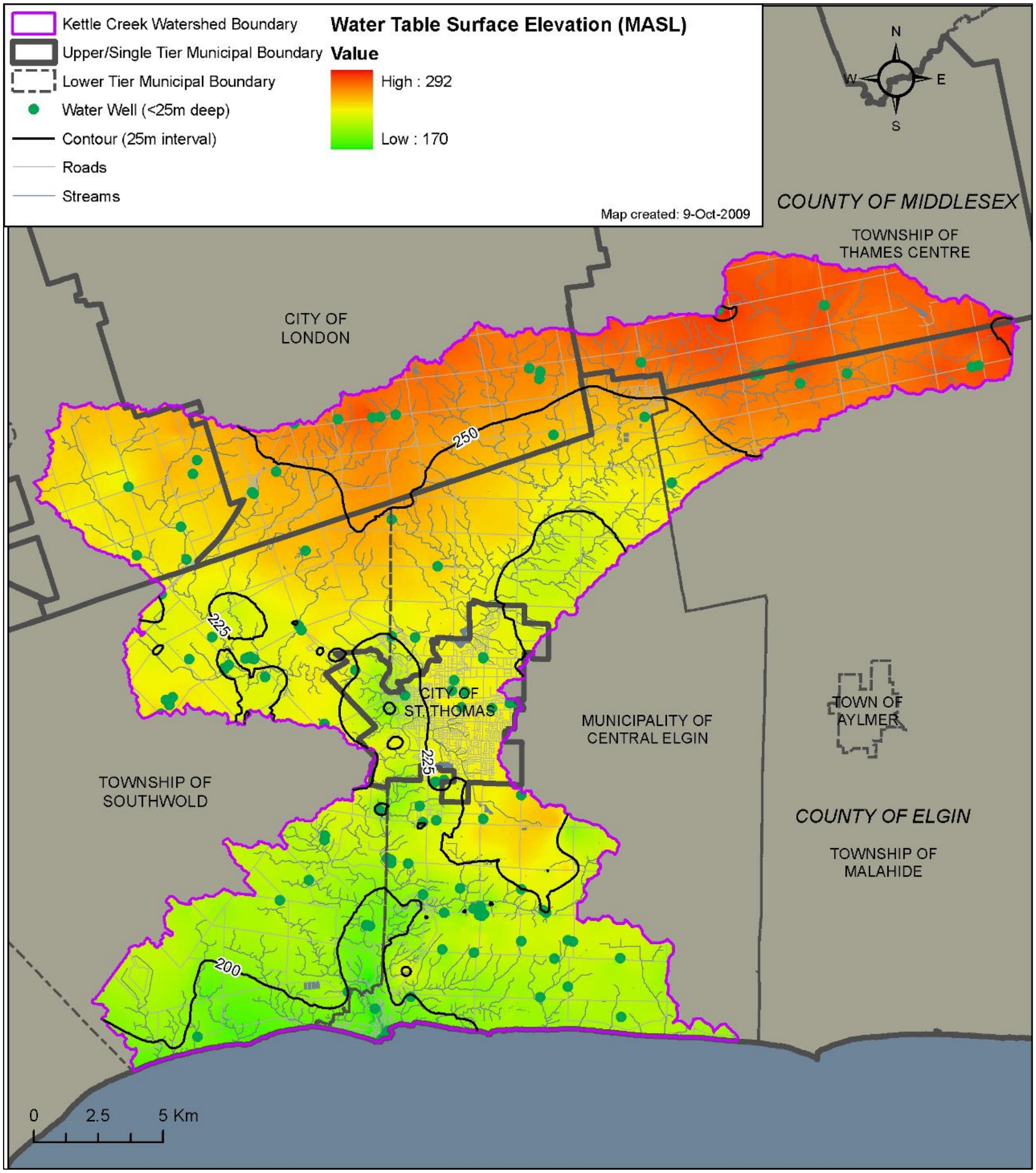
2.6.4 Bedrock Aquifer

Static groundwater elevations measured within the bedrock water wells were used to develop the bedrock potentiometric surface. Within the Kettle Creek watershed, the bedrock potentiometric surface was generated using the static water levels for all water wells terminating in bedrock (**Map 2-12**). The bedrock potentiometric surface is similar to the overburden potentiometric surfaces, and groundwater flow is from the northeast towards the Lake Erie shoreline in the south. Surface water features do not appear to have a significant impact on the bedrock groundwater flow directions. Bedrock groundwater elevations range from approximately 270 metres asl in the northeast to 170 to 190 metres asl along the Lake Erie shoreline.

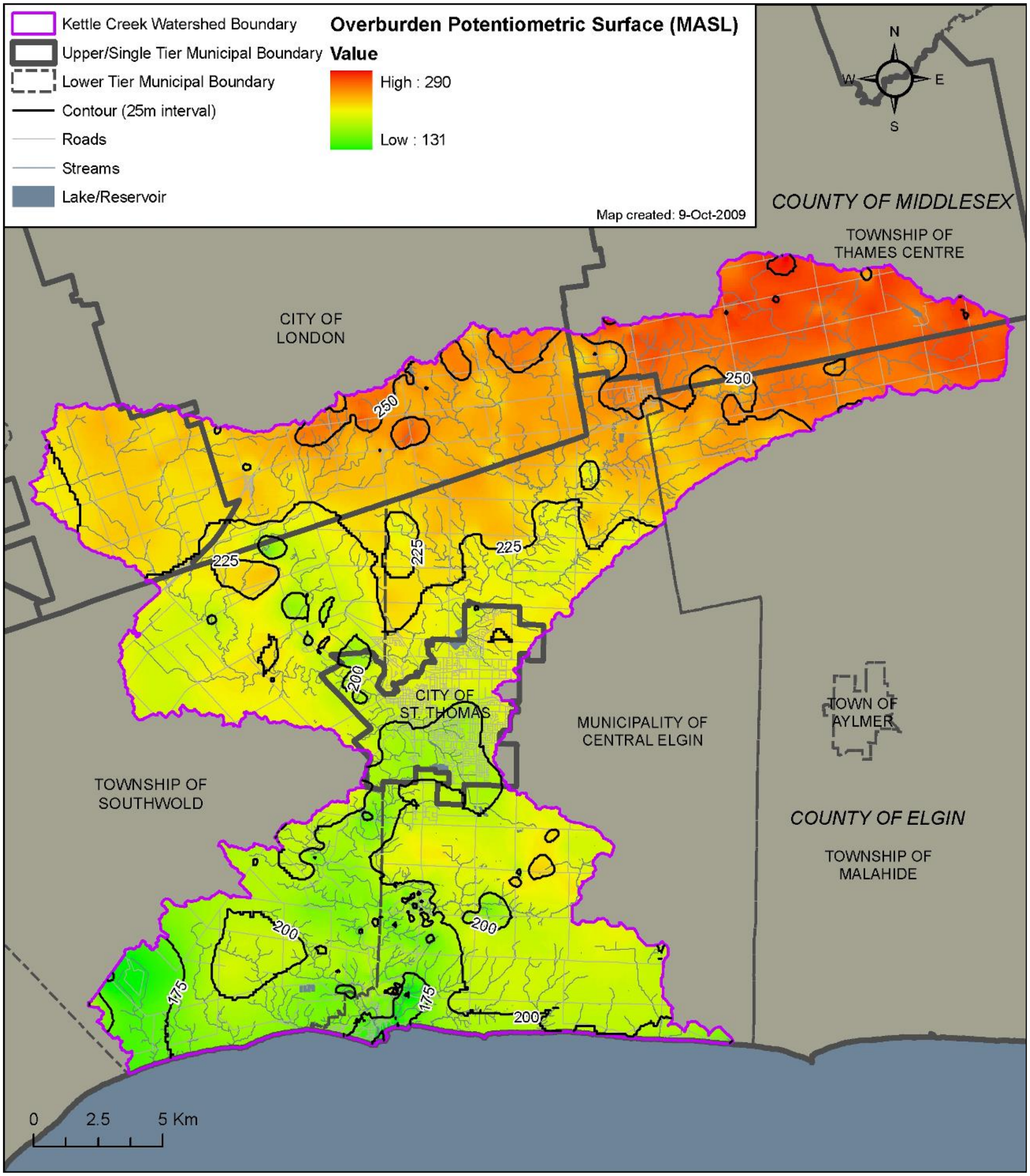
2.6.5 Groundwater Monitoring

Groundwater conditions are primarily monitored in the Kettle Creek watershed through the Provincial Groundwater Monitoring Network (PGMN), a network of wells distributed throughout the province that provide insight on long-term ambient trends and conditions (Glauser et al., 2008). The monitors are typically sited to be reflective of broad hydrogeologic conditions, away from areas where pumping or contamination may impact the data collected. The Ministry of the Environment, Conservation and Parks owns the monitoring infrastructure and manages the data gathered through the program, but in many cases the program is locally administered by conservation authorities.

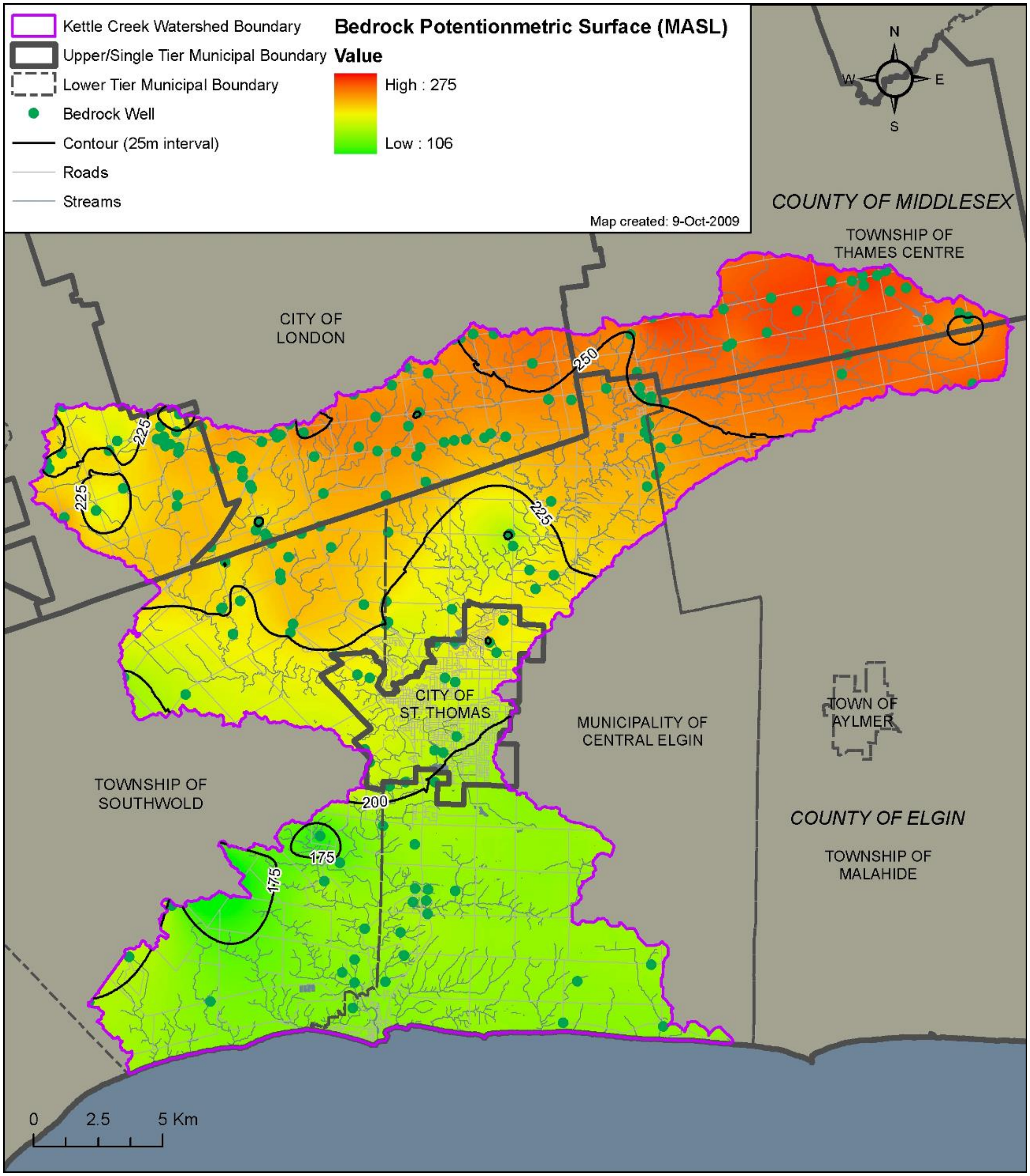
Map 2-10: Water Table Surface of Kettle Creek Watershed



Map 2-11: Overburden Potentiometric Surface of Kettle Creek Watershed



Map 2-12: Bedrock Potentiometric Surface of Kettle Creek Watershed



There are currently seven Provincial Groundwater Monitoring Network wells at seven locations within the Kettle Creek watershed **(Map 2-13**). The wells are usually located in close proximity to Kettle Creek or one of its tributaries and each of the wells are completed within the overburden. Water levels in the wells are monitored through a combination of manual and electronic means.

Groundwater level data from the Provincial Groundwater Monitoring Network (PGMN) wells is available on the Source Protection Information Atlas (accessed on October 4, 2021) for 2010 through to 2016. Groundwater levels within PGMN wells in the north part of Kettle Creek watershed are approximately 274 metres asl, with water levels ranging from 220 to 224 metres asl in the middle areas of the watershed. Groundwater levels in PGMN wells located in the most southern part of the watershed range from 202 to 205 metres asl.

2.7 Groundwater Quality Across the Watershed

In 2018, a Watershed Report Card was completed for the Kettle Creek Watershed. The watershed report card provides a snapshot of current conditions in the Kettle Creek watershed and helps to identify environmental issues that need to be protected, restored or managed. Kettle Creek Conservation Authority prepared the report card using data collected from 2013 to 2017.

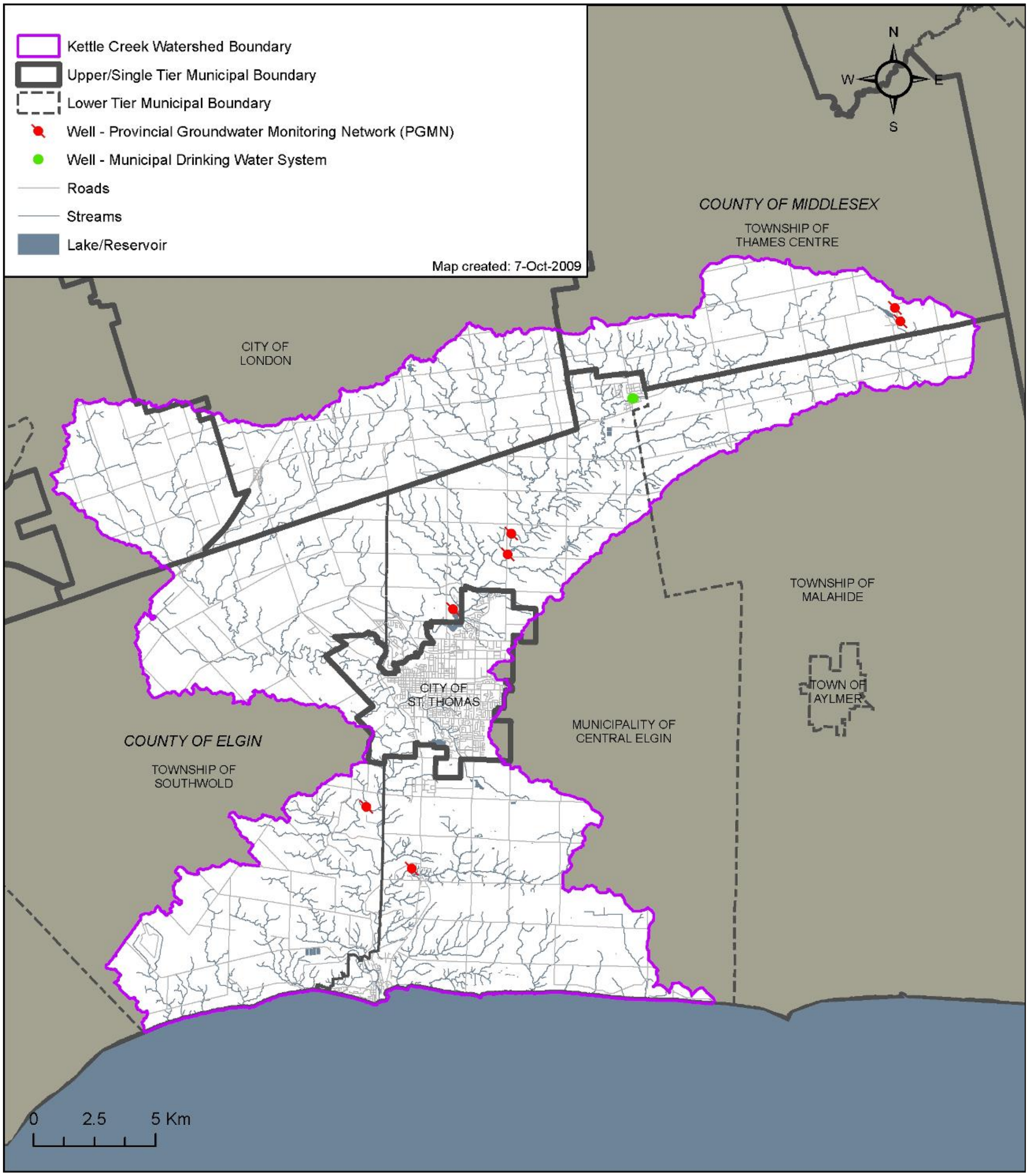
The Kettle Creek Watershed Report Card reported the following for groundwater quality (Kettle Creek Conservation Authority, 2018):

- Nitrate and chloride concentrations in groundwater are better than the drinking water guidelines in all monitored wells, and
- Groundwater quality results are limited to the aquifer from which the sample was taken and water quality may vary at an individual well.

Groundwater quality has the potential to be negatively impacted by human actions. Optimizing fertilizer application, regular maintenance of septic systems, decommissioning unused wells and the reduction of in use ion exchange water softeners can help to reduce the potential degradation of water quality resources (Kettle Creek Conservation Authority, 2018).

Any private wells that are located in close proximity to the municipal system may benefit from the protection afforded to its source by the Kettle Creek Source Protection Plan. Also, there are incentive programs that currently exist to help landowners to implement selected best management practices that improve groundwater quality. The Kettle Creek Clean Water Initiative and the Elgin Clean Water Program offer cost share incentives for landowners willing to undertake stewardship projects on private property that benefit groundwater quality (Dow, 2018).

Map 2-13: Provincial Groundwater Monitoring Well Locations in the Kettle Creek Watershed



2.8 Climate

The Kettle Creek Watershed, situated on the northern shore of Lake Erie, has a geographic location that provides a more temperate climate compared to other parts of Southern Ontario. The temperate climate denotes moderate, even precipitation throughout the year, summers that are warm to hot and humid and freezing temperatures in winter. Winters are mild compared to the rest of Ontario due to the watershed's southerly location and the moderating effect of Lake Erie.

General weather patterns in this region consist of four seasons. Winter is generally considered to have temperatures lower than 0ºC, beginning in December and lasting until late February or early March. Spring lasts approximately two months, followed by four months (June to September) of summer and two months of autumn (Sanderson, 1998). The average annual temperature from 1981 to 2010 is 8.7ºC. Daily minimum, maximum and average temperatures are presented for each month on **Figure 2-1**.

Lake Erie moderates the climate in this region by absorbing solar radiation and heat energy during the summer months and releasing heat slowly throughout the winter months. Winds blowing across the lake bring air warmer than the land in winter and cooler in summer, thereby moderating the air temperature over the Kettle Creek watershed, adding to a longer frost-free growing season in the lowland plains.

Annual average precipitation, from 1981 to 2010, in the watershed is 993 millimetres. The majority of precipitation falls as rain. Precipitation climate normal from 1981 to 2010 are presented in **Figure 2-1**.

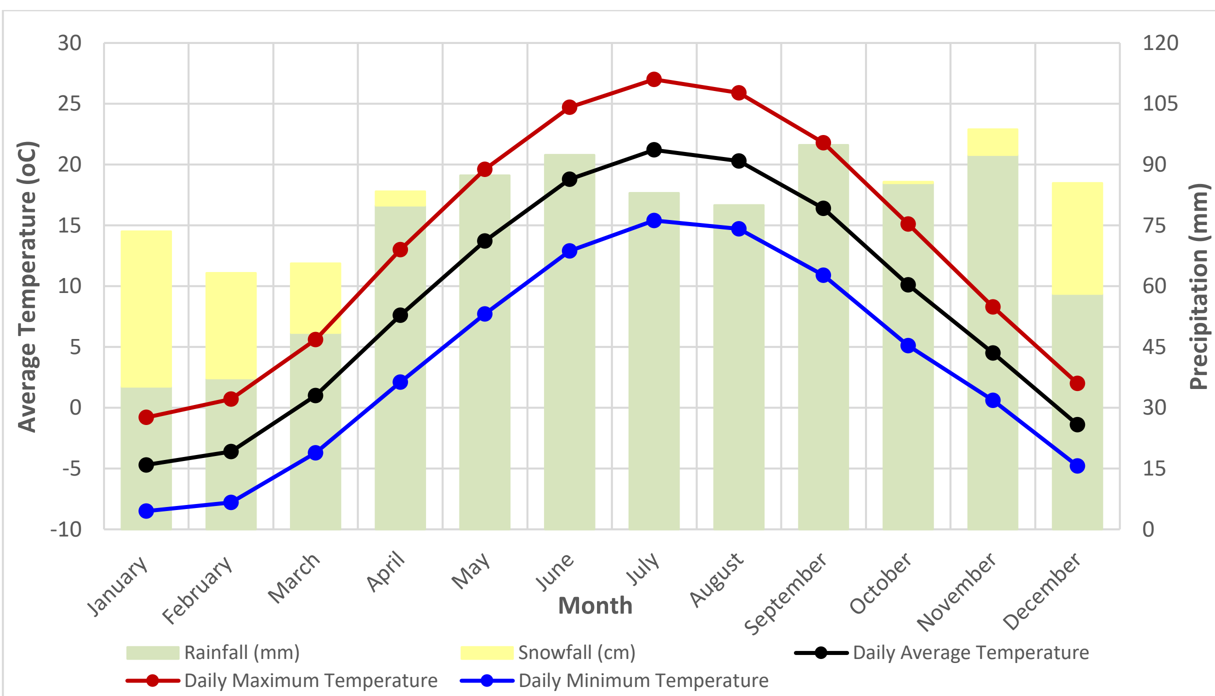


Figure 2-1: Monthly Temperature and Precipitation for St Thomas WPCP Climate Station – 1981 to 2010 Climate Normals

Precipitation is evenly distributed throughout the year, although the intensity, duration and frequency of precipitation are quite different among the seasons. The accumulation of snow in the winter months prolongs the effects of precipitation, as infiltration is delayed until a thaw. Spring thaw often brings long, low intensity rainfall and when coupled with the melting snow can make the spring season appear to be constantly wet and overcast. In summer many of the rainfall events are intense with short durations. The duration of events, coupled with the high evapotranspiration rates between events, leaves an impression of less rain than in other seasons in terms of frequency of rain-created runoff and recharge.

2.9 Land cover and land use

Land uses for the Kettle Creek Watershed are characterized by small urban commercial, industrial and residential centers, surrounded by less-populated rural land used for intensive agricultural production. **Map 2-14** shows the distribution of land cover across the watershed.

2.9.1 Valley lands

Kettle Creek's extensive valley lands are an important component of the region's natural heritage. Woodlots and shoreline vegetation included in the valley lands serve as buffers, protecting the land against erosion and the impact of agriculture and industry. At the same time, the valley lands offer habitat for species that normally would not be found near the creek. Many species use the stream bank area and forested buffers as wildlife corridors between woodlots and environmentally significant areas.

The depth of the valley offers an array of ecosystems and habitats providing a high diversity of wildlife communities on all levels. Aside from the creek, these areas include shoreline vegetation, clay or sand bluffs, forested uplands, lowlands and wetlands. The valley acts as a natural water collection system, as it collects run-off from groundwater seepage. The depths of the valley also provide short-term storage of storm and meltwaters, offering creek recharge and flood control. Moreover, small riverine wetlands contained within the valley lands also provide nutrients, control erosion and offer flow augmentation to the creek. The scarcity of wetlands in the watershed makes them a valuable resource for that reason alone. Other ecological functions served by the valley include nutrient and sediment transport, wildlife habitat and migration routes, and maintenance of a genetic pool for native flora and fauna.

2.9.2 Forest and vegetation cover

The Kettle Creek Watershed Report Card reported the following on forest and vegetation cover (Kettle Creek Conservation Authority, 2018):

- Forest conditions are rated as poor to fair, with forest cover being lost faster than it can be replaced.
- The current forest cover in Kettle Creek Watershed is 14 percent.
- Based on 2015 aerial photography, the watershed is losing 7.32 hectares of forest per year.

- Forestry programs offered in Kettle Creek Conservation Authority (KCCA) are critical to the watershed's overall health. Within the watershed an average of 50,000 trees are planted per year, which is barely keeping pace with the current rate of deforestation.
- Since 2001, KCCA has achieved a major milestone by planting over 1.2 million trees throughout the watershed. This is a major accomplishment for a small watershed where funding dollars and staff are limited. In addition, KCCA staff have investigated new ways to partner with municipalities and governmental agencies to plant trees.

The forest cover in the Kettle Creek watershed is shown in **Map 2-14.** The most common woodlots in the watershed are generally less than four hectares in size and are often fragmented from other forest tracts. As a result, forest interior is only about one percent. This is extremely low, indicating that most of the woodlots are too small and/or narrow to support sensitive species that require large habitats within a significant core area.

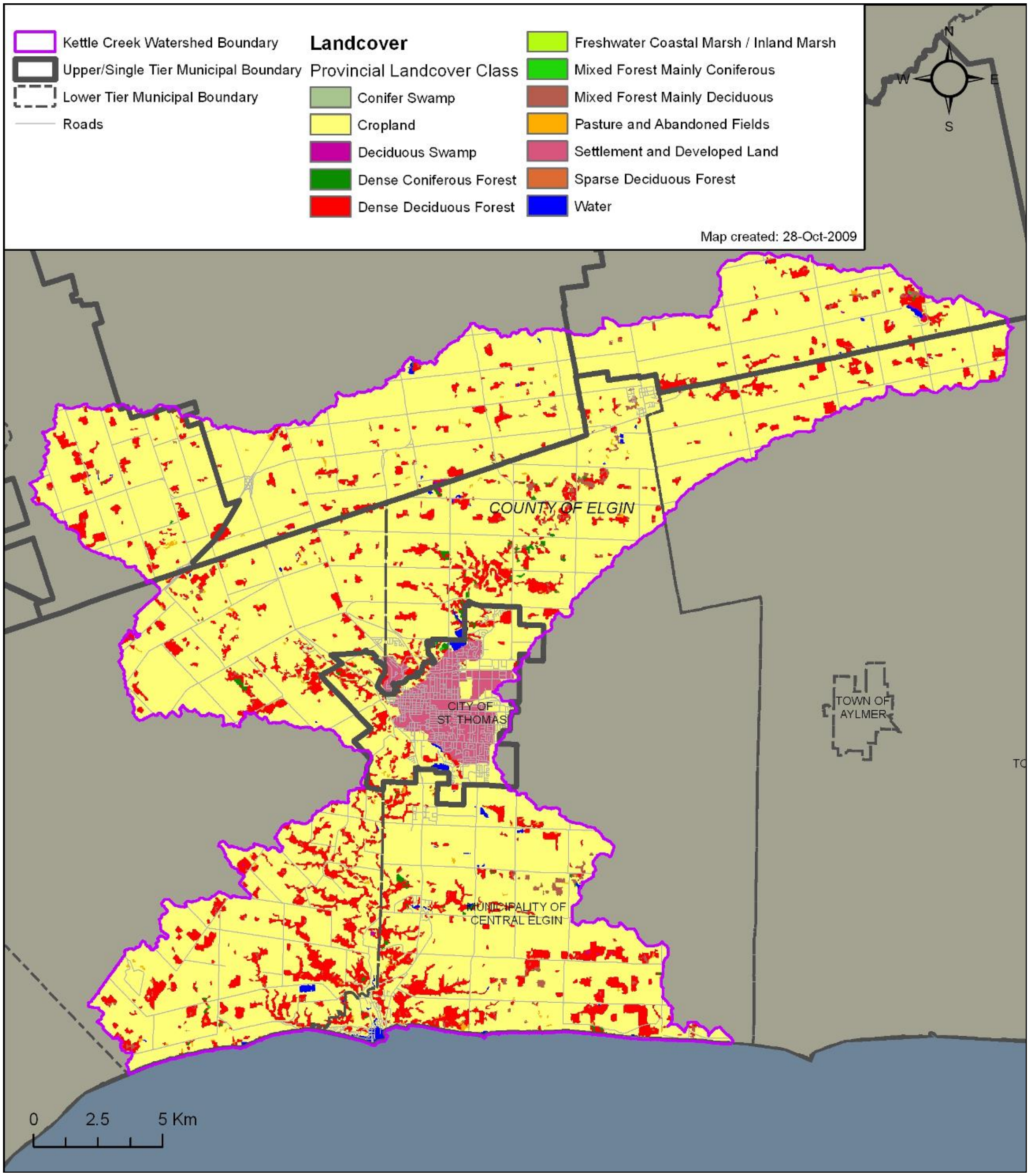
2.9.3 Wetlands

In the past, agriculture has had a significant impact on wetlands in the Kettle Creek watershed. In the 1960s and 1970s agriculture changed in the watershed from mixed farming to cash crop. The result was more intensive agriculture, with the removal of hedgerows and the use of marginal lands, to make larger fields. Tile and drainage were also established as a common practice to create drier, more workable parcels of land. Historically, the northwest part of the watershed was scattered with wetlands.

Percent wetland cover is the percentage of the watershed that is wetland habitat. There are four different types of wetland habitat: marsh, swamp, bog and fen. Environment Canada recommends 10 percent wetland cover in a watershed to support wildlife species. Wetlands play an important role in the ecological health of a watershed by filtering toxins, controlling flood waters, groundwater recharge and acting as nursery areas for many types of aquatic wildlife. Wetlands are also essential to many plant and animal species that depend on wetland habitat for all or part of their life processes, such as fish, amphibians and reptiles. They are often considered to be transitional habitats, which often form the connection between aquatic and terrestrial ecosystems (Dow, 2018).

According to the Kettle Creek Watershed Report (2018) the total percentage of wetlands left in the entire Kettle Creek watershed is 1.34 percent. KCCA has been working with landowners over the last five years to create and restore wetlands. Between 2013 and 2017, 19 wetlands were created and/or restored throughout the watershed. KCCA will continue to survey new wetland creation projects and continue to use remote sensing GIS to map potential wetland habitat in the watershed.

Map 2-14: Land Cover of Kettle Creek Watershed



2.10 Surface Water

2.10.1 Surface Water Characterization

Kettle Creek is predominantly a surface water driven system with a clay-rich till plain covering the majority of the watershed. The low permeability of the till cover tends to inhibit infiltration and produce large quantities of runoff during rain events. Flows in the creek, which pass quickly through the watershed due in part to the steep elevation drop between the headwaters in the north and the outlet to Lake Erie and the nature of the till cover, tends to result in low baseflows and flashy flood events. Groundwater has little influence on the surface water system except in the headwaters where Kettle Creek is fed by a groundwater maintained kettle lake and in the southeast corner where a shallow groundwater system contributes to a cool water fishery in Beaver Creek.

2.10.2 Surface Water Monitoring

Streamflow monitoring within the Kettle Creek Watershed is predominantly carried out by the Water Survey of Canada (WSC). Rating curves and gauge infrastructure are frequently maintained, with observed data undergoing extensive quality assurance and quality controls. As such, streamflow data from WSC stations is considered to be the highest quality streamflow data available.

The flow monitoring network in the Kettle Creek Watershed consists of three WSC stream gauges. The first gauge is on Dodd Creek below Payne's Mill and covers a drainage area of approximately 95 km^2. It has been in continuous operation since 1987. The other two gauges are on Kettle Creek. The stream gauge above St. Thomas captures a drainage area of 135 km^2 and has been in operation since 1985. The stream gauge at St. Thomas is the oldest in the watershed. It is located past the confluence of Dodd and Kettle Creeks and captures a drainage area of 330 km^2 or 75 percent of the watershed. This gauge has been in operation since 1945.

The following sections describe hydrologic conditions throughout the watersheds and make reference to a series of charts summarizing monthly flow distributions at selected gauges. These charts show median monthly flow, the 10th percentile monthly flow, and the 90th percentile monthly flow. The median monthly flow can be considered to represent low flows, and the 10th percentile monthly flow can be considered t represent high flows.

2.10.3 Upper Kettle Creek

The main branch of Kettle Creek originates at Lake Whittaker in the northeast corner of the Watershed. The lake provides moderate baseflows to Kettle Creek throughout the year barring severe drought conditions. The subwatershed has clay and silt till soils and has been cleared and drained for agriculture. The landscape produces high runoff and low recharge. The largest water storage reservoir in the watershed, Dalewood Reservoir is also located in the Upper Kettle Creek Subwatershed.

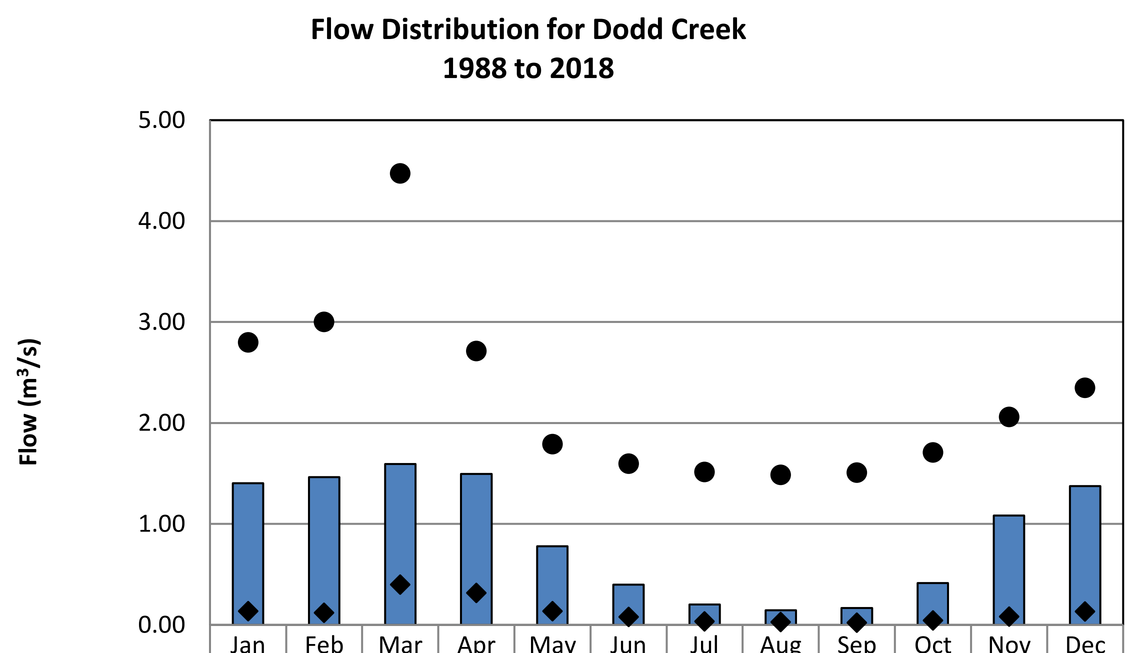
There is a stream gauge located above St. Thomas on Kettle Creek. It captures a drainage area of 135 km^2 and has been in operation since 1985. The Upper Kettle

Creek subwatershed drains an area of approximately 200 km^2 before it joins with Dodd creek near St. Thomas.

2.10.4 Dodd Creek

Dodd Creek is Kettle Creek's largest tributary, with a drainage area of approximately 130 km^2. The headwaters of Dodd Creek are in the northwest corner of the watershed. The creek flows south and west until it joins with Kettle Creek near the City of St. Thomas. Land use in the subwatershed is primarily agricultural. This relatively flat clay plain has little vegetation cover and few wetland features. The subwatershed is characterized by high runoff and little groundwater recharge. As a result, there is little continuous baseflow.

There is one stream gauge located on Dodd Creek. The gauge is located below Payne's Mill and covers a drainage area of approximately 95 km^2. The WSC has used the gauge since 1987, and the gauge's flow distribution is illustrated on **Figure 2-2**. A large difference between the 10th and 90th percentile flows indicates that streamflow is variable throughout the months, a characteristic of a runoff-driven system.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Median Flow	1.41	1.46	1.59	1.50	0.78	0.40	0.20	0.15	0.17	0.42	1.09	1.37
10th Percentile Flow	0.14	0.12	0.40	0.32	0.14	0.08	0.04	0.03	0.02	0.04	0.08	0.13
90th Percentile Flow	2.80	3.00	4.47	2.71	1.79	1.60	1.52	1.49	1.51	1.71	2.06	2.35

Figure 2-2: Flow Distribution of the Dodd Creek Gauge

2.10.5 Lower Kettle Creek

The Lower Kettle Creek Subwatershed begins at the confluence of Kettle Creek and Dodd Creek. The most southerly gauge on Kettle Creek is located near St. Thomas just downstream of the confluence of Dodd Creek and Kettle Creek. It has been in operation since 1945, and captures a drainage area of approximately 330 km^2 or 66 percent of the Kettle Creek watershed.

Unlike the upper part of the watershed, Lower Kettle Creek contains more sandy soils. This part of the Watershed has higher recharge and lower runoff than the silt and clay tills of the upper portions. One example is Beaver Creek, a tributary of Kettle Creek which drains an area on the eastern side of the Watershed. Beaver Creek is a cool water fishery supported by forest cover, wetland features, and relatively high baseflows. Kettle Creek empties into Lake Erie at Port Stanley.

Numerous small watercourses along the Lake Erie shoreline drain directly into Lake Erie. They drain a total area of approximately 80 km^2 with the largest draining 11.5 km^2 and the smallest less than 0.5 km^2. These watercourses are extremely steep with well-defined valley sections. There are no flow gauges located on any of these small watercourses.

2.10.6 Water Control Structures

There are three water control reservoirs owned and operated by the Kettle Creek Conservation Authority in the Kettle Creek Watershed including Dalewood Reservoir, Union Pond, and Lake Whittaker (**Map 2-15**).

The Dalewood Reservoir was originally owned by the City of St. Thomas and was used for the city’s water supply until insufficient surface water flows prompted St. Thomas to be connected to the Elgin Area Water Supply system. The Dalewood Dam, which is a stop-log structure, was constructed in 1928, and has been subject to extensive maintenance and rehabilitation. It is used today to augment stream flows and control flood events.

The Union Dam was built prior to 1900 and consists of an earthen embankment with a concrete spillway. The dam backs up water in a series of online ponds along Beaver Creek in the village of Union. The primary use of this reservoir is flood control, and baseflow augmentation. In 2003, the dam was upgraded to meet provincial maintenance and operations standards. The reservoir is approximately thirteen hectares in area with a holding capacity of approximately 8,000 m^3 (*Riggs, 2002*).

Lake Whittaker is an 11 hectare kettle lake that forms the headwaters for Kettle Creek. It is located at the uppermost height of land in the watershed. A small, one metre concrete weir with stop gaps serves to maintain static water levels in the lake while permitting continual outflows. The lake waters are sourced primarily from groundwater surfacing in adjacent wetlands and within the lake itself.

There are many privately-owned reservoirs and ponds that supplement baseflow in the Kettle Creek Watershed. Those located in headwater reaches are of highest value, including: Lake Margaret, Mill Creek Pond, Corners Pond, and Sandam Pond. Approximately 27 other dams and associated reservoirs can be found throughout the watershed that were constructed to collect and retain surface water flows.

2.11 Surface Water Quality

Surface water moves through the Kettle Creek watershed, before reaching Lake Erie at Port Stanley, a source of drinking water for 138,000 residents. Surface water quality reflects both the natural features (e.g., soil characteristics, tree cover) and land use of a watershed and is likely variable as a result of significant rainfall and snowmelt events. Low forest cover, intensive agricultural activities, and urbanization are conditions that can lead to impaired surface water quality. In addition, human activities on the land can negatively impact surface water quality through the use and/or application of fertilizers, pesticides, heavy metals, petroleum products and chemicals.

Although the predominant land use is rural / agricultural, historical data analysis suggests that urban stormwater and municipal wastewater discharge originating from the City of St. Thomas has had a significant influence on the water quality of the Lower Kettle Creek subwatershed. In addition, agricultural land-use within the watershed such as row cropping and tile drainage also contributes to high nutrient concentrations seen in Kettle Creek and its tributaries.

Phosphorus loading is a key issue facing surface water quality in the Kettle Creek watershed and the nearshore of Lake Erie. Phosphorus samples collected across the Kettle Creek watershed consistently exceed the Provincial Water Quality Objective.

Total Phosphorus is a nutrient that binds to soil particles and is an indicator of sedimentation, erosion and contaminants that are carried to the stream through surface runoff. Phosphorus is crucial to many aquatic life cycles; however, high concentrations of phosphorus can lead to low oxygen levels (anoxia), excessive algae blooms and impaired aesthetics. Domestic and industrial effluents (soaps, cleaning products) and urban and agricultural inputs (fertilizers, pesticides) are the main anthropogenic sources of phosphorus in the KCCA watershed.

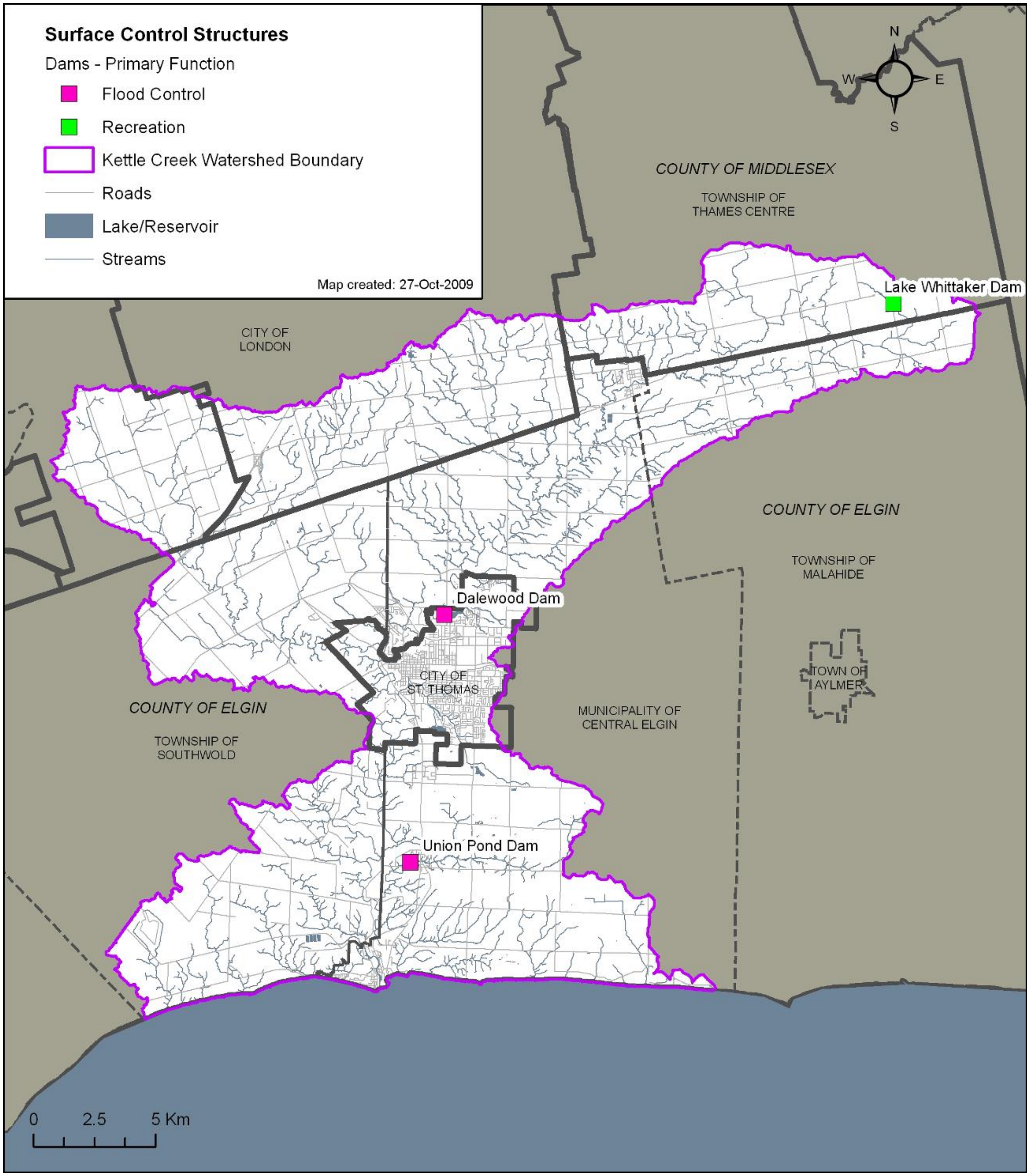
Surface water samples are collected monthly during the ice-free period typically from March to November at 10 locations across the watershed and are analyzed for a suite of parameters depending on the site. The ten sites are made up of four Provincial Water Quality Monitoring Network (PWQMN) sites and six Source Water Protection sites chosen to target specific long-term monitoring locations such as the outlet of a sewage treatment plant or downstream of a landfill or urban centre (**Map 2-16**). Samples are collected across all three subwatersheds: Dodd Creek, Upper Kettle Creek and Lower Kettle Creek. Effort is made to collect the monthly samples from a variety of flow conditions (i.e., normal conditions, spring freshet, summer low flow, and peak flows after a high-water event or flood event).

Water quality typically decreases in areas that have more human activity, such as agriculture. The highest land use in the Kettle Creek watershed is agriculture at 80 percent. Generally, nutrient loading and a lack of natural vegetative cover along watercourses are contributing to poor overall surface water quality.

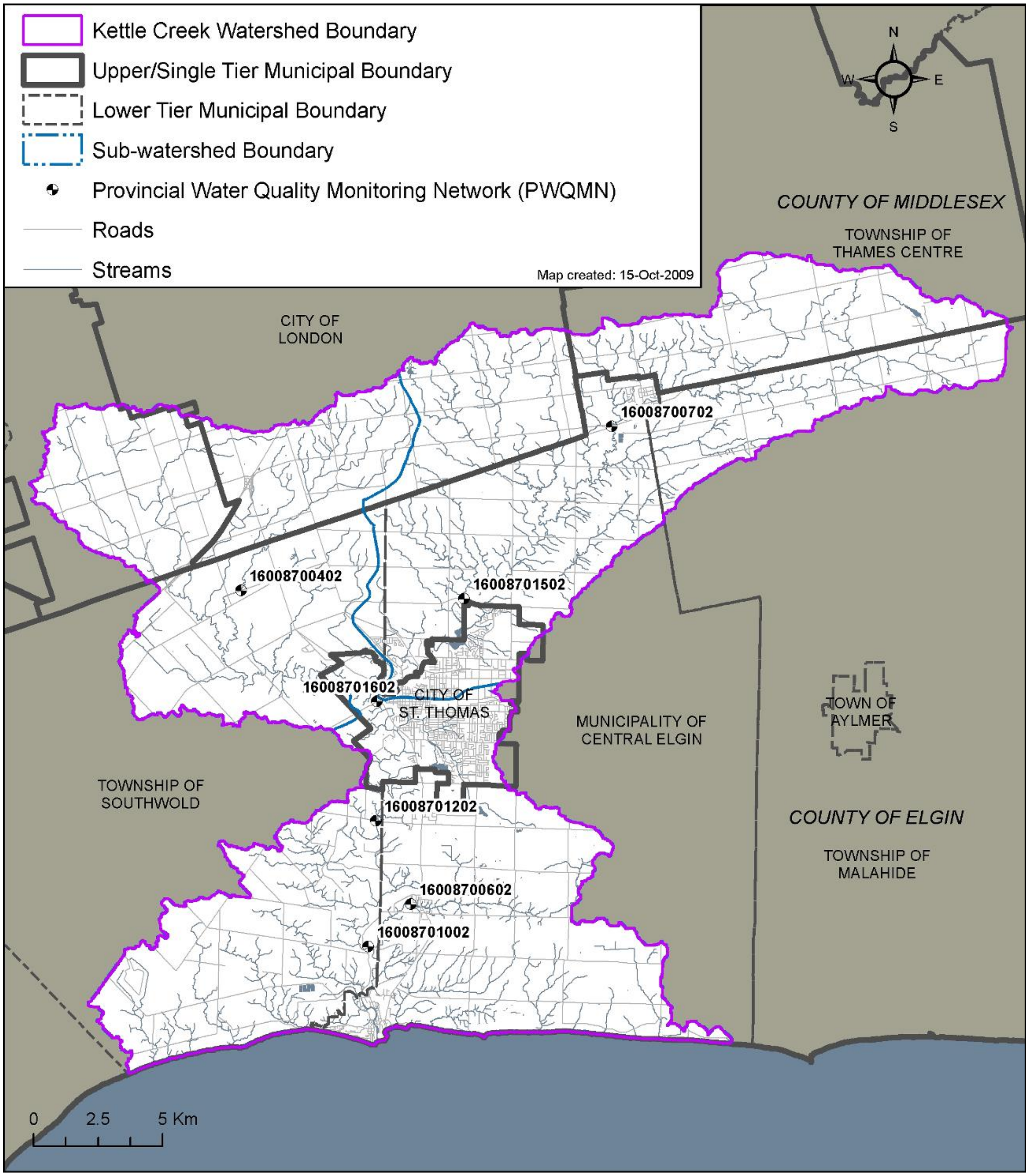
Beaver Creek, located in the southeastern portion of the Lower Kettle Creek subwatershed, primarily drains a small segment of the Norfolk Sand Plain. This difference in physiography makes Beaver Creek a very different system than either Kettle Creek or Dodd Creek. Beaver Creek remains one of the few cool to cold water systems in the watershed. As a result, several stewardship projects in partnership with local organizations have been successfully completed over the last 15 years to protect and enhance this significant aquatic habitat.

In general, surface water quality within the watershed is heavily influenced by erosion and sedimentation, flashy high-water events and decreasing summer base flows. Lower Kettle Creek and Dodd Creek subwatersheds are the most impaired regions within the watershed. Water quality appears to progressively deteriorate from upstream to downstream. Located on the Norfolk Sand Plain, Beaver Creek was found to be the least impaired region within the watershed. This is likely due to the natural characteristics of that sub-basin, primarily the sandy soils, natural vegetation cover and groundwater-sourced stream baseflow.

Map 2-15: Surface Water Control Structures in the Kettle Creek Watershed



Map 2-16: Provincial Water Quality Monitoring Network Sites in the Kettle Creek Watershed



2.11.1 Water Quality Conditions Specific to the Upper Kettle Creek Sub-basin

The Upper Kettle Creek subwatershed drains an area of 198 km^2 which extends from Lake Whittaker in the northeast corner of the watershed to just below the Dalewood Reservoir north of St. Thomas and drains over a fluted till plain. Land-use across this region is mainly agriculture except for the Village of Belmont (**Map 2-14**).

Draining a till plain, the bottom substrate of the Upper Kettle Creek is composed largely of sands and gravel. The majority of stream reaches in the subwatershed are channelized for drainage purposes, particularly in the northern portion of the subwatershed. The lower reaches of the Upper Kettle Creek subwatershed are predominantly in a natural state and provide good habitat for both the aquatic and terrestrial communities.

The main branch of Kettle Creek originates at Lake Whittaker, an 11-hectare groundwater-fed kettle lake. The Upper Kettle Creek subwatershed contains the largest water storage reservoir in the watershed, Dalewood Reservoir, which is used for flood control and baseflow regulation.

Environmental issues and restoration priorities for the subwatershed include erosion prevention, protection and creation of wetlands, source water protection and reforestation.

Stream flow in the Upper Kettle Creek system is typically characterized by low base flow with sporadic high flows during storm events. During these storm events, peak flows pass through the watershed very quickly and water levels return to base flow levels often within 24 hours. Streams characterized in this way are often referred to as "flashy" because of their erratic flow patterns and the rapid onset of peak flow conditions. This "flashy" system combined with intensive agricultural land use and unique physiology heavily influences the water quality within the subwatershed. Generally, water quality in Upper Kettle tends to be better than or as good as the rest of the watershed, apart from Beaver Creek, and tends to slightly deteriorate as it flows downstream from Lake Whittaker to the Dalewood Reservoir.

Lake Whittaker, a spring-fed lake, is a headwater source to Kettle Creek. Thus, water levels and quality found within Lake Whittaker directly influence levels found within Upper Kettle Creek. A 1971 water survey by the Department of Lands and Forests (Loblaw and Pell, 1975) indicated that Lake Whittaker was in an advanced state of eutrophication and in the stages of succession leading to a marsh lake. To date a marsh has developed in two locations: at the north end of the lake; and, adjacent to the outlet of Kettle Creek, in the south end. Low water levels and flow rates along with the eutrophication of Lake Whittaker resulted in the development of stagnant pockets of water with decomposing aquatic vegetation leading to minimal dissolved oxygen (KCCA, 1989). Low dissolved oxygen can limit the number of fish species capable of inhabiting the lake, reduce water quality, and thus affect recreational activities.

In 2012, Natural Resource Solutions Inc (NRSI) in partnership with Hutchison Environmental Sciences Ltd. (HESL) was retained by KCCA to conduct *A Study of Lake*

Whittaker to Determine its Health and Potential Aeration Requirements. Data on water and sediment quality, fish community, fish habitat and bathymetry were collected to determine the baseline conditions of Lake Whittaker to develop and implement a management strategy for the lake.

Most of the management issues in Lake Whittaker were found to be related to the early seasonal development and persistence of anoxia in the hypolimnion. Anoxia impairs lake quality by accelerating internal cycling of nutrients (i.e., internal phosphorus loading) that promote algal production, solubilization of metals that are toxic to aquatic life, limiting nitrification resulting in accumulation of toxic ammonia, promoting anaerobic respiration and production of toxic and odoriferous hydrogen sulfide, and limiting fish distribution, especially coolwater species which are present in Lake Whittaker. Phosphorus from internal loading in Lake Whittaker is passed downstream, contributing to the phosphorus loading and eutrophication in Kettle Creek.

Based on the recommendations resulting from the study, KCCA adopted a ‘status quo’ management plan which includes monthly surface water quality sampling during the ice-free season, dissolved oxygen and temperature profiling, phytoplankton and chlorophyll sampling and monthly total phosphorus concentrations. Over the last 10 years, Lake Whittaker water quality has maintained at a consistent level at or below the established environmental monitoring management triggers.

Within the downstream portion of the Upper Kettle Creek sub-basin is the Dalewood Reservoir. Kettle Creek Conservation Authority purchased the Dalewood Reservoir and surrounding lands, approximately 243 hectares, from the City of St. Thomas in 1976. Formerly the St. Thomas Waterworks Reservoir, this reservoir was historically used as a drinking water supply to the city. In 1967, St. Thomas’ water supply was connected to the Elgin Area Water Supply system, and by 1970 St. Thomas was supplied exclusively by this system.

Over time the Dalewood Reservoir has become heavily silted, which has allowed for the surrounding provincially significant wetland to expand. Although this expansion of the wetland can be considered an advantage, it is important to note that the Dalewood Reservoir is seen as both a sink and source of sediment within the watershed. Earlier studies focusing on the Dalewood Reservoir detail sediment related issues regarding increases in metals, nutrients, and bacterial concentrations. The source of these sediments is likely from a combination of intensive agricultural practices and the steep nature of the watershed. Although sedimentation of the reservoir has reduced habitat for some aquatic species, it has increased habitat for others. A more recent study (Riggs Engineering Ltd., 2004) suggests that the sediment loading within the reservoir has reached equilibrium.

Given these reported concerns with the water quality within the Dalewood Reservoir and the potential sediment loading to Kettle Creek, Kettle Creek Conservation Authority established a long-term water quality monitoring site directly downstream of the reservoir.

2.11.2 Water Quality Conditions Specific to the Dodd Creek Sub-basin

The Dodd Creek sub-basin is in the northwest quadrant of the watershed and drains over the Mount Elgin Ridges, a clayey till plain. Land-use across this region is mainly agriculture except for a few industrial sites north of Talbotville.

Dodd Creek drains a clay plain; therefore, the bottom substrates are composed mainly of silts with some sand and little gravel. Approximately 80 percent of the stream reaches in the watershed have been significantly altered, with many being straightened and channelized for drainage purposes. The areas near Paynes Mills are predominantly in a natural state and are considered the most stable with erosion being limited to natural processes.

Dodd Creek is Kettle Creek's largest tributary, with a drainage area of 131 km^2. The subwatershed is characterized by high runoff and very little groundwater recharge, which contributes to the low water levels and baseflow. Historically, wetlands likely contributed the bulk of the summer flows to Dodd Creek, but through settlement and the clearing of land for agriculture, few of these wetlands exist today, leading to many areas of the subwatershed drying up annually.

Due to the high proportion of agricultural land use in the subwatershed, combined with the predominantly clay soils, the priority subwatershed issues include: drainage; erosion; and "keeping the water on the land". The vast network of municipal drains that crisscross the subwatershed cause surface water to be immediately washed away, leading to increased sedimentation and erosion and negatively impacting groundwater recharge.

Stewardship efforts across the subwatershed focus on tree planting and creating windbreaks and riparian buffer strips do mitigate erosion and sedimentation. In addition, protecting and maintaining the remaining existing wetlands, while creating new wetland habitats in the subwatershed is a priority. These important habitats enhance water storage on the land to improve baseflows and act as sponges to prevent erosion and sedimentation downstream and function as a water filtering mechanism for improved water quality.

2.11.3 Water Quality Conditions Specific to the Lower Kettle Creek Sub-basin

The Lower Kettle Creek subwatershed drains an area of 185 km^2. Lower Kettle Creek begins at the confluence of Dodd Creek and Upper Kettle Creek at St. Thomas and flows into Lake Erie at Port Stanley. There are three main tributaries in the subwatershed: Mill Creek, Beaver Creek and Little Creek, all of which can support a cool water fishery.

The Lower Kettle Creek sub-basin drains two distinct physiographic regions. The lower portion of Kettle Creek drains over the Ekfrid Clay Plain while Beaver Creek, a tributary to the east of the Lower Kettle, drains primarily over the Norfolk Sand Plain. These two physiographic regions differ dramatically in soil composition which can influence the inherent water quality found.

Land-use across this region is mainly agriculture but is bordered north and south by the urban development of St. Thomas and Port Stanley, respectively. Land-use such as this can intensify the influence local geology has on the water quality within an area.

Generally, water quality tends to be impaired within Lower Kettle Creek and progressively deteriorates from upstream to downstream, reflecting the cumulative impact of the upstream watershed and the watershed's natural characteristics. The lower portion of Kettle Creek, downstream of St. Thomas, is highly productive and exhibits some of the highest nutrient and non-filterable residue loads within the watershed. In contrast, water quality within Beaver Creek is comparatively good as it drains mostly non-intensive agricultural land within the Norfolk Sand Plain. The sandy overburden is more likely to allow water to filter through to the water table, reducing run-off. Also, the coarser particles are less likely to transport nutrients, metals, and other contaminants than the silt and clay particles which are abundant throughout the rest of the watershed.

Similar to the Upper Kettle Creek subwatershed, the top environmental priorities for the subwatershed are erosion prevention, protection and creation of wetlands, source water protection and reforestation.

Phosphorus is the most serious nutrient loading issue within the Lower Kettle Creek subwatershed. Phosphorus enters water systems through human or animal wastes, fertilizers, soaps, industrial wastes and the disturbance of land and its vegetation. When too much phosphorus is available, plants grow rapidly which can result in algal blooms, decreased oxygen levels, and ultimately affect the health of the organisms living in the watercourse. One of the primary sources of phosphorus loading in the Lower Kettle Creek subwatersheds is sediment loading from erosion and surface runoff. However, the significant increase in concentrations found south of St. Thomas indicates that urban sources, such as wastewater treatment effluent, are also a contributor.

Polynuclear Aromatic Hydrocarbons (PAHs) are typical components of asphalts, fuels, oils and greases. Two main areas within Lower Kettle Creek located downstream of the George Street Drain in Port Stanley and adjacent to former petroleum tank farms have been identified as containing contaminated sediments. Several studies (Griffiths, 1988; Riggs Engineering Ltd., 2004; Acres and Associates, 2001) have investigated the extent and severity of the contamination. PAHs can be toxic to aquatic biota at elevated concentrations; however, PAHs tend to be relatively non-volatile and poorly soluble and therefore tend to be incorporated into the bottom sediments. According to the Ministry of the Environment (2009b), the PAH contamination in Kettle Creek is very localized and bound to sediment buried in the creek. Ultimately, the presence of PAHs can lead to odour problems, and habitat degradation for aquatic life.

Influence of Kettle Creek on Port Stanley Harbour

During significant runoff events such as spring runoff or following rainfall, high levels of sediment (e.g., suspended soil particles etc.) in Kettle Creek can be carried into the Port Stanley harbour and Lake Erie. Cumming Cockburn and Associates Limited (1987) determined that Kettle Creek deposits approximately 40,000 cubic metres of silty sediment into the Port Stanley harbour every year. This sediment plume is highly variable and highly dependent on localized west-to-east littoral drift in the lake (Riggs Engineering 2004). Further, sediment from the Kettle Creek watershed and erosion of the Lake Erie shoreline and bluffs has been shown to accumulate in the intake crib of the Elgin Area Water Supply System, which is located more than 4 kilometres east of the outlet of Kettle Creek, and therefore it is acknowledged that under certain circumstances the flows from Kettle Creek can have some influence on the Elgin Area Water Supply intake (Riggs Engineering 2004). Given the potential influence of Kettle Creek on the intake, the Elgin Area Water Supply System may undertake periodic sediment quality analysis at the intake to proactively detect any changes in the raw source water.

The nearshore area of Lake Erie is the interface between land and lake. It is a dynamic area that is heavily influenced by natural processes such as wind and wave action, drainage from tributaries and point source discharges. This is also an area which supports many human and natural uses: cottage development and associated recreation, beaches, and drinking water intakes and therefore, the quality of the nearshore waters is important to those that use this area of the lake.

There is a connection between the water quality conditions in the lower reaches of Kettle Creek and the near shore of Lake Erie. The discharge from Kettle Creek can be a key contributor to the variability in water quality along the shoreline of Lake Erie as the tributary drains heavily developed agricultural lands. Quantifying the concentration and amounts of pollutants leaving the Kettle Creek watershed as tributary discharge is essential to determine the potential effects on Lake Erie.

Between 2007 and 2009, KCCA collected surface water quality data for the Great Lakes Nearshore Monitoring Program in partnership with the MECP, Grand River Conservation Authority, Long Point Region Conservation Authority, and Catfish Creek Conservation Authority. Water samples were collected from the tributaries during a variety of stream flow, seasonal and weather conditions to characterize the water quality conditions within the tributaries.

Study results suggest that Kettle Creek is a significant contributor to phosphorus and reactive phosphate loading to the nearshore of Lake Erie. Reactive phosphate (orthophosphate) is the form of phosphorus which is more biologically available (easily used by algae) and, as a result, is more ecologically significant. Compared to other Lake Erie tributaries studied, the reactive phosphate levels are much higher in Kettle Creek—due in part to the natural attributes of the watershed combined with its intensive agricultural and urban land use.

2.12 Aquatic Habitat

The location of cold, cool and warm water aquatic habitats in the Kettle Creek Watershed are shown in Map **2**-**17.**

Generally, water quality conditions are described according to chemical and physical characteristics of stream water. However, biological indicators, such as benthic macroinvertebrates and fish species, should also be used in conjunction with chemical and physical characteristics to further describe the overall health of a watershed. Programs that monitor surface water such as the Provincial Water Quality Monitoring Network (PWQMN) and ground water quality, such as Provincial Groundwater Monitoring Network (PGMN), and benthic macroinvertebrate sampling are used to assess the health of aquatic habitats.

Water quality reflects both the natural features (e.g. soil characteristics, tree cover) and land use. Low forest cover, intensive agricultural activities, and urbanization can result in water quality conditions that need improvement.

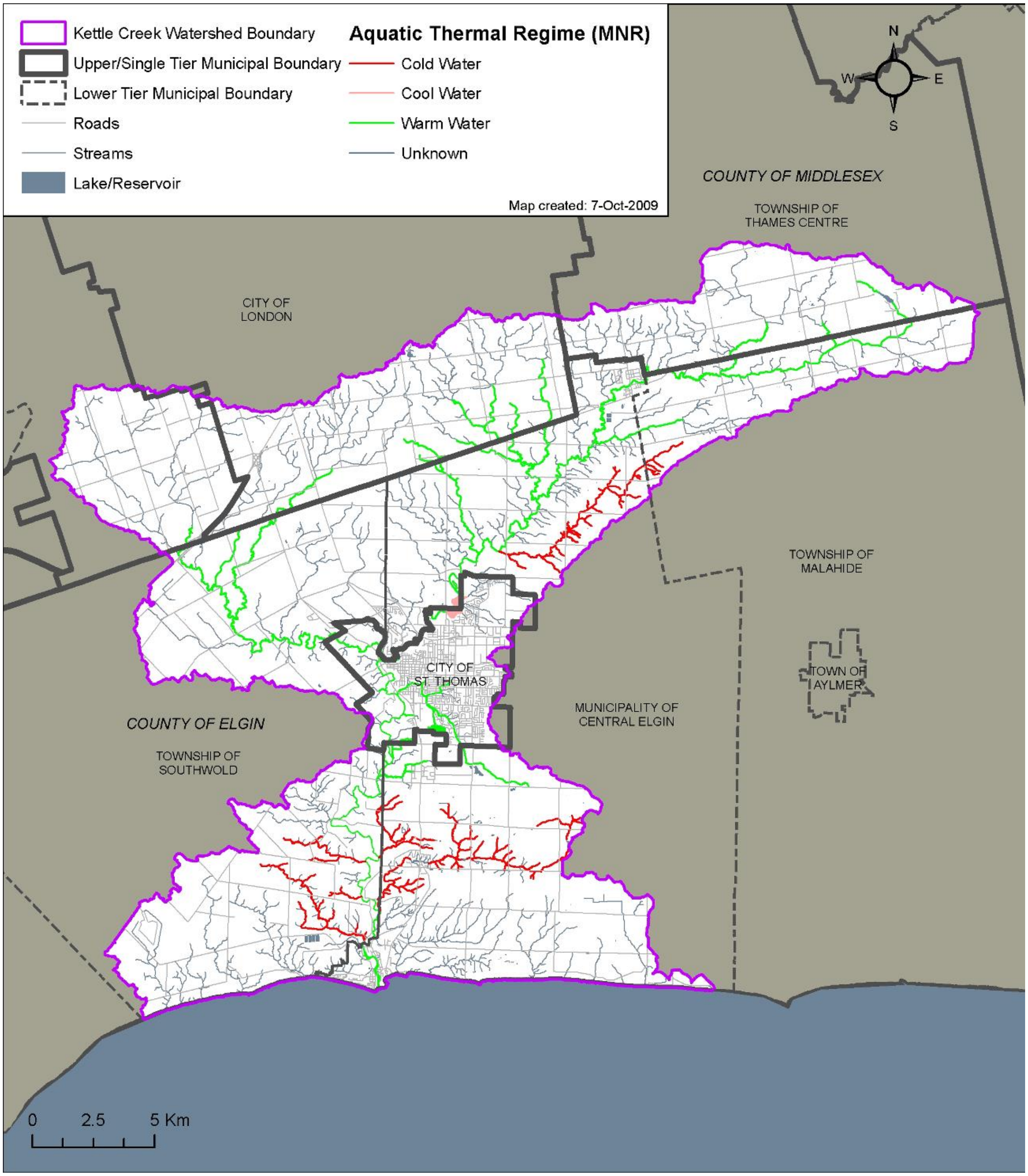
The dominant historical impacts leading to negative changes in aquatic habitats were the clearing and draining of forests and wetlands that took place after the European settlement of the area, and the subsequent agricultural utilization of large areas of the watershed. The hydrologic regime of the watershed was greatly altered by these events. The clearing of forests and draining of wetlands contributed to the warming of surface water temperatures, a decrease in dissolved oxygen levels, a reduction in recharge zones contributing to reduced baseflows, increased erosion, sedimentation and nutrient loading.

The Lower Kettle Creek and Dodd Creek subwatersheds are the most impaired regions within the watershed, with water quality appearing to progressively deteriorate from upstream to downstream. Located on the Norfolk Sand Plain, Beaver Creek was found to be the least impaired region within the watershed. This is likely due to the natural characteristics of the land—primarily the sandy soils, natural riparian vegetation cover and groundwater-sourced stream baseflow. Water quality typically decreases in areas that have more human activity, such as agriculture. The highest land use category in the Kettle Creek watershed is agriculture at 80%.

The Kettle Creek watershed is a contributor of phosphorus to Lake Erie. Over the last 10 years, 95 percent of the phosphorus samples collected across the Kettle Creek watershed exceeded the Provincial Water Quality Objective. Phosphorus loading is a key issue facing surface water quality in the Kettle Creek watershed. According to the 2018 Watershed Report Card, the Lower Kettle Creek subwatershed improved from an F grade (very poor) in 2013 to a D grade (poor) in 2018 for total phosphorus concentrations, while Dodd Creek and Upper Kettle Creek remained status quo.

Most of the tributaries within the Kettle Creek watershed are thermally stressed, and with the increasing trend in summer temperatures, it has become a primary water quality concern. High water temperatures can limit the diversity of aquatic species present and impact dissolved oxygen saturations. For the period between 2013 and 2017, summer water temperatures were consistently above 20°C and reached as high as 29.6°C, which is approaching the upper threshold for many warm water species. This suggests a relative increase of three degrees in summer surface water temperatures over the last 20 years. These higher summer water temperatures are amplified in the Upper Kettle and Dodd Creek subwatersheds by the lack of extensive riparian vegetation cover and relatively low natural base-flows.

Map 2-17: Aquatic Habitat in the Kettle Creek Watershed



As part of the Municipal Drain Classification project in partnership with Fisheries and Oceans Canada, fish and flow surveys have been conducted over the last seven years to classify municipal drains throughout the watershed.

The Dodd Creek subwatershed, including Dodd Creek and its many tributaries and drains supports a warmwater fish community. In the last 10 years, a total of 20 warm water community fish species have been identified in the Dodd Creek subwatershed including White Sucker, Least Darter, Green Sunfish and Fathead Minnow.

The Upper Kettle Creek subwatershed supports a diverse warmwater fishery throughout most of the subwatershed with Salt Creek supporting some cooler species. In the last 10 years, a total of 28 fish species have been identified in the Upper Kettle Creek subwatershed including Smallmouth Bass, Northern Hogsucker, Stonecat and one sensitive species, the Golden Redhorse. The Dalewood Dam is a major barrier to fish passage from the Lower Kettle Creek watershed into the Upper Kettle Creek watershed.

The Lower Kettle Creek subwatershed, including the main branch of Kettle Creek, Beaver Creek, Mill Creek and many tributaries supports a mixed warmwater/coolwater fish community. In the last 10 years, a total of 30 fish species have been identified in the Lower Kettle Creek subwatershed including Rainbow Trout, Golden Shiner, Golden Redhorse and Logperch.

While no intensive freshwater mussel surveys have been conducted within the Kettle Creek watershed, field observations over the last 10 years of live mussels and mussel shells have identified five species of mussel including White Heelsplitter, Fatmucket, Giant Floater, Pink Heelsplitter and Flutedshell.

Benthic macroinvertebrate monitoring is undertaken annually throughout the watershed. There are 10 baseline sites that are sampled every fall using the OBBN method and 15 Areas of Concern (AoC) sites that are divided by subwatershed and sampled on a three-year rotation cycle.

According to the 2018 Watershed Report Card, the Upper Kettle Creek subwatershed surface water quality degraded slightly from an overall grade of C achieved in 2013 (fair), to D (poor). This change in the surface water quality conditions was due to an increase in *E. coli* concentrations, and higher benthic Family Biotic Index (FBI) scores which suggests an increase in organic pollution in the long-term monitoring sites at the time of sampling (between 2013-2017). These results, combined with nutrient loading, low base flows, high water temperatures and a lack of natural vegetative cover along watercourses contribute to poor surface water quality.

Pollution present in creeks and streams can reduce the number of benthic invertebrate species in the system (i.e., species diversity), while frequently creating an environment that is favorable to a few species (i.e. pollution tolerant species).

A stream inventory completed in 1993 inventoried the following streams as being cold water systems: Little Creek, Beaver Creek, Salt Creek; cool water: Mill Creek, Spring Creek; and warm water: Pinafore Creek, Dodd Creek, Vessie Creek.

In 1981, Ecologistics Ltd prepared a report on the health of the Dalewood Reservoir. Results indicated that the reservoir was in “poor shape” due to decreased water flows, poor water quality and decreased aquatic life diversity. In addition, the reservoir suffers from sediment related issues regarding increases in metals, nutrients and bacterial concentrations. The source of these sediments is likely from a combination of intensive agricultural practices and the steep nature of the watershed. Although sedimentation of the reservoir has reduced habitat for some aquatic species, it has increased habitat for others through the expansion of the surrounding provincially significant wetlands. A more recent study (Riggs Engineering Ltd., 2004) suggests that the sediment loading within the reservoir has reached equilibrium.

Lake Whittaker is a natural inland lake fed by several springs. Low water levels and flow rates along with the eutrophication of Lake Whittaker resulted in the development of stagnant pockets of water with decomposing aquatic vegetation leading to minimal dissolved oxygen (KCCA, 1989). Low dissolved oxygen can limit the number of fish species capable of inhabiting the lake, reduce water quality, and thus affect recreational activities. A 2012 study on Lake Whittaker collected data on water and sediment quality, fish community, fish habitat and bathymetry to determine the baseline conditions of Lake Whittaker to develop and implement a management strategy for the lake. Over the last 10 years, water quality has maintained at a consistent level at or below the established environmental monitoring management triggers.

A fish community assessment prepared by NRSI in 2012 identified a total of 12 fish species comprising seven families including: White Sucker, Golden Shiner, Yellow Perch, Largemouth Bass and Rainbow Trout. The presence of 12 species is indicative of a moderately diverse fish community, as evidenced by their respective life history requirements, as well as trophic status and physical morphology. With the exception of Rainbow Trout, the fish community is composed primarily of generalist species which are not highly dependent on specific habitat requirements for spawning or life history processes and are considered to be flexible and adaptive. Rainbow Trout were stocked in Lake Whittaker for angling purposes prior to 2010. This species has habitat specific requirements for spawning, rearing, refuge and overwintering. The majority of the fish living in Lake Whittaker are indicative of a warm/coolwater fish community and are tolerant or moderately tolerant to warm temperatures, low dissolved oxygen levels and turbidity. In addition to demonstrating moderate diversity, this variety of species composition demonstrates that a complete range of trophic levels and ecological niches are currently being filled, allowing the existing fish community to function largely as a self-sustaining ecosystem.

Lake Margaret, located in St. Thomas, Ontario, is a man-made lake derived from a gravel pit. Since 2000, the lake has undergone some enhancements to improve fish habitat and water quality including shoreline habitat, deep water refuges, coastal wetland creation and the installation of three islands. Since 2016, the City of St. Thomas has contracted KCCA to complete Lake Monitoring every three years including fish community sampling, temperature and dissolved oxygen profiling and water quality sampling.

In general, the water quality in Lake Margaret is within expected ranges for this type of water body. Aquatic and terrestrial plant and animal life appears healthy and abundant. Most sampled values are under provincial water quality standards. Similar to Lake Whittaker, dissolved oxygen levels in the bottom of Lake Margaret were typical for anoxic (low oxygen) conditions from May to October until the lake turned over. Fish can usually avoid these stressed areas if there is sufficient lake volume for individuals to find refuge.

A fish community assessment prepared by NRSI in 2019 indicates that the fish community is composed of primarily generalist species which are not highly dependent on specific habitat requirements for spawning or life history processes. The fish that were found have similar habitat preferences and are considered flexible and adaptive species. A total of four fish species comprising two families, (Brown Bullhead, Bluegill, Largemouth Bass and Black Crappie) were observed in Lake Margaret, which is indicative of a simple, warmwater fish community, as evidenced by their respective life history requirements, as well as trophic status and physical morphology. The fish living in Lake Margaret are moderately tolerant to warm temperatures, low dissolved oxygen levels and turbidity. The lack of baitfish (*cyprinids*) within Lake Margaret may be a limiting factor for the existing fish population. The suspected cause for the missing *cyprinids* is a combination of Lake Margaret being a closed system and the lack of suitable habitat.

2.12.1 Water Quality Data Gaps

Water quality monitoring has historically focused on characterizing the chemical and physical attributes of the watershed. However, the utility of the data has been compromised by inconsistencies in the number and location of sites being monitored, and the sampling frequency due to time and funding constraints.

Since 2006, KCCA has a comprehensive and robust water monitoring program in place, using a combination of annual benthic macroinvertebrate sampling (BioMAP between 2006-2010, and Ontario Benthos Biomonitoring Network (OBBN) 2010-present), surface water monitoring, groundwater monitoring and fisheries community monitoring. Maintaining a consistent environmental monitoring program is the most effective way to monitor changes in the watershed, evaluate trends over time and provides valuable data to the watershed report card process.

2.13 Species at Risk

A list (2014) of species known to be threatened, endangered, extirpated or of special concern in the Kettle Creek watershed are listed below.

Threated Species

- Birds – Whip-poor-will, Chimney swift, Peregrine Flacon, Least Bittern, Bobolink,
- Fish – Lake Sturgeon, Lake Chubsucker, Spotted Gar
- Mammals – Grey Fox

- Molluscs – Mapleleaf mussel
- Plants – Colicroot, False Rue-anemone, Crooked-stem Aster
- Reptiles – Blanding's turtle, Eastern Hog-nosed snake

Endangered Species

- Birds – Acadian Flycatcher, Prothonotary Warbler, King Rail
- Fish – Pugnose Shiner
- Insect – Rusty-patched Bumble bee
- Mammals – Mountain lion or cougar, American Badger
- Molluscs – Fawnsfoot
- Mosses – Spoon-leaved moss
- Plants – False Hop Sedge, American Chestnut, Eastern Flowering Dogwood, Butternut, American Ginseng
- Reptiles – Spotted Turtle

Extirpated

- Birds – Greater Prairie-chicken
- Plants – Spring Blue-eyed Mary

Special Concern

- Birds – Black Tern, Common nighthawk, Olive-sided flycatcher, Cerulean Warbler, Bald Eagle, Yellow- breasted Chat, Red headed Woodpecker, Louisiana Waterthrush, Canada warbler
- Fish – Northern Brook Lamprey, Silver Chub
- Insects – Monarch, West Virginia White
- Mammals – Woodland vole
- Plants – Green Dragon, Blue Ash, Broad Beech Fern, Riddell's Goldenrod
- Reptiles – Snapping turtle, Northern Map Turtle, Milksnake, Eastern Ribbonsnake

2.14 Interactions between Human and Physical Geography

Land use practices in the watershed can have an increased risk to ground and surface water depending on the geology of the area. The geology can determine the infiltration, runoff and recharge rate of precipitation which corresponds to how fast and easily contaminants may be able to move and infiltrate the ground and surface water. The mix of clay and till materials covering most of the Kettle Creek Watershed drives much of the precipitation to run off into the creek and its tributaries. Clearing and draining of land for agricultural use throughout the watershed has increased the rate of runoff and created a flushing effect where soils and contaminants are carried overland and downstream to the outlet of the creek into Lake Erie.

Conversely, the tight till and clay deposits in the northern portion of the watershed provide significant protection from land uses to the groundwater sources for both the municipal supply for the Village of Belmont and private wells. The clay and till materials of the Ekfird Clay Plain and Mount Elgin Ridges reduces infiltration of surface water and contaminants to the drinking water supply aquifer.

Surface water quality within the Kettle Creek watershed appears to be negatively affected by increasing summer temperatures, decreasing baseflows, potentially low levels of dissolved oxygen, and extensive nutrient and sediment concentrations. Generally high phosphorus concentrations are seen in areas that drain highly intensive agricultural lands situated on till or clay plains, which is the case for both Dodd and Kettle Creek. However, there are also urban sources entering the creek, such as wastewater treatment plant effluent, that could also be elevating phosphorus levels found below St. Thomas (Evans and Lanthier, 2006).

Both the nutrient and sediment issues within the Kettle Creek watershed are primarily the result of runoff and erosion. These conditions are amplified by land-use practices, such as agriculture and urbanization, and the dramatic elevation change within the watershed (Evans and Lanthier, 2006).

2.15 Summary of Watershed Characterization Peer Review

In 2022, as part of the Section 36 Update to the Kettle Creek Assessment Report, revisions were made to the Kettle Creek watershed characterization section using the 2018 Kettle Creek Watershed Report Card and Background Report (Dow, 2018), where information was available.

The descriptions in this section of the Assessment Report are excerpts or summaries taken from the Kettle Creek Watershed Characterization Report (KCCA, 2008). The Characterization Report is based on the best available information on the watershed at the time of writing. The components of the Characterization Report were based on the requirements of technical guidance documents provided by the Ministry of the Environment (Module 1, the Watershed Characterization Technical Guidance, April 2006).

In 2007, the draft Characterization Report was reviewed by a Peer Evaluation Committee made up of conservation authority experts in hydrology, hydrogeology and water quality. The peer evaluators reviewed the draft reports for consistency with the requirements of the MOE Technical Guidance modules, which have since been replaced by the Assessment Report: Technical Rules under Ontario Regulation 287/07 (O. Reg. 287/07).

Comments provided by the Peer Evaluation Committee that referred to requirements of the Assessment Report: Technical Rules were taken into consideration, where data was available, in the development of Section 2 of the Kettle Creek Assessment Report.

2.16 Watershed Characterization Data Gaps

The following data gaps have been identified in the Watershed Characterization component of the Assessment Report.

- Location of federal lands in the watershed – data on the location of federal lands is not currently available. As new information is released, it will be included in an amendment to the Assessment Report.
- Lost of non-municipal drinking water systems – working with the public health units and the MECP to improve the available data on non-municipal drinking water systems. This information will be included in an amendment to the Assessment Report.
- Location of monitoring locations related to drinking water systems – Working with municipalities to improve the available data on non-municipal drinking water systems. This information will be included in an amendment to the Assessment Report.

2.17 Section Summary

- The Kettle Creek Watershed is located in southwest Ontario and covers an area of approximately 520 km^2 draining to Lake Erie. Much of the land of the watershed is used for agriculture with the City of St. Thomas located in the centre of the watershed. The watershed is broken up into three subwatersheds: Dodd Creek, Upper Kettle and Lower Kettle.
- The main physiographic regions within the Kettle Creek Watershed are the Mount Elgin Ridges, the Ekfrid Clay Plain, and the Norfolk Sand Plain. The watershed is underlain by a series of gently dipping sedimentary rocks overlain by unconsolidated sediments of variable thickness and porosity.
- The upper portions of the watershed are characterized by high runoff and little recharge from tight soils and agricultural lands. The lower portions of the watershed have sandy soils and more moderate runoff and recharge rates with a fairly steep and deeply incised river valley. Numerous Lake Erie tributaries form small gullies along the Lake Erie shoreline.
- The primary aquifer complex is comprised of broad unconfined shallow sand and gravel units located between St. Thomas and Lake Erie. Deeper confined overburden aquifers are found within the central parts of the watershed. The

Dundee Formation forms the bedrock aquifer in the watershed; however, it is largely untapped since adequate groundwater resources are found within the overburden.

- Surface water quality within the Kettle Creek watershed reflects both the natural features (e.g., soil characteristics, tree cover) and land use of a watershed and is likely variable as a result of significant rainfall and snowmelt events. Phosphorus loading is a key issue facing surface water quality in the Kettle Creek watershed and the nearshore of Lake Erie. Both the nutrient and sediment issues within the Kettle Creek watershed are primarily the result of runoff and erosion. These conditions are amplified by land-use practices, such as agriculture and urbanization, and the dramatic elevation change within the watershed.

3.0 WATER QUANTITY RISK ASSESSMENT

A Water Budget is an understanding and accounting of the movement of water and the uses of water over time, on, through and below the surface of the earth.

The Water Quantity Risk Assessment provides a framework to evaluate the reliability of surface water intakes or wellheads in the context of the local watershed. The objective of the framework is to help managers identify: 1) drinking water sources which may not be able to meet current or future demands and 2) the drinking water threats contributing to the water quantity problem. The risk assessment is carried out using three tiers that have been designed to minimize the amount of water budgeting work needed for wells and surface water intakes that are not under hydrologic stress.

A water budget and Tier 2 stress assessment was carried out for the Kettle Creek watershed area as part of a larger study for Catfish Creek, Kettle Creek, and Long Point Region. Because the study began as a more detailed Tier 2 study in 2005, no separate studies were completed at the Conceptual Understanding and Tier 1 assessment stages. The results of the Kettle Creek Water Budget and Tier 2 Stress Assessment are documented in this Assessment Report.

The Kettle Creek water budget and Tier 2 stress assessment are documented in two reports: Long Point Region, Kettle Creek and Catfish Creek Integrated Water Budget – Final Report, April 2009 and Long Point Region, Catfish Creek and Kettle Creek Tier 2 Water Quantity Stress Assessment – Final Report, May 2009.

3.1 Tier 2 Water Budget

The Tier 2 Water Budget and Water Quantity Stress Assessment were completed by AquaResource Inc. as part of a larger suit of studies conducted to increase the understanding of water pathways in the Kettle Creek Watershed. The following provides a summary of the reports and tools which comprise the larger suite of studies that document the full Water Budget as given in this Assessment Report.

- Long Point Region, Kettle Creek and Catfish Creek Integrated Water Budget (AquaResource, 2009a): conceptual water budget, integrated water budget including quantity and movement of water within and across subwatersheds
- Long Point Region, Kettle Creek and Catfish Creek Tier 2 Water Quantity Stress Assessment (AquaResource, 2009b): Water quantity stress assessment.
- Water Use in the Catfish Creek Watershed (Bellamy & Wong, 2005a): water use.
- Westward Expansion of the Norfolk GW model for the Catfish and Kettle Creek Watersheds (WHI, 2007): groundwater quantity and flow assessment and water levels.
- Catfish Creek Watershed Hydrologic Model (Schroeter & Associates, 2006): surface water quantity and flow assessment and recharge abstraction.

- Catfish Creek Watershed Characterization (Gauser et al, 2008): describe the physical and human characteristics of the watershed.
- Norfolk County Groundwater Flow Model (WHI, 2003): groundwater quantity and flow assessment and water levels.

The Integrated Water Budget Report was completed using a set of water budget tools (groundwater flow and hydrologic numerical models). To simulate surface water flows and partitioning of precipitation, a continuous hydrologic model for the Kettle Creek watershed was built using GAWSER (Schroeter & Associates, 2006b). Hydrologic modelling is able to simulate stream flows that reflect seasonal hydrologic processes. To simulate groundwater flows, a regional-scale groundwater flow model was developed and calibrated to available water level and streamflow data using FEFLOW. The regional groundwater flow model was designed to represent average annual groundwater flow conditions, with particular focus on volumetric flow from one subwatershed to another. Together these modelling tools provide a physical means of quantifying flows through the system for determining available water resources in the Study Area.

Significant efforts were undertaken to better quantify and characterize the consumptive water demand throughout the Study Area. The water demand characterization completed in this study included efforts to verify Permit To Take Water (PTTW) information, gathering “actual pumping” data, estimating agricultural demand based on discussions with the farming community, validating actual use information through calibration of the surface water model, and gathering relevant information contained within Ministry of the Environment’s Permit To Take Water paper files.

The Tier 2 Water Quantity Stress Assessment (AquaResource, 2009b) was prepared as a structured means of evaluating the degree of potential water quantity stress throughout an area by comparing the volume of water demand to that which is practically available for use. The results of streamflow and groundwater flow modelling and water demand estimates from the Integrated Water Budget were incorporated into the Tier 2 Water Quantity Stress Assessment.

Water Budget and the Water Quantity stress assessment was calculated based on three subwatersheds as shown in **Map 2-2** and below**.**

- Upper Kettle subwatershed – area of 199 km^2 with the Belmont Drinking Water System
- Dodd Creek subwatershed – area of 131 km^2 with no municipal system
- Lower Kettle subwatershed – area of 190 km^2 with no municipal system

3.2 Water Use

Water use is expressed in two ways: the amount of water pumped, and the amount of water consumed. Consumed water is the amount of water pumped and not returned to the source from which it was pumped.

The amount of water pumped was determined by contacting municipalities for information on public water supplies, surveying non-agricultural Permit-To-Take-Water holders, utilizing Statistics Canada data to estimate rural domestic and agricultural water use, reviewing Permit-To-Take-Water information from the Ministry of the Environment including the Permit-To-Take-Water database and Permit-To-Take-Water paper records at the Ministry of the Environment offices, and running an irrigation demand model. The seasonality of a water taking sector was considered when estimating the annual volume of extracted water.

The amount of water consumed was determined by applying a consumptive factor to each taking based on the specific purpose of the taking, while taking into account the source of water and the return of waste water. Specific consumptive use factors are based on work by AquaResource (2005) with modifications to agricultural water use based on Isidoro et. Al. (2004) and comments from the peer review committee.

There are seven water use sectors active within Kettle Creek Watershed. **Table 3-1** ranks the seven sectors by their proportion of total demand.

Table 3-1: Top Water Users in the Kettle Creek Watershed

Rank	Purpose	Takings (m^3/year)	Percentage of Total Demand
1	Municipal Water Supply	6,040,000	76%
2	Rural Domestic	760,000	10%
3	Agricultural Irrigation	565,000	7%
4	Agriculture (Livestock watering)	364,000	5%
5	Golf Course Irrigation	199,000	3%
6	Other – Dewatering	62,000	1%
7	Minor Uses	1000	<0.1%

Source: Bellamy & Wong, 2005b

3.2.1 Municipal Systems

Belmont (population of 1,800) contains the only groundwater source for municipal water takings in the Kettle Creek Watershed. All other municipalities receive their water from Lake Erie from either primary or secondary water systems from the Elgin Area Water

Supply System intake in Lake Erie, located near Port Stanley. These communities include St. Thomas (40,000 residents), and smaller communities in both Central Elgin and Southwold (9,000 residents). The water that is distributed via pipelines running through Elgin County also supplies approximately 25 to 30 percent of the rural and urban districts of the City of London both within and outside of the watershed region. Municipal water use totaled six million cubic metres in 2004 in this region. The location of the municipal water wells and surface water intakes in this area are illustrated on **Map 3-1** and **Map 3-2** respectively.

The drinking water supply system for the Town of Belmont consists of two deep artesian wells, a pumphouse, underground reservoir and distribution system. The system is classified by the MECP as a Large Municipal Residential System (LMRS). The overburden aquifer is sand and gravel and is confined by a thick layer of clay.

The Elgin Area Water Supply System is owned by the Elgin Area Water Supply System Joint Board of Management but operated and maintained by American Water Services Canada Corporation. The intake and treatment plant facility are located in the Municipality of Central Elgin along the north shore of Lake Erie in the town of Union, two kilometres east of Port Stanley. Treated water from the Elgin Area Water Supply System is distributed to seven municipalities (Aylmer, Bayham, Central Elgin, London, Malahide, Southwold and St. Thomas) through distribution systems owned and operated by the receiving municipality. The water treatment plant has a rated capacity of 91,000 m^3 per day and serves a population of approximately 94,400 people. The Elgin Area Water Supply System supplies the majority of serviced communities within Kettle Creek with drinking water, including Southwold, London, St. Thomas and Elgin.

3.2.2 Private Drinking Water Supplies

A total of 1,427 domestic wells are located in the Kettle Creek Watershed official boundaries, with 54 (3.8 percent) of these wells being classified as bedrock wells and 1,349 (94.5 percent) as overburden wells. There are few bedrock wells in the Kettle Creek watershed; most are found along the very top of the watershed. Bedrock wells range in depth from about 40 metres to almost 103 metres in this region, with the median depth being 79.9 metres. Domestic bedrock and overburden wells as given in the Ministry of the Environment's Water Well Information System (WWIS) are illustrated on **Map 3-3** and **Map 3-4**, respectively.

Domestic overburden wells (**Map 3-4**) are much more common and range in depth from 2.8 metres to 97.0 metres with a median depth of 24.4 metres. The range of overburden well depths reflect the thick overburden sediments, and the widespread distribution of overburden aquifers in this area. Overburden wells were drilled throughout the watershed, with some wells clustered along the divide between Central Elgin and Southwold Townships. There are no known wells in the City of St. Thomas (probably because servicing predates water well information collection).

Unserviced domestic water use was estimated closely following methodology from the Grand River Water Use Study (Bellamy & Wong, 2005b). These estimates were made by combining Census of Population data for areas known not to be serviced by a municipal system, with a per capita water use rate of 160 L/d/cap. A per capita rate of 160 L/d/cap was estimated by Vandierendonck and Mitchell (1997), and is consistent with the Ministry of the Environment's Groundwater Studies Technical Terms of Reference (2001) which suggests an unserviced per capita rate of 175 L/d/cap. The estimates were pro-rated by area to the subwatershed areas and are included below.

- Upper Kettle subwatershed – Rural Domestic Demand of 0.005 m3/s
- Dodd Creek subwatershed – Rural Domestic Demand of 0.004 m3/s
- Lower Kettle subwatershed – Rural Domestic Demand of 0.014 m3/s

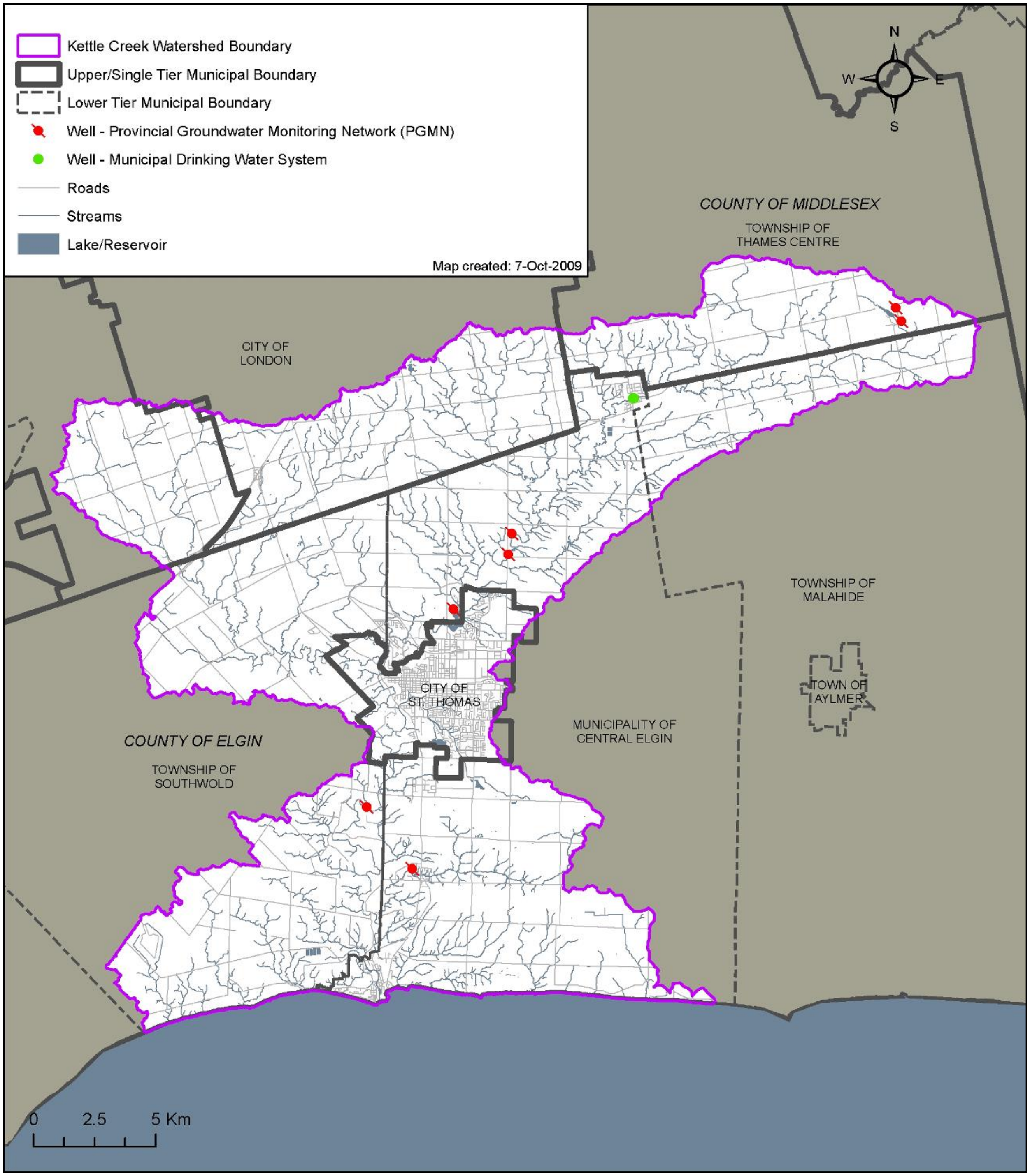
Due to appropriate concerns about poor water quality, this unserviced domestic demand is almost exclusively obtained from groundwater. Therefore, it is assumed that all unserviced domestic demand draws water from groundwater supplies. Consistent with the water consumption ratios for other Water Supply categories, the consumptive ratio is assumed to be 0.2. For domestic water wells, this assumption implies that 80 percent of pumped water is returned to groundwater through septic systems.

3.2.3 Non-Drinking Water Use

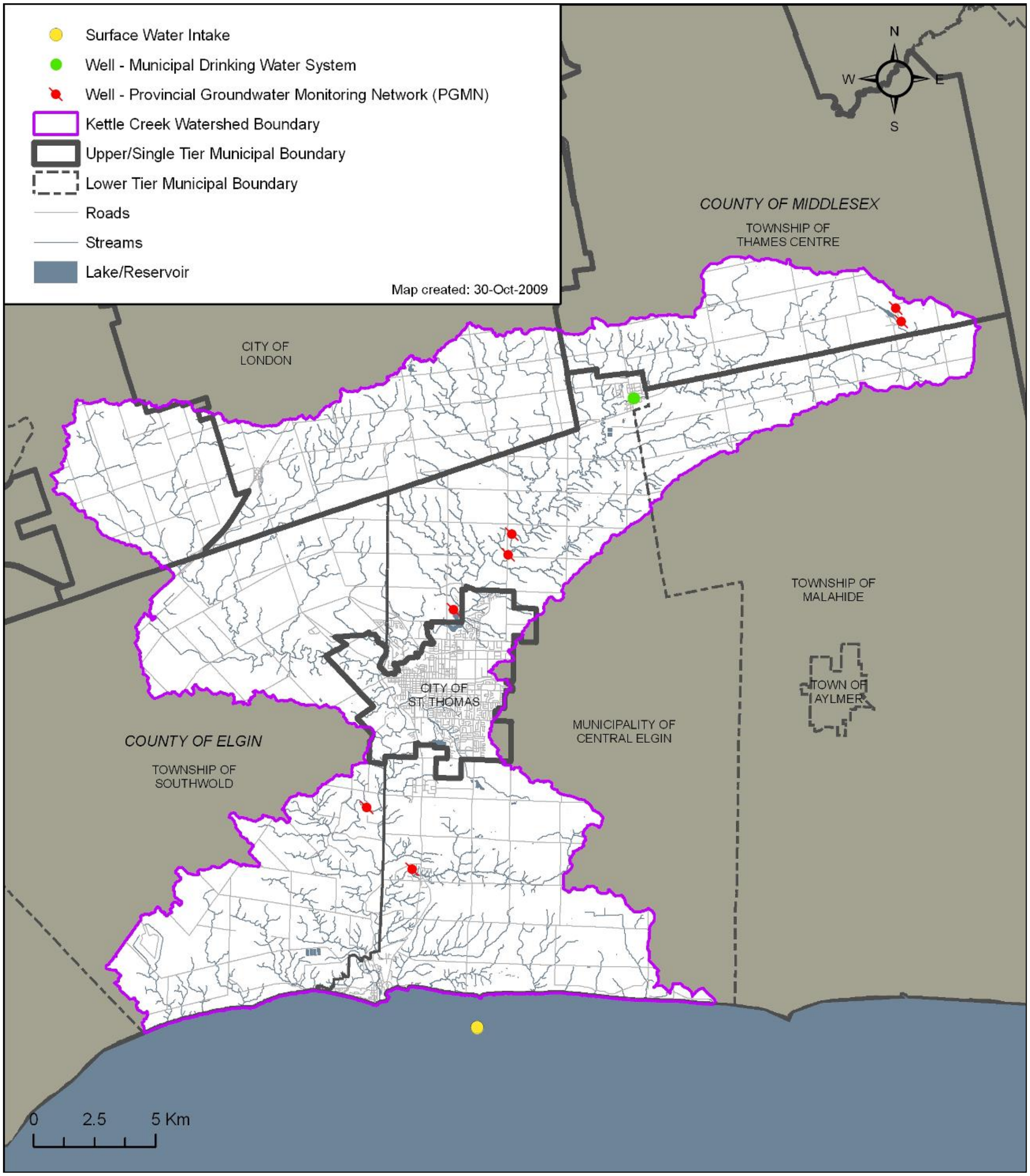
Permitted water takings in the Kettle Creek Watershed are generally limited to the southern portion of the area, where surficial granular materials are present. There are approximately 50 permits that extract water from 67 differing locations within the Kettle Creek Source Protection Area's jurisdiction (**Map 3-5**).

Water takings are evenly supplied from groundwater and surface water sources. Agricultural water takings comprise 45 percent of all takings, while water supply, commercial and miscellaneous uses making up the majority of the remaining permitted takings.

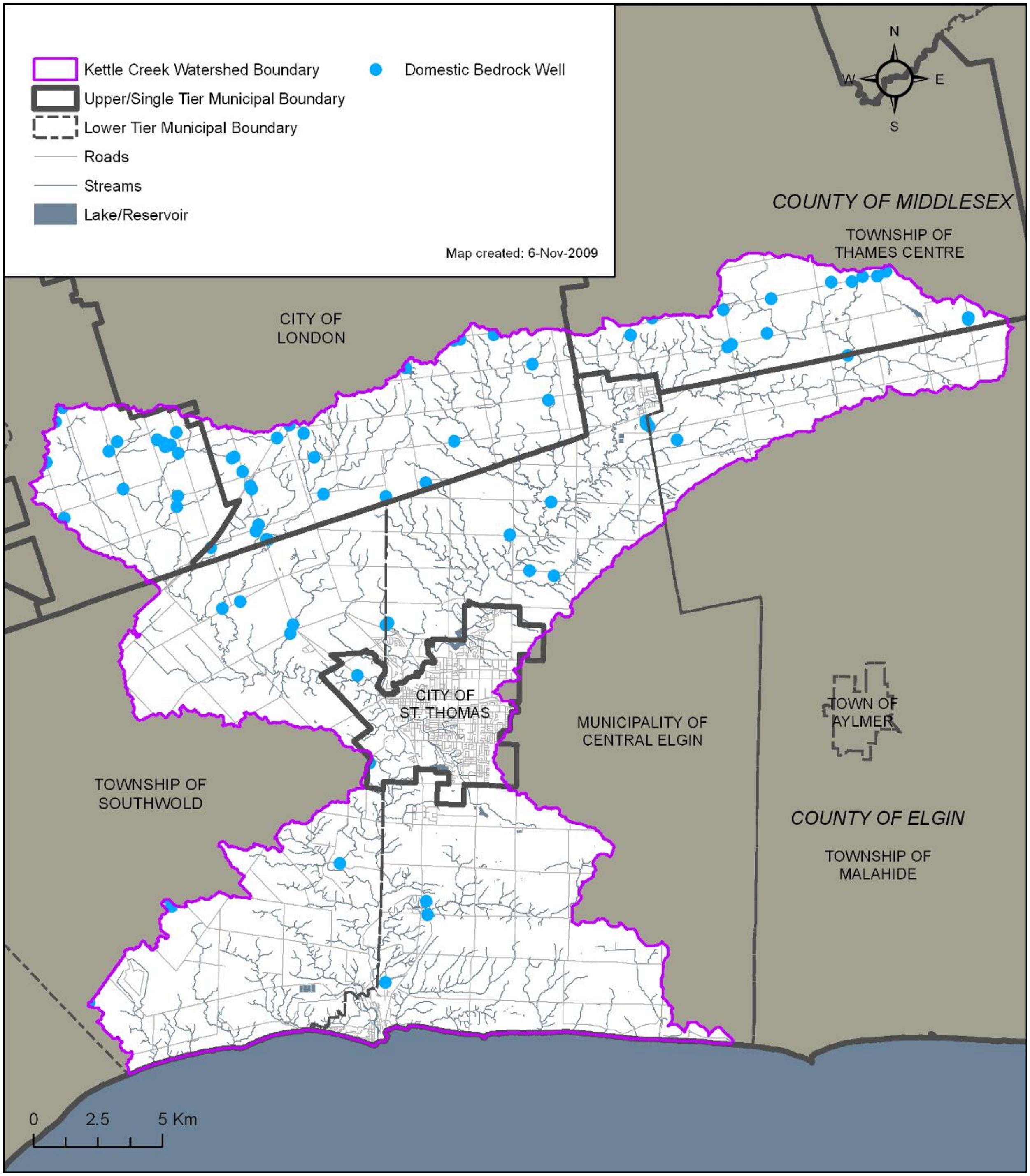
Map 3-1: Municipal Water Wells in the Kettle Creek Watershed



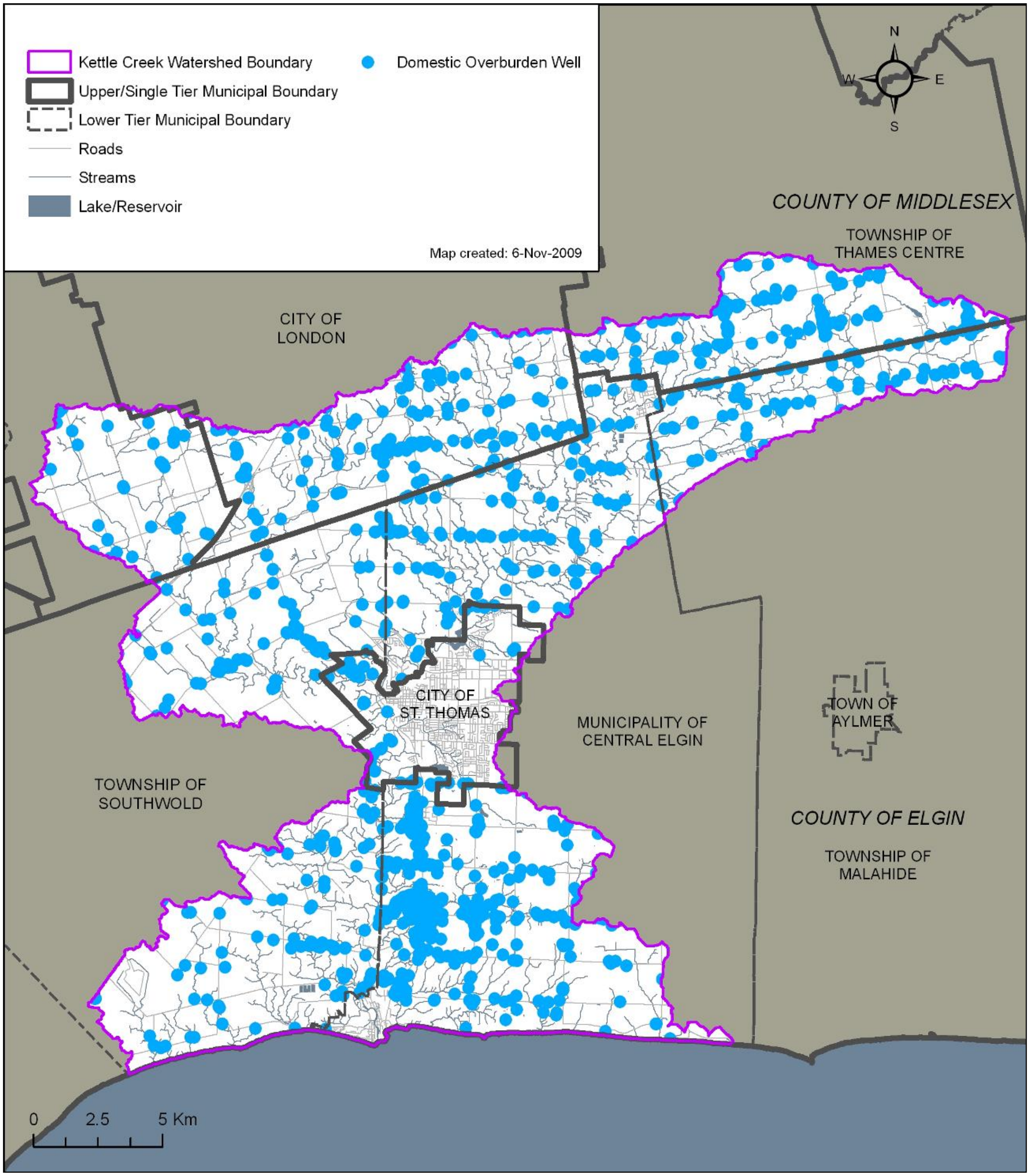
Map 3-2: Surface Water Intakes in the Kettle Creek Watershed



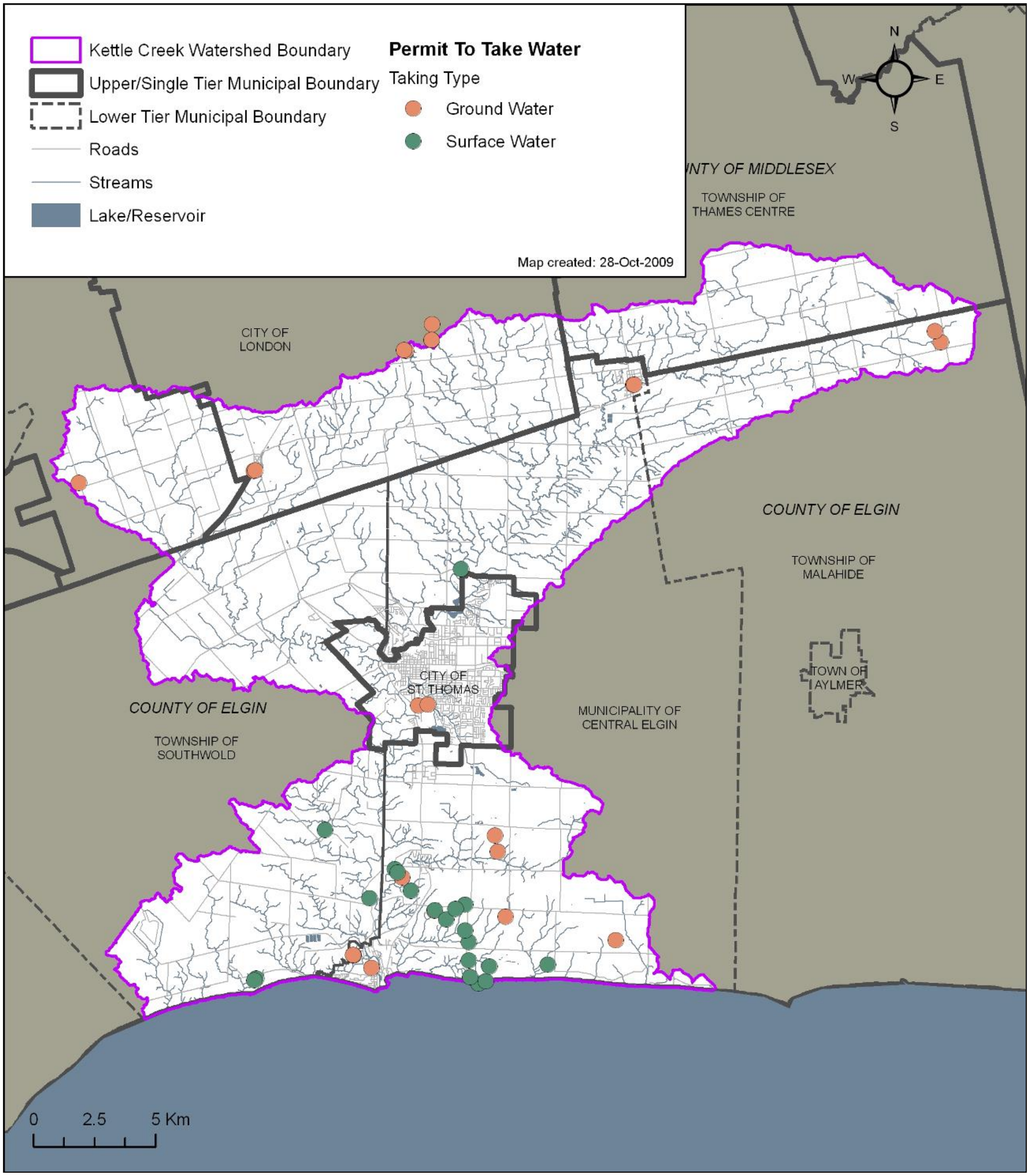
Map 3-3: Domestic Bedrock Wells in the Kettle Creek Watershed



Map 3-4: Domestic Overburden Wells in the Kettle Creek Watershed



Map 3-5: Permits to Take Water in the Kettle Creek Watershed



3.2.4 Permitted Rate

Permitted rates were obtained from the Ministry of the Environment Permit-To-Take-Water database. **Table 3-2** shows the total permitted rate of active permitted water takings categorized by subwatershed and source. The total permitted rates are 0.28 m^3/s for groundwater and 0.25 m^3/s for surface water sources, representing a total rate of 0.53 m^3/s.

Table 3-2: Permitted Rate

Subwatershed	Permitted (m^3/s) Groundwater	Permitted (m^3/s) Surface Water	Permitted (mm) Groundwater	Permitted (mm) Surface Water
Upper Kettle	0.12	0.02	20	3
Dodd Creek	0.02	0.00	5	0
Lower Kettle	0.14	0.23	23	38
Total	**0.28**	**0.25**	**48**	**41**

3.2.5 Pumped Rate

Pumped rates include the estimated pumped rates from both permitted uses and non-permitted uses. To calculate the pumped rates from permitted uses, reported rates were used where available. If reported rates were not available, pumped rates for non-agricultural permits were estimated based on maximum permitted rates and a monthly demand factor based on the specific purpose listed for the permit, to take into consideration the seasonality of the taking based on the work in the Grand River Water Use Study (Bellamy & Wong, 2005b).

For agricultural permits, pumping rates were determined by applying an irrigation demand model (Bellamy & Wong, 2005a) which uses soil moisture generated by the hydrologic model to determine the occurrence of an irrigation event. The results show that irrigation is required, on average, 32 days per year. A pumping factor of 60 percent of the permitted rate was determined based on a number of reported pumping rates. The number of irrigation dates and the pumping factor were used to determine pumping rates on an average annual basis.

For non-permitted (permit exempt) water use, the GRCA developed a methodology to quantify non-permitted agricultural water use as part of the Grand River Water Use Study (Bellamy & Wong, 2005b). Legal non-permitted agricultural water use includes livestock watering, equipment washing, pesticide/herbicide application or any other minor use of water. Kreutzwiser and de Loë (1999) developed a series of coefficients, that when applied to the Census of Agriculture Data, can be used to estimate agricultural water use. The Water Use Assessment applied this methodology to estimate water use on a watershed basis. Non-permitted agricultural water use is pro-rated based on estimates for each subwatershed by area.

- Upper Kettle subwatershed non-permitted agricultural demand is 0.005 m3/s

- Dodd Creek subwatershed non-permitted agricultural demand is 0.002 m3/s
- Lower Kettle subwatershed non-permitted agricultural demand is 0.005 m3/s

Due to the census-based estimation technique, it is not possible to reliably determine the source of water for the agricultural water users. In the absence of this information, it is assumed that half of the demand is serviced through groundwater sources, and half is serviced through surface water sources.

Table 3-3 summarizes the estimates of the volume of water pumped, expressed as an annual average rate, for all users. The pumped rate is the average annual amount of water that has been withdrawn from watercourses or aquifers, without allowing for the consumptive nature of the taking. Pumped demand shows approximately 0.09 m^3/s pumped on an annual average basis, compared to 0.53 m^3/s that is permitted. This large difference is attributed primarily to the seasonality of agricultural permits, which are the dominant water use within the region.

Table 3-3: Average Rate Pumped

Subwatershed	Groundwater (m^3/s)	Surface Water (m^3/s)
Upper Kettle	0.02	0.01
Dodd Creek	0.01	0.00
Lower Kettle	0.03	0.02
Total	**0.06**	**0.03**

* Total = Estimated + Reported. Due to rounding errors, small summing discrepancies may exist.

3.2.6 Consumptive Use

Table 3-4 summarizes the estimated consumptive demand (source scale) within each subwatershed. The consumptive nature of the non-permitted agricultural water use is a point of uncertainty. In the absence of such information, and to arrive at a conservative estimate of the consumptive non-permitted agricultural water demand, it was assumed that 100 percent of the water taken is consumed. Based on the relatively small volumes estimated within this category as compared to the total consumptive water demand, this assumption is considered acceptable.

The table shows the maximum and minimum monthly and average annual demand for both surface water and groundwater sources. On an average annual basis, 0.04 m^3/s of water is estimated to be consumed from aquifers and 0.01 m^3/s is consumed from rivers and creeks.

There is significant monthly variability within most subwatersheds in the Study Area due to the dominant agricultural sector, which removes water only during the summer months. Consumptive demands for groundwater are larger than for surface water because groundwater takings are not recycled back to the aquifer.

Table 3-4: Consumptive Demand (By Hydrologic Source Unit)

Subwatershed	Groundwater Demand (m^3/s) Maximum Monthly	Groundwater Demand (m^3/s) Minimum Monthly	Groundwater Demand (m^3/s) Average Annual	Surface Water Demand (m^3/s) Maximum Monthly	Surface Water Demand (m^3/s) Minimum Monthly	Surface Water Demand (m^3/s) Average Annual
Upper Kettle	0.04	0.01	0.02	0.00	0.00	0.00
Dodd Creek	0.00	0.00	0.00	0.00	0.00	0.00
Lower Kettle	0.05	0.01	0.02	0.04	0.00	0.01
Total	**0.09**	**0.02**	**0.04**	**0.04**	**0.00**	**0.01**

Although efforts have been made to determine actual pumping rates for permit holders there is still a number of permits without reported pumping rates in which standard seasonality and consumption factors had to be used. The biggest water use sector, agricultural, has the most uncertainty since this use is climate driven. Water use in the Kettle Creek watershed is steady with no indication of an increase in water use.

3.3 Surface Water Budget

3.3.1 Surface Water Model

The Kettle Creek Watershed continuous surface water model was built using the Guelph All-Weather Sequential-Events Runoff (GAWSER) model program. This modelling software is a physically-based deterministic hydrologic model that is used to predict the total streamflow resulting from inputs of rainfall and/or snowmelt. The infiltration routine uses the Green-Ampt equation to partition precipitation into runoff and infiltrated water (recharge). Potential evapotranspiration is calculated using the Linacre model. Evapotranspiration is then calculated by removing available water from depression storage and the soil layers until wilting point is reached. Modelling procedures are fully documented in the GAWSER Training Guide and Reference Manual (Schroeter & Associates, 1996). Runoff, recharge and evapotranspiration were then aggregated to the subwatershed scale for the water budget.

The Kettle Creek Watershed hydrologic model was built by Schroeter and Associates in 2006. The study area has 38 catchments, ranging in size from 0.4 km^2 to 42 km^2, with the average size being 13.7 km^2.

Each catchment was assigned to one of five Zones of Uniform Meteorology (ZUMs) for climate data input. Climate data from the AES climate station at St. Thomas was used for the Kettle Creek Watershed hydrologic model, but was adjusted on an individual basis for each ZUM based on additional historic climate data sets from AES, the CA and private sources (Schroeter and Associates, 2006b). Missing precipitation and temperature data was filled in using data from nearby stations based on a process described by Schroeter et al (2006b). Climate data for the period November 1960 to November 2004 was used for this study.

Each catchment is comprised of 9 hydrologic response units (HRU), one impervious and 8 pervious. The HRUs were delineated by overlaying the quaternary geology with land cover information. Land cover information was taken from LANDSAT imagery obtained from the Great Lakes Conservation Blueprint Project for Terrestrial Biodiversity project which was produce by MNR's Natural Heritage Information Centre.

Prior to the overlay, both the quaternary geology and land cover information were grouped into categories of similar hydrologic response which then creates 18 HRUs (**T**able **3-5**). Then the 8 pervious hydrologic response units that cover the most land area in each catchment, along with the impervious hydrologic response units, are applied to each catchment in the model.

Table 3-5: Summary of Kettle Creek Hydrologic Response Units

HRU	Description	Groundwater Reservoir	HRU	Description	Groundwater Reservoir
1	Impervious	NA	10	Sand Till Medium Vegetation	Fast
2	Wetland	Fast	11	Sand Till High Vegetation	Slow
3	Clay Till Low Vegetation	Fast	12	Sand Gravel Low Vegetation	Slow
4	Clay Till Medium Vegetation	Fast	13	Sand Gravel Medium Vegetation	Slow
5	Clay Till High Vegetation	Slow	14	Sand Gravel High Vegetation	Slow
6	Silt Till Low Vegetation	Fast	15	Urban Clay	Fast
7	Silt Till Medium Vegetation	Fast	16	Urban Silt	Fast
8	Silt Till High Vegetation	Slow	17	Urban Sand	Slow
9	Sand Till Low Vegetation	Fast	18	Urban Sand Gravel	Slow

Contributions from human sources were also modeled by including wastewater treatment plant outflow. Wastewater treatment plant outflow from the City of St. Thomas was added as part of the baseflow from the catchment in which the outfall is located.

Calibration of the model to observed stream flow at all three gauges in the watershed was completed by Schroeter and Associates (2006b) as part of the model building exercise. Calibration focused on the average and median monthly flows as well as median and 90th percentile flows.

3.3.2 Surface Water Budget

The surface water budget components are determined from the hydrologic model (precipitation, evapotranspiration, runoff and recharge) and from the water use study for surface water takings. Surface water budget components have significant temporal variability. Results presented are based on average annual conditions for the 1980-2004 period and it is recognized that these results may vary significantly based on climate conditions. The analysis does not account for changes in water storage that would occur from one time period to the next.

The average annual precipitation is approximately 969 millimetres per year. The hydrologic model has estimated average annual evapotranspiration to be 609 millimetres per year. The average runoff rate across the Study Area is 218 millimetres per year, with an average groundwater recharge rate of 143 millimetres per year. Water taken from watercourses, that is not immediately returned to the surface water system, is approximately 0.01 m^3/s, or 1 millimetre per year. While precipitation and evapotranspiration rates have some degree of spatial variability, runoff and recharge rates have the most significant spatial variability due to changing soils, surficial geology, and land cover.

Table 3-6 and **Table 3-7** summarize the water budget components for each of the subwatersheds in mm and m^3/s, respectively. The negative values in the ‘SW Taking’ column represents the amount of water taken from the surface water source that is not immediately returned to the source.

Many elements of the water budget modelling process using the hydrologic model are subject to uncertainty. Although the calibration process is performed in an attempt to reduce uncertainty, the model results and water budgets reflect the uncertainty in the input parameters as well as limitations in the modelling approach. The model is designed to reflect general characteristics of each catchment relating to land cover, climate, soils and vegetation, and stream and river hydraulics. Calibration is limited to the available stream flow data and does not include many of the smaller Lake Erie tributaries.

Table 3-6: Surface Water Budget (mm/year) in the Kettle Creek Watershed

Subwatershed	Area (km^2)	Precip.	ET	Runoff	Recharge	SW Taking	Inflow	Outflow	Flow Yield
Upper Kettle	199	970	608	237	125	-1	-	339	339
Dodd Creek	131	966	602	239	125	0	-	345	345
Lower Kettle	190	970	615	181	174	-2	593	1045	452
Total Area	520	969	609	218	143	-1	-	-	382

Table 3-7: Surface Water Budget (m^3/s) in the Kettle Creek Watershed

Subwatershed	Area (km^2)	Precip.	ET	Runoff	Recharge	SW Taking	Inflow	Outflow	Flow Yield
Upper Kettle	199	6.12	3.84	1.50	0.79	0.00	-	2.14	2.14
Dodd Creek	131	4.02	2.51	1.00	0.52	0.00	-	1.44	1.44
Lower Kettle	190	5.84	3.70	1.09	1.05	-0.01	3.57	6.30	2.72
Total Area	520	15.98	10.05	3.59	2.36	-0.01	-	-	6.30

3.4 Groundwater Water Budget

3.4.1 Groundwater Model

The steady-state groundwater flow model developed for the Long Point Region watershed area, Catfish Creek watershed and Kettle Creek watershed was developed using FEFLOW. The model builds upon earlier work completed by WHI (2003, 2007). The original modelling effort was completed as part of the Norfolk County Groundwater Study (WHI, 2003). The Norfolk County model was extended by WHI (2007) to encompass the Catfish Creek and Kettle Creek watersheds. The groundwater model is a regional flow model encompassing an area of approximately 4000km^2 with 31 subwatersheds. It has six overburden/unconsolidated layers, two bedrock layers and approximately one million nodes.

The mesh designed by WHI (2007) was redesigned to enhance the ability to conform to key features. The horizontal distribution of node points (discretization) was redesigned to incorporate all major river features as well as permitted pumping locations and to conform to all subwatershed boundaries.

The number of vertical layers applied within the current version of the model was also modified from that developed by WHI (2007). The WHI version of the model contained four bedrock layers (1-weathered and 3 un-weathered) that extended more than 500 meres into the underlying bedrock (with ~100 metres overburden). A review of available borehole data and reflection from experienced hydrogeologists suggested that the active, fresh-water portion of the bedrock was limited to the upper 50 metres (Theo Beukeboom, pers. Comm.). As a result, flow through the bedrock layers was simulated using two layers (one weathered and one un-weathered) with a thickness of 5 metres and 50 metres respectively. Overburden layers were not modified from the earlier version. The model was developed to have layers follow a series of hydrostratigraphic units (WHI, 2007). However, a review of this representation as well as the stratigraphic sequences in the area suggests that more work would be needed to explicitly delineate and represent physical hydrostratigraphic units. Consequently, the overburden layers are considered to represent a means of subdividing the unconsolidated sediments, without a direct link to specific stratigraphic units. To compensate for this, properties within each model layer are assigned based on the lithology of the surrounding boreholes.

Recharge estimates were taken from the hydrologic model and applied to the groundwater model to provide a connection between the surface and groundwater numerical models. Streams and rivers within the groundwater model were given specified head values. Stream stage was taken from the available Digital Elevation Model. To determine appropriate lateral boundary conditions for the model, water level trends around the perimeter of the model were carefully reviewed. Where water level trends suggested that natural flow boundaries exist (groundwater divides), a no-flow boundary was applied. In other areas where water level trends indicated cross-boundary flow, fixed water level boundary conditions equivalent to the equipotential heads in those layers were applied. The review process also included evaluation of all cross-boundary flows to ensure that the direction and magnitude of cross-boundary flows was reasonable.

The best available data was used to determine the location, screened interval and pumping rate for wells. Reported “actual” pumping rates were used where available (municipal pumping wells and through surveys). For other permits to take water, the consumptive use estimate for the source was applied. Non-permitted water takings are not represented within the model.

Initial overburden hydraulic conductivity estimates were derived based on borehole lithology records within each model layer, while bedrock values were applied to be consistent with values from previous studies. Initial estimates of hydraulic conductivity were subsequently modified through the model calibration process. Layer thicknesses, however, were not modified during model calibration. As a result, the calibration of the ability of the groundwater system to transmit flow was primarily accomplished by varying hydraulic conductivity.

Observed groundwater levels (head) and groundwater discharge (portion of stream baseflow) were used as calibration targets for the groundwater model. Water levels selected for use in calibration included those with high location reliability and with static water levels observed in the period 1980-onward (2450 well water levels) from the Ministry of the Environment water well information system. Only wells with Ministry of the Environment reliability codes of 5 or better were used. In addition to the water level calibration targets used, baseflow discharge estimates at 15 locations throughout the model domain for the 1980 to 2005 period were also used as calibration targets.

3.4.2 Groundwater Budget

Table 3-8 summarizes the average annual groundwater budget for the Study Area. It is linked to the surface water budget by the recharge rate. Water taken from aquifers, that is not immediately returned to the groundwater system, is approximately 0.06 m^3/s, or 4 millimetres per year. The groundwater model estimates average annual groundwater discharge to surface water features to be 1.27 m^3/s. Additionally, approximately a net flow of 0.05 m^3/s flows into the Study Area from adjacent watersheds, and 1.07 m^3/s flows out of the area to Lake Erie.

Table 3-8: Average Annual Water Budget Summary (Groundwater) in the Kettle Creek Watershed

Water Budget Parameter	Value (m^3/s)	Value (mm/year)
Recharge	2.36	143
Net Flow In Across Watershed Boundaries	0.05	3
Net Flow into Lake Erie	1.07	65
Net Discharge to Surface Water Features	1.27	77
GW Taking	0.06	4

Table 3-9 and **Table 3-10** summarize the water budget components for each of the subwatersheds in millimetres and m^3/s, respectively. The negative values in the ‘GW Taking’ column represents the amount of water taken from an aquifer that is not immediately returned to the source. Negative values in the River Discharge column indicate that flow is leaving the groundwater system to the surface water system.

Any model developed to represent a natural system is inherently a simplification of that system. One of the largest points of uncertainty in the groundwater flow model is in the geologic conceptual model. This uncertainty has led to the definition of numerical model layers that are neither representative of hydrostratigraphic conditions, nor are they uniformly distributed. A lack of borehole logs that penetrate to depth in this area exacerbate the uncertainty associated with the geologic conceptual model and the assigned hydraulic conductivities. Every effort was made to minimize the uncertainty, but results should only be viewed from a regional flow system scale.

Table 3-9: Groundwater Water Budget (mm/yr) in the Kettle Creek Watershed

Subwatershed	Area (km^2)	Recharge	GW Taking	Lake Erie Discharge	Outside watershed	River Discharge	Inter-Basin Transfer	Flow In Ratio
Upper Kettle	199	125	-4	--	-13	-74	-6	-38%
Dodd Creek	131	125	-1	--	0	-57	-17	-53%
Lower Kettle	190	174	-5	-178	16	-94	21	-43%
Total Area	520	143	-4	-65	3	-77	--	--

Table 3-10: Groundwater Water Budget (m^3/yr) in the Kettle Creek Watershed

Subwatershed	Area (km^2)	Recharge	GW Taking	Lake Erie Discharge	Outside watershed	River Discharge	Inter-Basin Transfer	Flow In Ratio
Upper Kettle	199	0.79	-0.02	--	-0.21	-0.46	-0.10	-38%
Dodd Creek	131	0.52	-0.01	--	0.00	-0.24	-0.28	-53%
Lower Kettle	190	1.05	-0.03	-1.07	0.26	-0.57	0.34	-43%
Total Area	520	2.36	-0.06	-1.07	0.05	-1.27	--	--

3.5 Integrated Water Budget

This section presents the integrated water budget for the Kettle Creek Watershed. This integrated water budget considers average annual estimates of key hydrologic parameters relating to both surface water and groundwater resources, and the integration between the two.

Values reported are based on annual averages and may exhibit significant seasonal variation. Due to the regional perspective of this analysis, the subwatershed descriptions may lack local details that may have local hydrologic significance. Local scale interpretation and/or models may provide differing results than those presented here averaged spatially and temporally. **Table 3-11**,**Table 3-12**, **Table 3-13**, **Table 3-14** summarize the water budget components for each of the subwatersheds in mm and m^3/s, respectively. **Table 3-15** describes the components of the water budget.

Table 3-11: Integrated Water Budget (mm/year) in the Kettle Creek Watershed for Surface Water Systems

Subwatershed	Precipitation	ET	Runoff	Recharge	Average Inflow	Average Outflow	Flow Yield	SW Taking
Upper Kettle	970	608	237	125	--	339	339	-1
Dodd Creek	966	602	239	125	--	345	345	0
Lower Kettle	970	615	181	174	593	1045	452	-2
Total Area	969	609	218	143	--	--	382	-1

Table 3-12: Integrated Water Budget (mm/year) in the Kettle Creek Watershed for Groundwater Systems

Subwatershed	GW Taking	Lake Erie Discharge	Outside watershed	Surface Water Discharge	Inter-Basin Transfer	Flow In Ratio
Upper Kettle	-4	--	-13	-74	-6	-38%
Dodd Creek	-1	--	0	-57	-17	-53%
Lower Kettle	-5	-178	16	-94	21	-43%
Total Area	-4	-65	3	-77	--	--

Table 3-13: Integrated Water Budget (m3/s) in the Kettle Creek Watershed for Surface Water Systems

Subwatershed	Precipitation	ET	Runoff	Recharge	Average Inflow	Average Outflow	Flow Yield	SW Taking
Upper Kettle	6.12	3.84	1.50	0.79	--	2.14	2.14	0.00
Dodd Creek	4.02	2.51	1.00	0.52	--	1.44	1.44	0.00
Lower Kettle	5.84	3.70	1.09	1.05	3.57	6.30	2.72	-0.01
Total Area	15.98	10.05	3.59	2.36	--	--	6.30	-0.01

Table 3-14: Integrated Water Budget (m3/s) in the Kettle Creek Watershed for Groundwater Systems

Subwatershed	GW Taking	Lake Erie Discharge	Outside watershed	Surface Water Discharge	Inter-Basin Transfer	Flow In Ratio
Upper Kettle	-0.02	--	-0.21	-0.46	-0.10	-38%
Dodd Creek	-0.01	--	0.00	-0.24	-0.28	-53%
Lower Kettle	-0.03	-1.07	0.26	-0.57	0.34	-43%
Total Area	-0.06	-1.07	0.05	-1.27	--	--

Table 3-15: Summary of Water Budget Components

Parameter	Source	Description
Precipitation	Data Analysis / GAWSER	Climate data used to represent the precipitation over each of the subwatersheds is summarized by GAWSER.
Evapotranspiration	GAWSER	GAWSER estimates actual evapotranspiration for each hydrologic response unit (HRU).
Runoff	GAWSER	When the precipitation exceeds the infiltration capacity of a soil, overland runoff is created.
Recharge	GAWSER	GAWSER estimates the amount of groundwater recharge for each HRU.
Average Inflow	GAWSER	The total streamflow entering the subwatershed from upstream subwatersheds.
Average Outflow	GAWSER	The total average annual streamflow leaving the subwatershed. This includes any upstream inflows to the subwatershed as well as flow generated by the specific subwatershed in question.
Flow Yield	GAWSER	This component quantifies the amount of streamflow increase seen in the particular subwatershed, on an average annual basis. The value is the difference between the average inflow and the average outflow.
Surface Water Taking	Water Use Estimates	The amount of water taken from a surface water source and not immediately returned to that source. Includes estimates from permits as well as rural domestic and permit-exempt agricultural use.
Groundwater Taking	Water Use Estimates	The amount of water taken from an aquifer and not immediately returned to that source. Includes estimates from permits as well as rural domestic and permit-exempt agricultural use.
Lake Erie Discharge	FEFLOW	This component identifies groundwater flow through the boundary of the groundwater flow model at Lake Erie. This is representative of groundwater flux to Lake Erie.
Outside Watershed	FEFLOW	This component identifies groundwater flow through the boundaries of the groundwater flow model, except for Lake Erie. This is representative of groundwater flow out of, or into, the Study Area. Negative flows indicate water leaving the basin, positive flows indication water entering the basin.
Surface Water Discharge	FEFLOW	This parameter quantifies the groundwater flux to rivers and streams in the particular subwatershed. Negative values indicate that flow is leaving the groundwater system to the surface water system

Parameter	Source	Description
Inter-Basin Transfer	FEFLOW	The amount of groundwater flow to another subwatershed within the Study Area. Positive values indicate where the subwatershed is experiencing a net increase of groundwater flow from adjacent subwatersheds. Negative values indicate where the subwatershed is experiencing a net loss of groundwater flow to adjacent subwatersheds.
Flow In Ratio	FEFLOW	This parameter is the ratio of groundwater discharge (river discharge + extractions) to the amount of recharge in a particular subwatershed. Where the value is negative, it indicates a percentage of recharge that is leaving the basin. Where the value is positive, it indicates how much water, with respect to existing recharge, is entering the subwatershed.

3.5.1 Upper Kettle Creek Subwatershed

The Upper Kettle Subwatershed is located in the northeast portion of the Kettle Creek Watershed and is characterized by having predominantly low permeability surficial materials. Port Stanley Till dominates the subwatershed, with few isolated pockets of surficial sand and gravels. The topography is relatively flat. Average annual precipitation for this subwatershed is 970 millimetres which is average for the Kettle Creek Watershed (969 millimetres). Evapotranspiration for this subwatershed is estimated to be approximately 608 millimetres, compared to an average of 609 millimetres. Due to the low permeability surficial materials, the subwatershed generates more surface runoff (237 millimetres) than the area average (218 millimetres), and less groundwater recharge (125 millimetres) than the area average (143 millimetres).

Most overburden aquifers within this subwatershed are confined to pockets of pervious deposits found within the Port Stanley and Tavistock Tills. Singer et al. (2003) also named a “South London Aquifer” that is located within Upper Kettle. This South London Aquifer consists of sand and gravel deposits ranging in thickness from several metres up to 50 metres. The aquifer is confined under till deposits up to 60 metres in thickness. Groundwater discharge, as predicted by the groundwater flow model, is minimal throughout most of this subwatershed. There is a net groundwater loss of approximately 0.44 m^3/s to the West Catfish and Lower Kettle Subwatersheds.

There is minimal water demand in this subwatershed, with only 0.12 m^3/s of groundwater permitted and 0.02 m^3/s of surface water permitted. Including non-permitted agricultural and rural domestic demand, it is estimated that 0.03 m^3/s is pumped on an average annual basis. Of the pumped water, 0.02 m^3/s is not returned to the original source. This subwatershed contains the Belmont municipal system.

3.5.2 Dodd Creek Subwatershed

Dodd Creek is the main tributary to Kettle Creek and is located in the western portion of the Kettle Creek Watershed. The surficial materials of the subwatershed are predominately Port Stanley Till, but do have a slightly higher proportion of granular deposits than the Upper Kettle Subwatershed. The average annual precipitation for Dodd Creek is 966 millimetres, which is slightly lower than the area average precipitation (969 millimetres). Evapotranspiration is estimated to be approximately 602 millimetres, which is lower than the area average of 609 millimetres. Similar to the Upper Kettle subwatershed, the low permeability surficial materials cause higher than average surface runoff (239 millimetres), and lower than average groundwater recharge (125 millimetres).

Aquifers within Dodd Creek are limited to isolated pockets of granular deposits found within the tills. The South London Aquifer, as described for the Upper Kettle Subwatershed, may also extend into the Dodd Creek Subwatershed. Groundwater discharge is minimal throughout most of the Subwatershed; however, pockets of groundwater discharge may occur where watercourses intersect surficial granular deposits.

There is very low water demand within this subwatershed, with 0.02 m^3/s of groundwater permitted, and no surface water permitted. Including the non-permitted takings, the total amount of pumping within the Dodd Creek Subwatershed is estimated to be 0.01 m^3/s; very little pumped water is returned to its original source.

3.5.3 Lower Kettle Creek Subwatershed

The Lower Kettle Subwatershed is the last subwatershed to discharge into Kettle Creek before the creek empties into Lake Erie. The delineated subwatershed area also includes numerous gullies and small tributaries that discharge directly into Lake Erie. The surficial materials within this Subwatershed include a mixture of Port Stanley Till in the northeast, glaciolacustrine deposits in the west, and granular material in the south and southeastern portion. The precipitation for the Lower Kettle Subwatershed is 970 millimetres, which equals the average for the watershed. Evapotranspiration is estimated to be approximately 615 millimetres, which is higher than the area average of 609 millimetres. Due to a higher variability in surficial materials than in the upstream subwatersheds, the Lower Kettle Subwatershed produces less surface runoff (181 millimetres) than upstream areas, and more groundwater recharge (174 millimetres).

Singer et al. (2003) described a significant overburden aquifer located within the Lower Kettle Creek Subwatershed, the South Central Elgin Aquifer, which is located between St. Thomas and Lake Erie. The aquifer is generally less than 10 metres in thickness, but in locations may be more than 25 metres. The aquifer is confined in the northern portions but becomes unconfined towards the south. This Subwatershed receives a large groundwater inflow from upstream subwatersheds (0.60 m^3/s) and the most significant groundwater outflow from the Subwatershed is predicted to occur via Lake Erie. A moderate groundwater discharge (0.57 m^3/s) is estimated to occur in the lower reaches of Kettle Creek as well as into some of the Lake Erie gullies.

Water demand for the Lower Kettle Creek Subwatershed is higher than the Upper Kettle Creek Subwatershed. Approximately 0.12 m^3/s of groundwater is permitted, and 0.02 m^3/s of surface water is permitted. Including all water uses, it is estimated that 0.05 m^3/s is pumped, of which 0.03 m^3/s is not returned to its original source.

3.6 Interactions between Groundwater and Surface Water

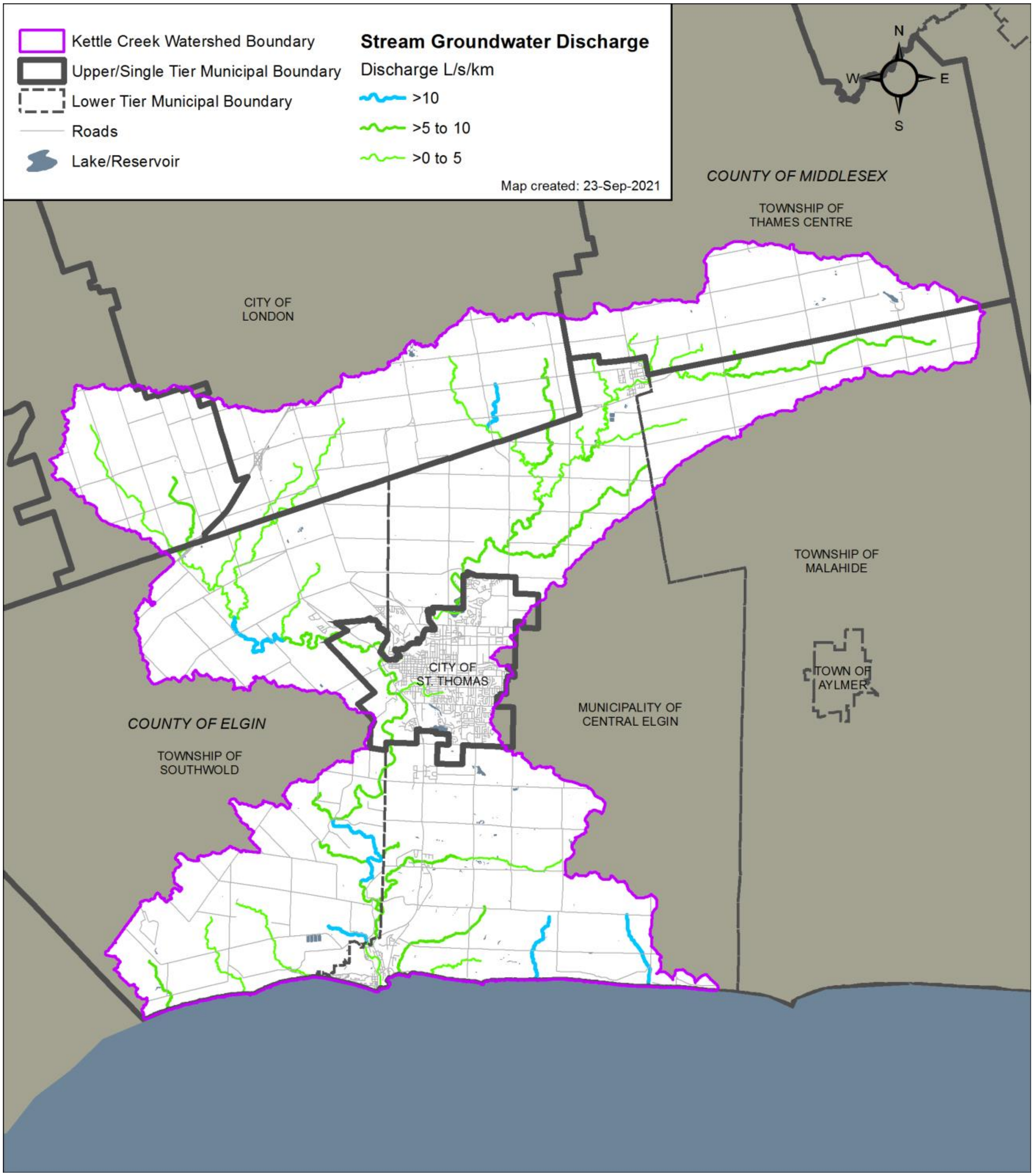
The calibrated groundwater model provides a synthesis of available information that can be used to increase the understanding about the groundwater flow system and its interaction with the surface water system.

Map 3-6 presents the distribution of groundwater discharge flux to the streams and rivers throughout the Study Area. The majority of the stream network in the Kettle Creek watershed has low discharges from groundwater.

The thick fine-grained overburden with low permeability inhibits a large degree of interaction between the groundwater and surface water systems in the Kettle Creek Watershed. Groundwater influences the surface water system in the headwaters of Kettle Creek by feeding Lake Whittaker which in turn produces baseflows for the creek. Beaver Creek in the south travels through sandy deposits and groundwater discharge supports a cool water fishery in this creek.

Inflow from surface water bodies into the groundwater system are not well understood in this area.

Map 3-6 Groundwater Discharge in the Kettle Creek Watershed



3.7 Tier 2 Water Quantity Stress Assessment

All Kettle Creek subwatersheds were evaluated at the Tier 2 level for water quantity potential stress for both groundwater and surface water using the percent water demand calculation given below. Subwatersheds with either a ‘moderate’ or ‘significant’ potential for stress and a municipal drinking water system would then be recommended to have a Tier 3 Water Quantity Risk Assessment conducted.

Being classified as having a Moderate or Significant potential for stress does not necessarily imply that a subwatershed is experiencing local hydrologic or ecologic stress. This classification indicates where additional information is required to understand local water supply sustainability and potential cumulative impacts of water withdrawals.

3.7.1 Surface Water Stress Assessment

For surface water systems, the percent water demand equation is carried out using monthly estimates. The maximum Percent Water Demand for all months is then used to categorize the surface water quantity potential for stress into one of three levels; Significant (>50 percent), Moderate (20 percent to 50 percent) or Low (<20 percent).

3.7.2 Existing Conditions Percent Water Demand

The monthly unit consumptive surface water demand estimates are shown in **Table 3-16** for each subwatershed and were calculated as described in the Water Use Section.

The monthly Qsupply (Median Flow) and Qreserve (90th percentile flow) were calculated using hydrologic model predicted streamflow at the outfall of each subwatershed for the period 1980 to 2004. A longer-term period was not used for averaging as it was felt that the current water demand estimates would not be representative of historical water use. **Table 3-17** shows the supply and reserve terms, in addition to their difference, used in the Stress Assessment equation (Qsupply minus Qreserve).

Monthly Percent Water Demand for surface water is calculated using the Percent Water Demand equation, as well as the values shown in **Table 3-16** and **Table 3-17**.The results of this calculation are included in **Table 3-18.**

The potential for stress classification is determined based on the thresholds presented in **Table 3-19**. The stress classification for each of the three subwatersheds are low for Upper Kettle, Dodd Creek, and Lower Kettle subwatersheds.

Table 3-16: Surface Water Unit Consumptive Demands (L/s) in the Kettle Creek Watershed

Subwatershed	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Upper Kettle	3	3	3	3	3	5	5	5	5	3	3	3
Dodd Creek	1	1	1	1	1	1	1	1	1	1	1	1
Lower Kettle	3	3	3	3	3	31	39	43	35	3	3	3

Table 3-17: Surface Water Supply Flows (L/s) in the Kettle Creek Watershed

Sub-watershed	Term	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Upper Kettle	Qsupply	2,195	2,921	4,290	4,047	2,564	2,213	651	468	537	954	1,888	2,812
Upper Kettle	Qreserve	256	300	373	809	497	73	66	63	60	124	220	207
Upper Kettle	Difference	1,939	2,621	3,918	3,237	2,067	2,139	585	405	477	830	1,668	2,605
Dodd Creek	Qsupply	1,478	2,052	3,156	2,806	1,665	1,428	461	336	370	466	1,168	1,843
Dodd Creek	Qreserve	156	300	491	664	385	125	79	55	40	34	31	73
Dodd Creek	Difference	1,322	1,752	2,666	2,142	1,280	1,303	382	282	330	433	1,137	1,770
Lower Kettle	Qsupply	3,941	3,647	4,799	5,081	4,188	4,019	1,846	1,198	945	1,192	2,085	3,807
Lower Kettle	Qreserve	1,193	1,543	2,259	3,209	2,753	1,331	810	595	507	657	799	841
Lower Kettle	Difference	2,747	2,104	2,540	1,872	1,435	2,687	1,037	603	438	535	1,286	2,966

Table 3-18: Percent Water Demand Estimate (Surface Water) in the Kettle Creek Watershed

Subwatershed	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Max
Upper Kettle	0%	0%	0%	0%	0%	0%	1%	1%	1%	0%	0%	0%	1%
Dodd Creek	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Lower Kettle	0%	0%	0%	0%	0%	1%	4%	7%	8%	0%	0%	0%	8%

Note: Shaded cells have Percent Water Demand greater than the Moderate Stress Threshold (20 percent)

3.7.3 Additional Surface Water Scenarios

There are no planned systems in this study area and as such no evaluation of planned systems was completed.

All three Kettle Creek subwatersheds have a low potential for stress classification and therefore a future water use scenario needs to be applied. As the urban areas within the Kettle Creek Watershed are seen as low-growth, future land use changes are expected to have minimal, to no, impact on average subwatershed water budget parameters. As such, water budget parameters for existing land use conditions were used for the supply and reserve terms.

The Kettle Creek watershed does not have a surface water municipal intake; therefore, evaluation of a drought scenario is not required.

3.7.4 Surface Water Stress Assessment Results

Based on the Percent Water Demand calculations for current and future conditions, and the results of the Drought Scenario, there were no Kettle Creek subwatersheds classified as having a Moderate or Significant potential for stress for stress. The results of the Tier 2 Surface Water Stress Assessment are illustrated on **Map 3-7.**

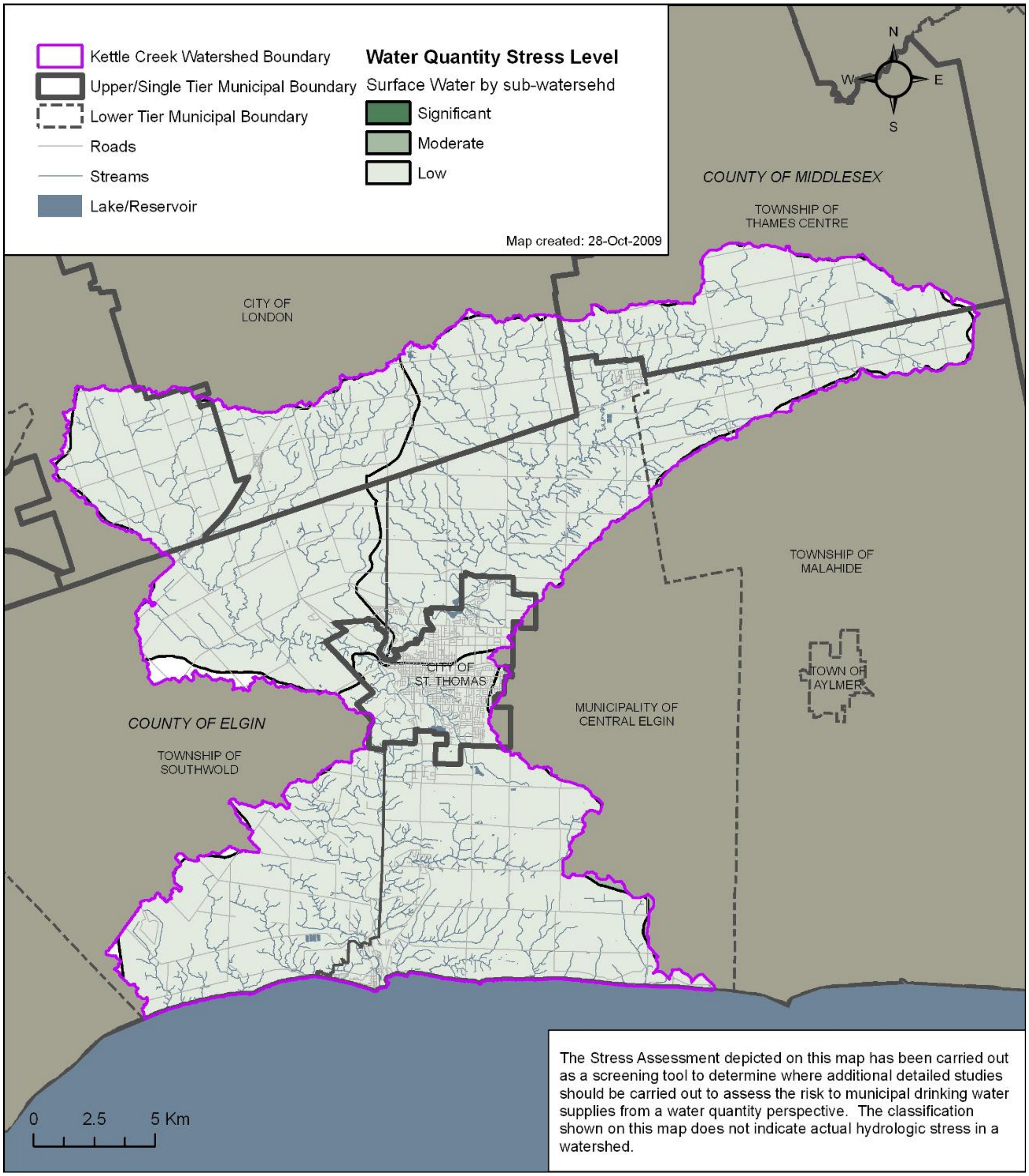
3.7.5 Groundwater Stress Assessment

For groundwater systems, the Stress Assessment calculation is carried out for the average annual demand conditions and for the monthly maximum demand conditions; groundwater supply is considered constant. The stress level for groundwater systems is categorized into three levels (Significant, Moderate or Low) according to the thresholds listed in **Table 3-19**.

Table 3-19: Groundwater Potential Stress Thresholds

Groundwater Potential Stress Level Assignment	Average Annual	Monthly Maximum
Significant	> 25%	> 50%
Moderate	> 10%	> 25%
Low	0 to 10%	0 to 25%

Map 3-7: Water Quantity Stress Levels by Surface Water Sub-watershed in the Kettle Creek Watershed



3.7.6 Existing Conditions Percent Water Demand

Table 3-20 contains the monthly estimates of unit consumptive groundwater demands calculated for each subwatershed. The average and maximum monthly demands are shown in the table; they are used to estimate subwatershed potential stress in the groundwater stress assessment.

Groundwater supply is calculated as the sum of the average annual recharge and the total amount of groundwater flowing laterally into each subwatershed. The groundwater Flow In for each subwatershed is calculated from the model results as the sum of all positive flow vectors into each area. Groundwater reserve is calculated as 10 percent of the estimated groundwater discharge to surface water streams in each subwatershed. The groundwater reserve for each subwatershed is given in **Table 3-21.**

The results of the Groundwater Stress Assessment are shown in **Table 3-21**. The estimated potential for hydrologic stress for the Upper Kettle, Dodd Creek, and Lower Kettle subwatershed are low. Upper Kettle subwatershed contains the Belmont groundwater system. The other subwatersheds do not have a groundwater system.

There are no planned systems in this study area and as such no evaluation of planned systems was completed.

Table 3-20: Groundwater Unit Consumptive Demands (L/s) in the Kettle Creek Watershed

Subwatershed	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg	Max
Upper Kettle	12	12	12	12	13	39	40	37	37	12	11	10	21	40
Dodd Creek	2	2	2	2	2	3	4	5	4	2	2	2	2	5
Lower Kettle	5	5	5	5	5	35	46	50	36	5	5	5	17	50

Table 3-21: Groundwater Stress Assessment in the Kettle Creek Watershed

Subwatershed	Supply and Demand (L/s) GW Flow In	Supply and Demand (L/s) Groundwater Recharge	Supply and Demand (L/s) Groundwater Reserve	Supply and Demand (L/s) Average Demand	Supply and Demand (L/s) Maximum Demand	% Water Demand Average Water Demand	% Water Demand Maximum Water Demand
Upper Kettle	0	789	46	21	40	3%	5%
Dodd Creek	45	520	25	2	5	0%	1%
Lower Kettle	298	1051	55	17	50	1%	4%

3.7.7 Future Conditions Percent Water Demand

The Percent Water Demand was also calculated using future demand estimates. Future demand only accounts for projected increases in municipal demand. All other non-municipal water demand was assumed to be equal to current demand. Since the urban areas within the Study Area were seen as areas of low-growth, future land use changes were expected to have minimal, to no, impact on average subwatershed water budget parameters. Therefore, water budget parameters for existing land use conditions were used for the supply and reserve terms.

Municipal future water demand was estimated by applying future population estimates to current average daily per capita water use, for each municipal water system. Future population is based on municipal official plans current to 2006, while current water use data was collected from water system owners and operators. All future water demand is projected to 2031. Further explanation of future water demand calculations is given in the Status Report on Municipal Long Term Water Supply Strategies (Shifflett, 2007). The only municipal water system is the community of Belmont. The estimated average day increase in groundwater demand was calculated to be 189 m^3/d or 2 L/s.

Groundwater supply and reserve remained unchanged for the Groundwater Stress Assessment estimated for future conditions. Future average monthly demand and maximum monthly demand were estimated by summing the demands under current conditions with the additional average increase in demand for future conditions. The results of the Percent Groundwater Demand under future conditions are presented in **Table 3-22**.

No subwatersheds were classified as having a potential for stress relating to groundwater takings equal to Moderate or Significant, under existing and future conditions.

Table 3-22: Groundwater Stress Assessment Components with Future Demand Estimates in the Kettle Creek Watershed

Subwatershed	Supply and Demand (L/s) GW Flow In	Supply and Demand (L/s) Groundwater Recharge	Supply and Demand (L/s) Groundwater Reserve	Supply and Demand (L/s) Average Demand	Supply and Demand (L/s) Maximum Demand	% Water Demand Average Water Demand	% Water Demand Maximum Water Demand
Upper Kettle	0	789	46	23	42	3%	6%
Dodd Creek	45	520	25	2	5	0%	1%
Lower Kettle	298	1051	55	17	50	1%	4%

3.7.8 Drought Scenario

Both a two year and a ten-year drought scenario were considered. These scenarios are designed to capture probable periods of drought conditions; both short- and long-term duration droughts. With the surface water simulation producing groundwater recharge estimates for the 1960 to 2004 time period, the impacts of any drought within this time period can be assessed.

The 1960's represent a recorded period of low precipitation, for which estimated recharge is available from the hydrologic model simulations. Since this information is readily available, the two-year and ten-year scenarios were evaluated during the same simulation for this Stress Assessment. Information relating to the planned pumping rates for municipal wells was not available and therefore the drought assessment is only carried out for existing pumping rates.

The maximum drawdown resulting from the drought scenario for the two Belmont municipal wells in the Kettle Creek watershed are 0.26 metres and 0.43 metres below the initial water level in Well 1 and Well 2, respectively. These results are based on a regional groundwater flow model that is not calibrated to the local scale of individual well fields.

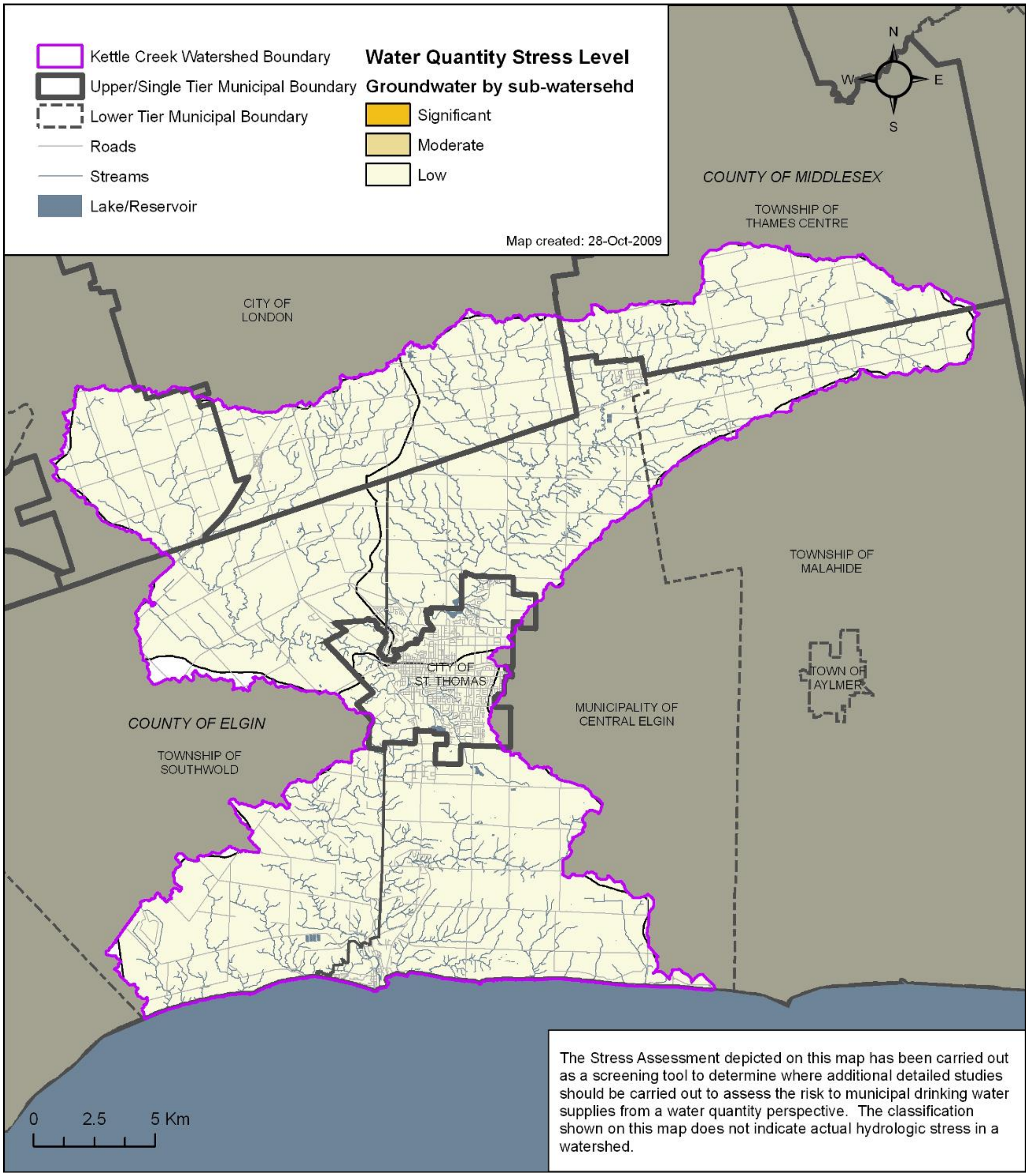
It is assumed that all municipal wells would be constructed with an available drawdown of approximately 5 metres. As both municipal wells are shown to have a maximum drawdown less than this threshold it is unlikely that there are instances of a municipal well being unable to pump water due to drought impacts. Therefore, no subwatersheds will be classified as having a moderate potential for stress based on the drought scenario.

3.7.9 Groundwater Stress Assessment Results

Based on the Percent Water Demand calculations for current and future demand conditions, and the results of the Drought Scenario, the groundwater stress classifications are low for the Upper Kettle, Dodd Creek, and Lower Kettle subwatersheds.

Since the Upper Kettle subwatershed was not classified as having a Moderate or Significant potential for stress under either demand condition, the Belmont municipal water supply does not require a Tier 3 Water Quantity Risk Assessment. **Map 3-8** shows that there are no Kettle Creek subwatersheds requiring further stress assessment review.

Map 3-8: Water Quantity Stress Levels by Groundwater Sub-watershed in the Kettle Creek Watershed



3.8 Uncertainty / Limitations

All water budget calculations contain inherent uncertainty due to incomplete data, data inaccuracies, and imperfect estimation and simulation tools. Many of the sources of uncertainty have been documented throughout the Water Budget sections. It is important to consider the regional-scale nature of the analysis and interpretation presented. The methods used and the amount of data available were suitable for regional water budgeting purposes.

Any model developed to represent a natural system is inherently a simplification of that natural system. Part of the reason for this is that the complexities of the physical system can never be known well enough to incorporate all details into a numerical context. In reality, most of the scientific approach involves representing physical conditions observed using approximations of larger-scale functionality; hydraulic conductivity is an example of this. This approximation does not negate the ability of scientists and practitioners to utilize numerical models as tools to help understand and manage natural systems; however, there is a need to recognize the limitations of such tools when interpreting model results.

Every effort was made to minimize uncertainty in the Water Quantity Risk Assessment: data was cross checked with additional sources, models were calibrated to the highest quality of monitoring data available, and an external peer review team was consulted.

3.9 Tier 2 Water Budget and Water Quantity Stress Assessment Peer Review

In October 2006, Lake Erie Region Source Protection Region staff developed a Terms of Reference (TofR) to guide the peer review process for the Long Point Region, Catfish Creek and Kettle Creek Tier 2 Water Budget and Water Quantity Stress Assessment. A peer review committee was established early in the water budget development process and was involved frequently throughout the water budget and water quantity stress assessment studies from terms of reference development through to finalization of the reports. The TofR was developed in accordance with the provincial guidance document, entitled *Peer Review Water Budget Interim Direction*, *Version 2.0 (DRAFT)* (dated August 9, 2005). The Peer Review Committee consisted of the following external reviewers:

- Dr. Dave Rudolph, University of Waterloo
- Dr. Hugh Whiteley, University of Guelph
- Dr. Rob Schincariol, University of Western Ontario
- Chris Neville, S.S. Papadopulos and Associates
- John Warbick, Ministry of Agriculture & Rural Affairs (intermittent)

The preparation of the Water Budget and Water Quantity Stress Assessment was broken into two phases. Phase 1 involved the collection of background information for the preparation of a Draft Interim Report in November 2007 for peer review. Although the report was initially signed-off by the Peer Review Committee in March 2008 as the Interim Water Budget Report, the report was revised and posted in April 2009 using new information and a revised modelling approach applied in Phase 2.

Phase 2 of the Water Budget and Water Quantity Stress Assessment involved the completion of existing, future and drought scenarios and the identification of significant groundwater recharge areas (SGRAs) in accordance with the Source Protection Technical Rules (MOE, 2009a). The removal of vulnerability scoring from SGRAs was completed due to updates to the Technical Rules (MOECC, 2017). The report was revised and ultimately posted in August 2009 based upon final Peer Reviewer input and sign-off. A summary report of the peer review process (Etienne, 2009), including materials used by the Peer Reviewers along with their comments was also posted in August 2009.

3.9.1 Water Budget Peer Review

The Peer Review Committee, which was assembled in March 2007, was invited to comment on the TofR for the project. Upon selection of the consultant for the preparation of the Water Budget report, a kick off meeting was held on May 31, 2007. At this meeting the team considered the uncertainty of the geological conceptual model based on the paucity of deep bedrock data within the study area. It was agreed that the consultant could develop a calibrated model within an acceptable level of confidence for the peer reviewers using the available data and appropriate assumptions.

The Peer Review Committee reconvened in September 2007 to review the initial findings of the consultant and to advise the consultant on their modelling approach. New information gathered from the Ontario Geological Survey (OGS) generated some concerns about the conceptual model, forcing the consultant to rethink some of their initial assumptions. In addition, the consultant identified the significant amount of calibration required to balance potential irrigation demand with observed summer baseflows. As a result of these significant uncertainties, the consultant requested an additional month to conduct groundwater sensitivity runs in the FEFLOW model and to fine tune the irrigation assumptions in the GAWSER model.

The draft Water Budget report was circulated for peer review in November 2007 and the committee met to receive a presentation of the report on November 22, 2007. The Peer Reviewers were asked to submit their initial comments and questions for discussion at a subsequent meeting on December 17, 2007. A comment matrix was prepared and circulated to the peer review team prior to the December 17th meeting. The written comments in the matrix were discussed at this meeting, and responses (leading to actions) were added to the matrix which directed the consultant’s revisions to the draft report.

In January of 2008, the consultant took the consolidated comments from the matrix and developed a strategy for revising the Integrated Water Budget Report. One of the main points raised by the Peer Reviewers throughout Phase 1 was the need clarify the certainty in the modelling. The revised Integrated Water Budget Report was delivered in

March 2008 and circulated to the Peer Reviewers for another round of document review during which the team compared the revisions to their comments in the matrix. The comments received indicated that it would be appropriate for the consultant to proceed with the next phase of work on the Water Quantity Stress Assessment.

3.9.2 Water Quantity Stress Assessment Peer Review

The Peer Review Committee reconvened in March 2009 to review the draft Water Quantity Stress Assessment report. The committee met to receive a presentation of the report on March 19, 2009. By this time, the consultant had revisited the FEFLOW and GAWSER models developed in Phase 1 to address a number of the uncertainties raised by the Peer Review Committee. New water use data and revised models were used to bring the Integrated Water Budget report up to date for posting in April 2009.

The Peer Reviewers were asked to submit their initial comments and questions for discussion at a subsequent teleconference on April 7, 2009. As was the case in Phase 1, a comment matrix was prepared and circulated to the team prior to the conference call. The written comments in the matrix were discussed at the teleconference, and responses (leading to actions) were added to the matrix which directed the consultant's revisions to the draft report.

As another part of the review process, the consultant solicited specific comments from the Peer Reviewers on the preferred approach to SGRA delineation as required by the Technical Rules (MOE, 2009a). The final document was subsequently circulated to the Peer Reviewers for another round of document review during which the team compared the revisions to their comments in the matrix. The Peer Reviewer sign-off correspondence received indicates that the Tier 2 Integrated Water Budget and Water Quantity Stress Assessment reports are scientifically defensible and satisfy the provincial guidelines for water budget documents. For the most part, the Peer Reviewers were satisfied that their comments had been received and addressed in a professional manner by the consultant. As a result, the documents provide clear direction for further municipal Tier 3 Water Quantity Risk Assessments

In August 2009, the Peer Review of the Kettle Creek Tier 2 Integrated Water Budget and Water Quantity Stress Assessment was considered substantially complete and all reports were posted on the Lake Erie Region Source Protection website.

The removal of vulnerability scoring from SGRAs was completed due to updates to the Technical Rules (MOECC, 2017).

3.10 Section Summary

- A Water Budget is an understanding and accounting of the movement of water and the uses of water over time, on, through and below the surface of the earth. The Water Quantity Stress Assessment was undertaken at a Tier 2 level. Methods used and amount of data available were suitable for regional water budgeting purposes.

- The Belmont groundwater wells are the only municipal water taking included in the water quantity stress assessment.

- Water budget components were aggregated to the subwatershed and watershed scale. Surface water components of the water budget were determined using a continuous numerical hydrologic model, while the groundwater components of the water budget were determined using a steady-state numerical groundwater flow model. Water taking components were estimated based on surveys, modelling, and water use inventories.

- Recharge estimates were taken from the hydrologic model and applied to the groundwater model to provide a connection between the surface and groundwater numerical models.

- Upper Kettle and Dodd Creek subwatersheds have high surface runoff and low groundwater recharge. There is low groundwater discharge to surface water and low water use in these subwatersheds. The Lower Kettle subwatershed has moderate runoff and recharge. There is a large amount of groundwater inflow to the subwatershed and outflow to Lake Erie. There are moderate amounts of groundwater discharge to surface water and water use in this subwatershed is also moderate.

- The Groundwater and Surface Water Subwatershed Stress Assessment classified all three subwatersheds as having low potential for stress under existing, future and drought scenarios.

- No municipal systems require a Tier 3 Stress Assessment in the Kettle Creek Watershed.

4.0 WATER QUALITY RISK ASSESSMENT

4.1 Intrinsic Groundwater Vulnerability in Kettle Creek Watershed

Numerous approaches are available to estimate groundwater vulnerability (i.e., Intrinsic Susceptibility Index (ISI), Aquifer Vulnerability Index (AVI), Surface to Well Advective Time (SWAT), Surface to Aquifer Advective Time (SAAT)). For the Kettle Creek Watershed, the SAAT model was chosen to estimate aquifer vulnerability. This is one of the approved methods under the *Clean Water Act,* 2006 Technical Rules.

Aquifer vulnerability mapping using the SAAT method was completed by Earthfx (2008) and is shown on **Map 4-1**. Areas of high and medium vulnerability across the southern extents of the watershed generally correspond to the shallow unconfined aquifer of the Norfolk Sand Plain. The northern extents of the watershed have been predominantly mapped as low vulnerability. This area is generally comprised of the clay-rich Port Stanley Till, which provides protection to the deeper, confined overburden aquifers.

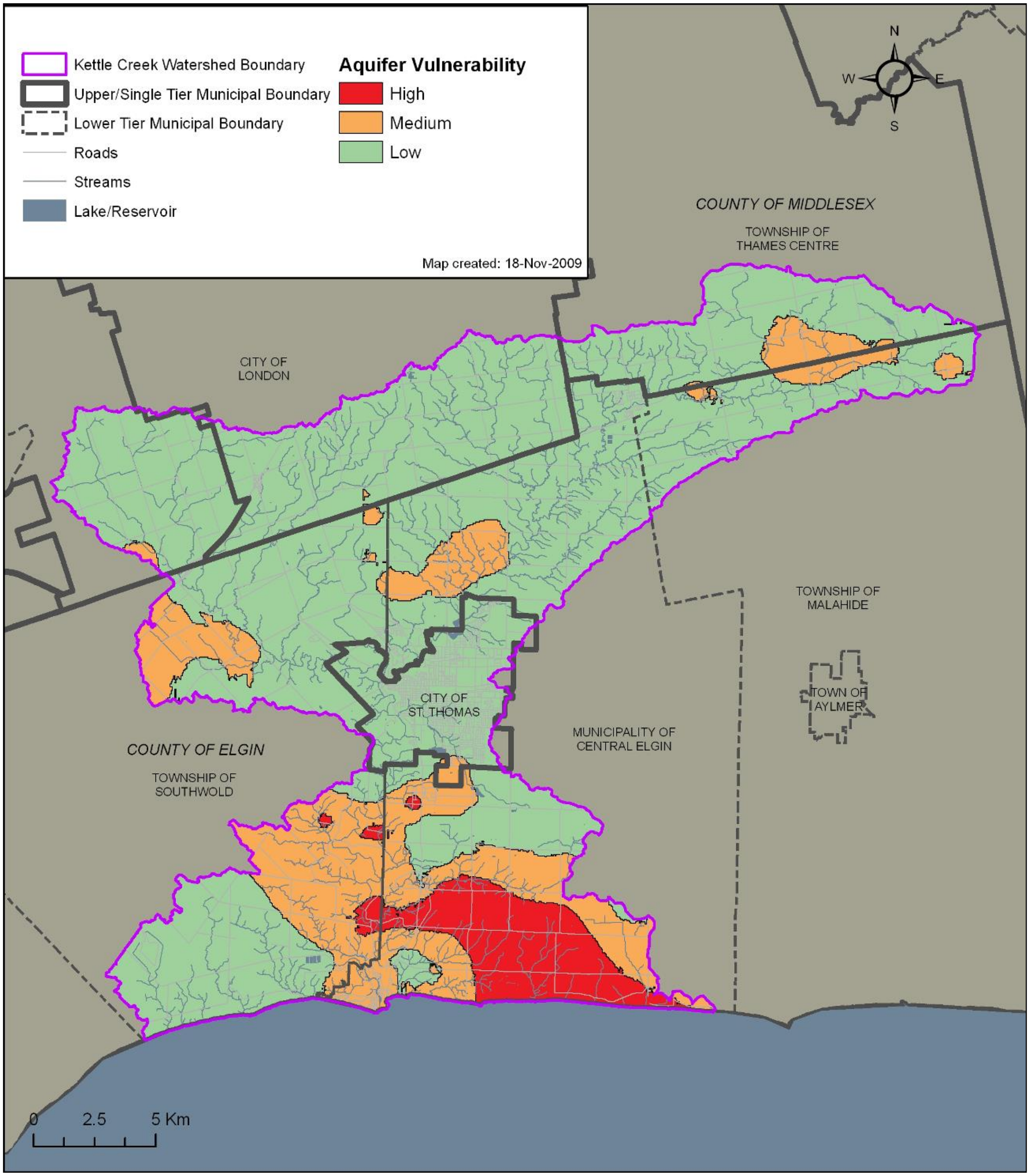
Intrinsic Groundwater Vulnerability Methodology

The basis for the vulnerability calculation was the MECP's Water Well Information System (WWIS). However, the base database was built upon by adding information from the Ministry of Transportation's GEOCRES database. Data were also improved using the following methods:

- Location Quality Assurance (QA) Update: Much of the pre-2004 data in the Lake Erie Source Protection Region database had location information that was processed and corrected by the MNR. More recent information, made available by the MOE in August 2006, did not include the MNR location assessment and corrections and, instead, relied on an older location classification system. The different QA classification codes were reconciled, and a consistent classification system was developed.

- Assigning Digital Elevation Model elevations to all boreholes: Consistent surface elevations are required for assessing aquifer geometry, water table and potentials in the deeper aquifers. The latest DEM elevation (MNR Version 2.0 DEM) was assigned to the surface recorded for each borehole. All elevation related information, including well construction, geology and water level data was then corrected to the new reference elevation. Boreholes with ground elevations based on engineering surveys (QA code 1) were assumed to have better elevation data than the DEM and were not assigned the DEM elevation. Selection of High Quality Wells: Wells with an integrated QA code of less than 6 were considered to be of "high quality" and were used in the vulnerability calculations.

Map 4-1: Aquifer Vulnerability in the Kettle Creek Watershed



- Update Bedrock Flags: Shallow bedrock wells are handled specially. Although the number and extent of these wells is limited, they are important in some areas. The bedrock flag code in the database was checked against the bedrock lithology material codes for consistency. Other internal consistency checks were also performed to confirm the selection of these wells.

- Update well screen classifications: Correct well screen data is important for identifying the target aquifer. Many wells in the MECP WWIS database have missing or incomplete information on well construction and do not have a well screen zone defined. A series of procedures and QA checks were made to assign screen zones to those wells.

The SAAT method estimates aquifer vulnerability in units of time. The travel time has two components: unsaturated zone advective time (UZAT) and the water table to aquifer advective time (WAAT).

The input parameters and data sources for each parameter for the UZAT and WAAT calculations are listed below:

For the unsaturated zone advective time (UZAT) calculation, the following inputs are required:

- Depth to water table; computed by subtracting the interpolated water table surface from the land surface digital elevation model (MNR Version 2.0 DEM),

- Mobile moisture content; assigned to each geologic material based on specific yield values obtained from Todd (1980), and

- Infiltration rate; assumed to be equal to recharge rates developed by Schroeter & Associates (2006).

The water table to aquifer advective time (WAAT) calculation required the following inputs:

- Aquifer porosity; estimated for each geological material from Todd (1980),

- Thickness of the geologic layer; calculated from the borehole logs, and

- Vertical hydraulic conductivity; estimated based on the geologic materials listed in the borehole logs.

Estimated depth to water table was computed by subtracting the interpolated water table surface from land surface elevation. The mobile moisture content of the surface material was used as a surrogate for the average moisture content of the soil under steady-state drainage at the infiltration rate. The value of average moisture content under steady-state drainage should lie somewhere between field capacity and porosity for the particular soil. It was felt that the mobile moisture content in the unsaturated zone was more likely to be related to the drainable porosity than to field capacity.

Accordingly estimates of mobile moisture content were assigned to each geologic material based on representative specific yield and porosity values obtained from Table 2.5 in Todd (1980).

It was assumed that the infiltration rate was equal to the recharge rate determined from maps developed by Schroeter & Associates (2006a, 2006b, 20006c) using the GAWSER model.

If multiple layers of different types of unsaturated materials were present, the travel time through each layer was calculated and then summed over the total depth to get a total travel time.

Finally, the Technical Rules (MECP, 2021) indicate SAAT values are translated into aquifer vulnerability categories according to the following thresholds:

- < 5 year vulnerability of high
- ≥ 5 years, < 25 years vulnerability of medium
- ≥ 25 years vulnerability of low

Peer Review of Aquifer Vulnerability

The Earthfx (2008) SAAT report was peer reviewed by Chris Neville of S.S. Papadopulos. The review found the Earthfx (2008) report to be in compliance with the *Clean Water Act*, 2006 Technical Rules, and concluded the evaluation to be an excellent report with the analyses conducted at a high level of expertise. A number of detailed comments were provided for the report however, these were provided as additional commentary and did not point to any particular flaws in the assessment.

Given that the peer review comments would not change the overall outcome of the Earthfx (2008) study, no changes were made to the report following the review.

Limitations and Uncertainty

Although numerous steps were taken to exclude WWIS data of lower reliability, the uncertainty associated with several of the components of the WWIS (location accuracy, reliability of geologic log, measurement of water level, etc.) represent a significant limitation in the assessment. There is also natural variability in the hydraulic conductivity which is not captured in the analysis.

However, given that the vulnerability analysis used the most current methods (under the *Clean Water Act*, 2006 Technical Rules) and data available, the uncertainty rating at this time can be considered low.

4.2 Highly Vulnerable Aquifers

Areas calculated as being of high vulnerability are considered Highly-Vulnerable Aquifers (HVAs). Highly Vulnerable Aquifer areas in Kettle Creek Watershed are identified as the red areas on **Map 4-2.**

4.2.1 Vulnerability Scoring in Highly Vulnerable Aquifers

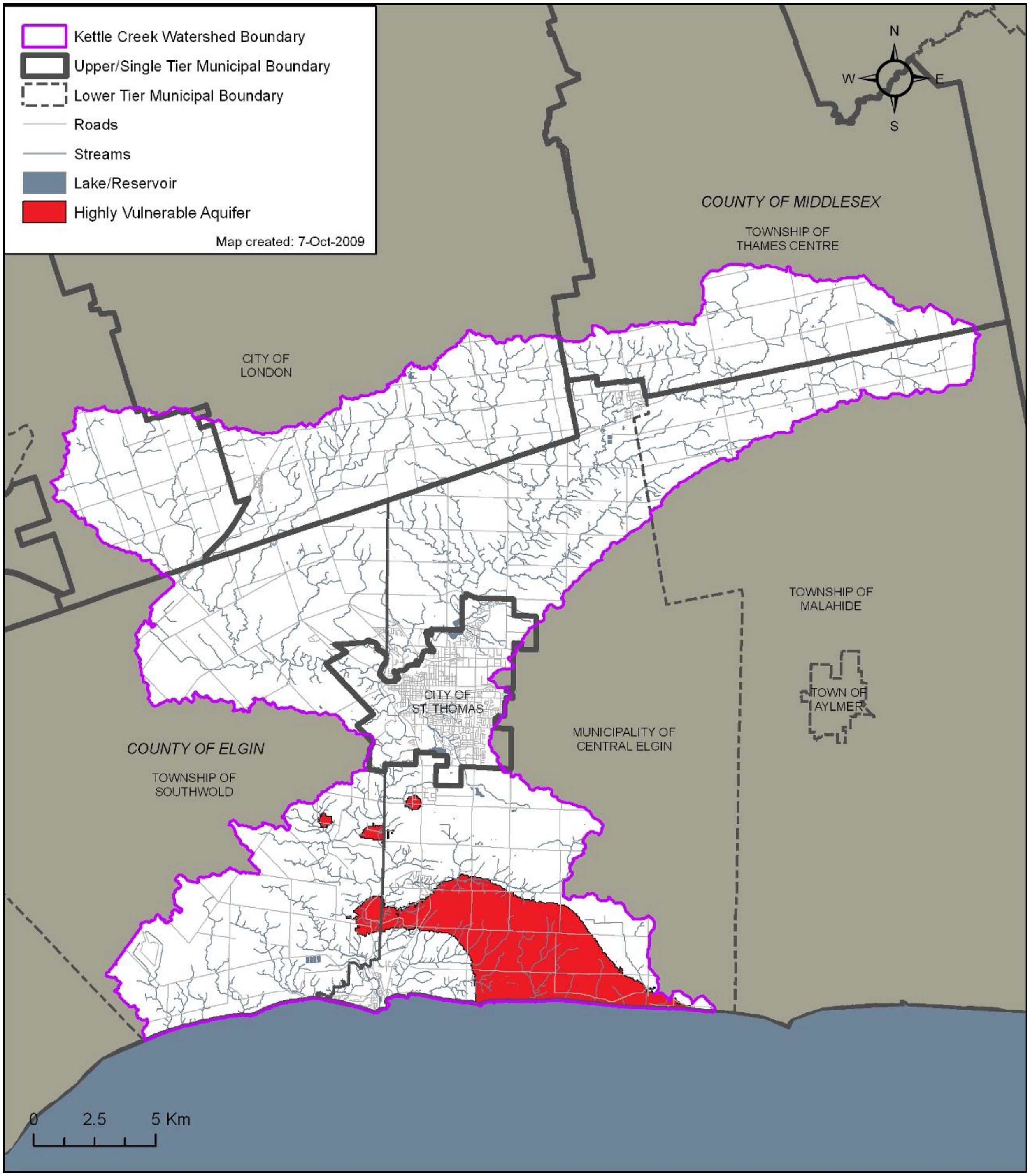
According to the Technical Rules, highly vulnerable aquifer areas outside of the Wellhead Protection Areas are assigned a vulnerability score of 6. The highly vulnerable aquifer areas illustrated on **Map 4-2**, therefore, receive a vulnerability score of 6.

4.2.2 Managed Lands and Livestock Density in Highly Vulnerable Aquifers

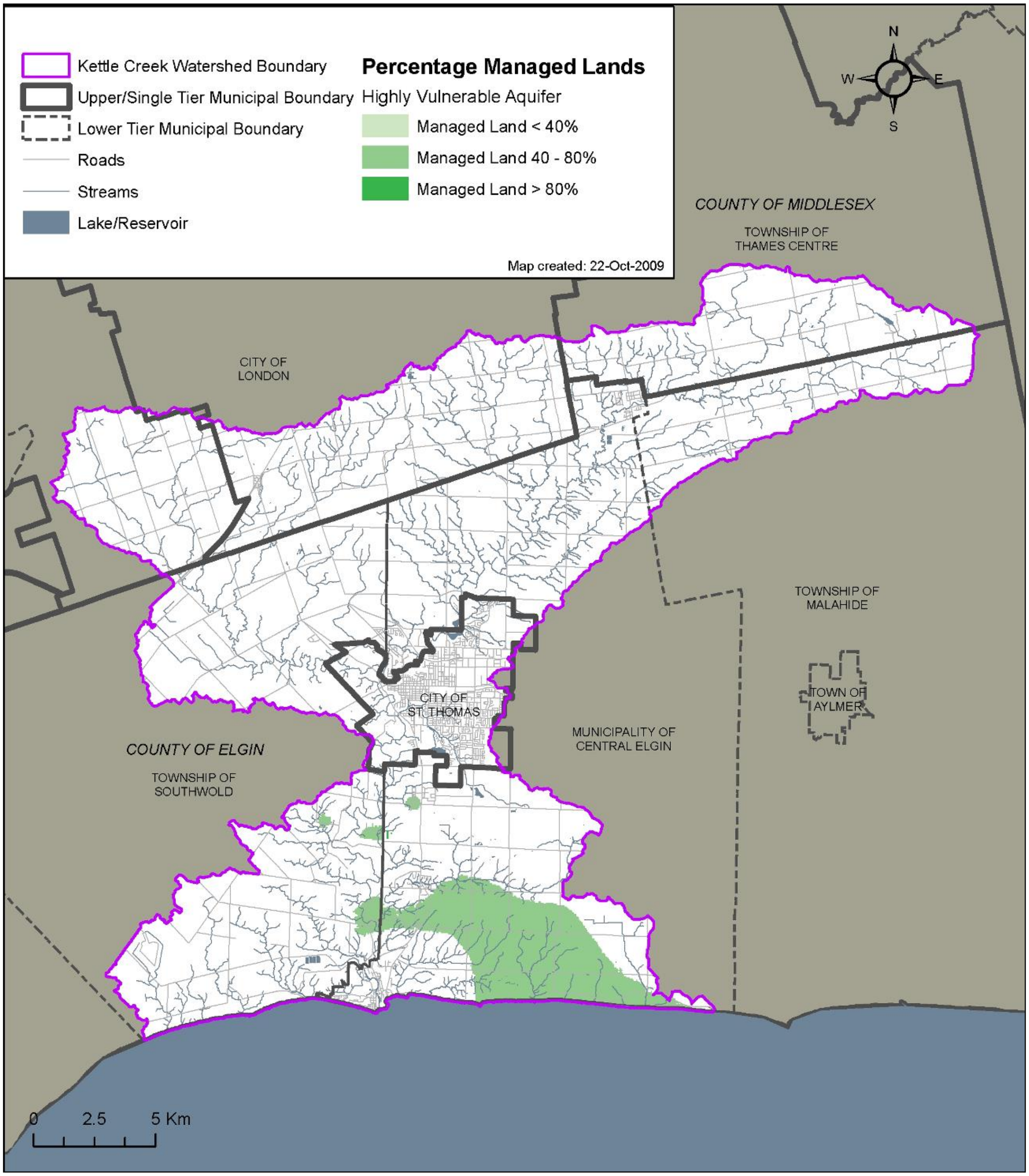
This section provides a description of the results of calculations of the percent managed lands and the livestock density within Highly Vulnerable Aquifer (HVA) areas. **Map 4-3** and **Map 4-4** show that in the highly vulnerable aquifer areas in the Kettle Creek watershed, the managed lands percentage is between 40 and 80 percent (moderate); while the majority of livestock density is less than 0.5 nutrient units per acre (low). A very small area located southwest of St. Thomas has a livestock density of greater than 1.0 nutrient units per acre.

The methods to calculate the managed lands and livestock density calculations follow the Technical Bulletin entitled "Proposed Methodology for Calculating Percentage of Managed Lands and Livestock Density for Land Application of Agricultural Source of Material, Non-Agricultural Source of Material and Commercial Fertilizers" issued by the Ministry of the Environment in September 2009.

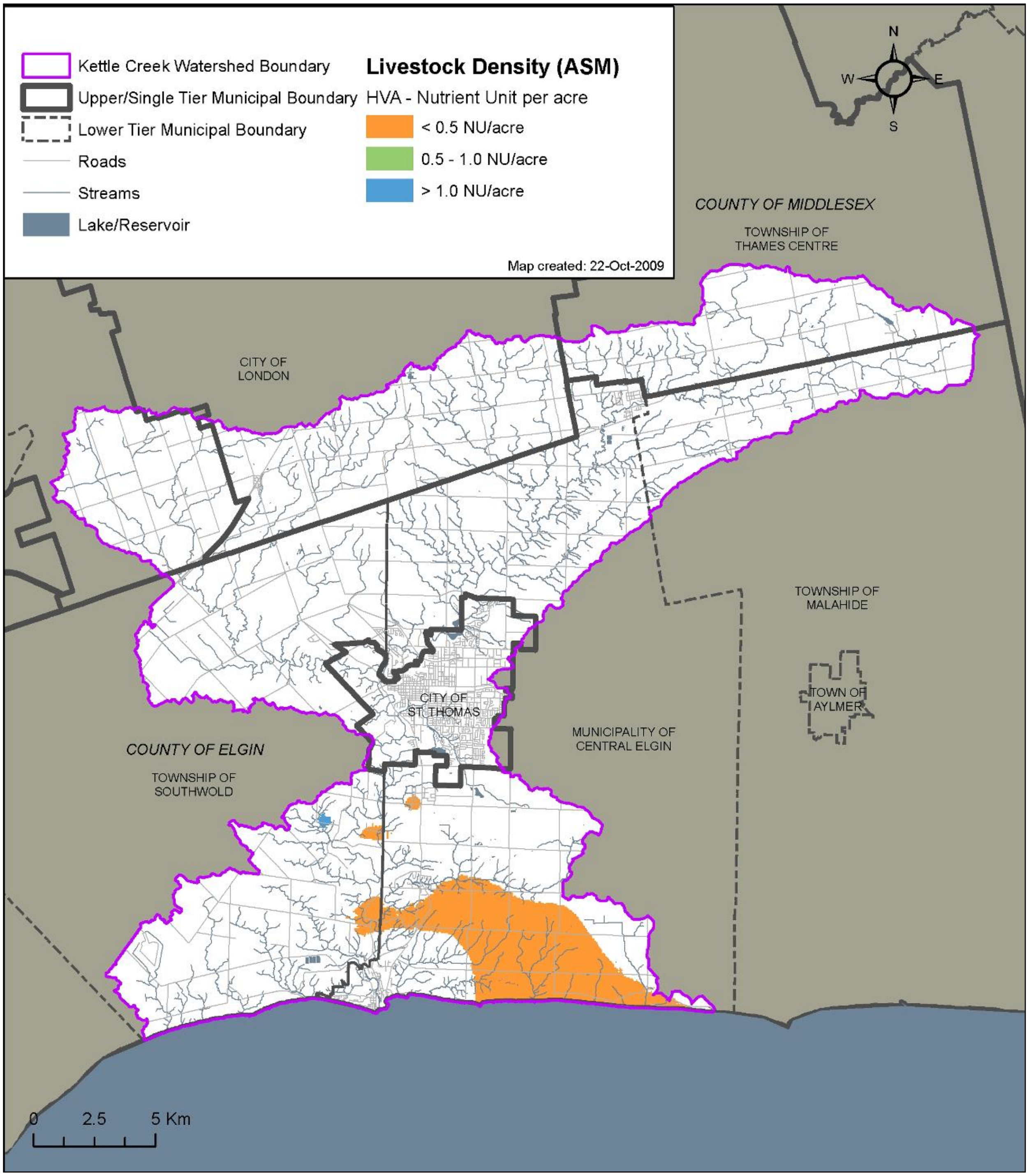
Map 4-2: Highly Vulnerable Aquifers in the Kettle Creek Watershed



Map 4-3: Percent Managed Lands in Highly Vulnerable Aquifers in the Kettle Creek Watershed



Map 4-4: Livestock Density in Highly Vulnerable Aquifers in the Kettle Creek Watershed



Managed Lands Area Methodology

Managed lands are divided into two “categories”: agricultural managed lands and non-agricultural managed lands (NAML). Agricultural managed land includes cropland, fallow and improved pasture land that may receive agricultural source material (ASM). Non-agricultural managed lands include golf courses, residential lawns and other turf that may receive commercial fertilizer or non-agricultural source material (NASM).

Land use classifications for land area are based on data from the Municipal Property Assessment Corporation (MPAC), who provide a parcel layer in GIS format (see **Table 4-2** for description). Each parcel has a code describing the main land cover classification, including codes for agricultural land, residential, commercial and industrial land. All MPAC farm codes (3-digit numbers starting with 2) were considered in the agricultural managed lands calculation if they were within or partially within the HVA areas. All other categories were considered in the non-agricultural category to determine the amount of non-agricultural managed lands if they intersected the highly vulnerable aquifer areas.

In some cases, additional classification was required where the MPAC data layer did not provide enough information on which to determine the land use on a parcel of land. Using 2006 ortho-photo (see **Table 4-3** for description), air photo interpretation was used to determine whether a parcel of land should be classified as agricultural or non-agricultural. If possible, air photos were used to determine the type of agricultural or non-agricultural activity on a parcel of land. In the calculation of managed lands, areas of wetlands, impervious areas, wooded areas, water bodies and aggregate license areas were removed from consideration. The calculations for agricultural managed lands and non-agricultural managed lands are described below. The non-agricultural managed lands and agricultural managed lands areas will be added together and divided by all the parcel areas that intersect the highly vulnerable aquifer areas to get a percent managed land value.

Agricultural Management Land Calculation

All parcels of land classified as agricultural within or touching the highly vulnerable aquifer were used in the calculation of agricultural managed lands. To account for buildings and other areas that do not receive nutrients, all farms were given a managed lands ratio of 0.9, meaning that it was estimated that 90 percent of the total area of farmland is applied with agricultural source material.

For each separate (discontinuous) unit of Highly Vulnerable Aquifer, the area of agricultural managed land within or touching the HVA was summed. Where a parcel of land fell only partially within a highly vulnerable aquifer area, the entire parcel area was included in the calculation. This area was then added to the area within the highly vulnerable aquifer classified as non-agricultural managed lands to get the total percent managed land in each highly vulnerable aquifer area.

Non-Agricultural Managed Land Calculation

All parcels within or touching the HVA areas that had a non-agricultural MPAC code or were classified as non-agricultural using air photo interpretation, were used in the calculation of non-agricultural managed lands. To account for buildings and other areas that do not receive nutrients, all parcels were given a managed lands ratio as seen in **Table 4-1**.

The non-residential values in **Table 4-1** were generated through air photo interpretation. Areas that were deemed to be managed lands in each category were compared to the rest of the area within the parcel to determine an appropriate ratio. The average value for each parcel estimated in each category was rounded to the nearest 5 percent to give an overall managed land ratio.

The managed land ratio for residential areas is based on estimates used the City of Kitchener Alder Creek Subwatershed Study. The percentage of pervious cover used in this study provides a good estimate of the area that may receive commercial fertilizer on residential properties.

Table 4-1: Managed Land Ratios for Land Use Categories

Major Category	Specific Category	Managed Land Ratio
Farm	all types of farms	0.9
Golf Course	Driving range/golf centre - stand alone, not part of a regulation golf course	0.6
Golf Course	Golf course	0.95
Institutional	Non-school, i.e., hospitals	0.6
Institutional	School (elementary or secondary, including private)	0.65
Open Space	Residential development land	0.55
Open Space	Vacant land condominium (residential)-defined land that's described by a condominium plan	0.55
Other	Cemetery	1
Other	Large office building (generally multi - tenanted, over 7,500 square feet)	0.45
Other	Local government airport	0.9
Other	Place of worship - with a clergy residence	0.55
Other	Place of Worship - without a clergy residence	0.55
Other	Private airport/hangar	0.65
Other	Property in process of redevelopment utilizing existing structure(s)	0.55
Recreational	Amusement park	0.5
Recreational	Commercial sport complex	0.45
Recreational	Exhibition grounds/fair grounds	0.7
Recreational	Municipal park (excludes Provincial parks, Federal parks, campgrounds)	0.65
Recreational	Non-commercial sports complex	0.5

Major Category	Specific Category	Managed Land Ratio
Recreational	Recreational sport club - non commercial (excludes golf clubs and ski resorts)	0.6
Residential	High-density, multi-unit	0.55
Residential	Residential-Low Density (standard single dwelling units)	0.45

For each discontinuous unit of highly vulnerable aquifer, the total area of non-agricultural managed land within or touching the highly vulnerable aquifer was summed. Where a parcel of land fell only partially within a highly vulnerable aquifer, the entire parcel area was included in the calculation. This area was then added to the area within highly vulnerable aquifers classified as agricultural managed lands to get the total percent managed land in each highly vulnerable aquifer area.

Livestock Density Methodology

The calculation of livestock density within highly vulnerable aquifer areas was based on the calculation of Nutrient Units per acre (NU/ac) of agricultural managed lands.

Barn Identification and Nutrient Units

To determine the nutrient units, each parcel of land that intersects the highly vulnerable aquifer areas was assessed for the presence of a livestock barn. The size of the barn is used as a surrogate for the number of livestock and the amount of nutrients that could be generated by those livestock on that farm unit. The description in the MPAC farm code was used initially to screen for the livestock parcels in determining the livestock type. Livestock housing areas were estimated for barns on these parcels.

Partial coverage of building footprints was available for the study area, but where data gaps existed, the buildings on parcels having a farm code were digitized based on interpretation of 2006 air photos.

Each type of livestock has its own nutrient unit conversion factor, to determine the number of animals that generate 1 NU. For instance, one beef cow produces 1 NU and requires 100 square feet of living space in a barn, so the relationship for beef barns is 100 square feet per NU. The ratio assumes that the capacity of each livestock barn is at the maximum to generate or have the potential to generate that amount of nutrients.

Through air photo interpretation, the type of livestock housed in each barn was determined, and the area of the housing area was measured. A table included in the technical memo provided by the Ministry of the Environment summarizes the relationship between barn area, livestock type and nutrient units generated. By multiplying the area of the barn by the nutrient unit per area ratio, the total number of nutrient units for the farm unit was determined.

Livestock Density Calculation

For the calculation of livestock density, all nutrient unit values for barns in each separate highly vulnerable aquifer area were summed and then divided by the total acreage of agricultural managed land for that particular highly vulnerable aquifer area.

Input Data

The calculations for managed land and livestock density were completed as a desk-top exercise. The input data used to calculate the percent managed land and the livestock density are listed in **Table 4-2**. Information is given on the source of the data layer, the purpose for using the data and a description of where the data originated.

Table 4-2: Data used for Managed Land and Livestock Density Calculations

Data Input	Description	Source	Purpose
Parcels (polygon)	Municipal Property Assessment Corporation parcel fabric with primary roll number	Sub-license from Municipal Property Assessment Corporation (MPAC) under the Ontario Parcel Agreement	Minimum map unit for identifying different classes of property and farm operation types
Tax assessment record (partial) (table)	Municipal Property Assessment Corporation tax assessment database by primary roll number containing property code and farm operation code	Sub-license from Municipal Property Assessment Corporation (MPAC)	Linked to parcels, identifies tax-assessed land use, and for agricultural properties identifies primary farm operation, livestock or crop.
Wetlands (polygon)	Natural Resources Values Information System (NRVIS)	Sub-license from Ontario Ministry of Natural Resources (MNR)	Used to mask for non-managed land
Water body (polygon)	Natural Resources Values Information System (NRVIS)	Sub-license from Ontario Ministry of Natural Resources (MNR)	Used to mask for non-managed land
License Aggregate Areas (polygon)	Pits and quarries from the Natural Resources Values Information System (NRVIS)	Sub-license from Ontario Ministry of Natural Resources (MNR)	Used to mask for non-managed land
Wooded Areas (polygon)	Southern Ontario Land Resource Information System (SOLRIS)	Sub-license from Ontario Ministry of Natural Resources (MNR)	Used to mask for non-managed land

Data Input	Description	Source	Purpose
Building footprints (polygon)	Building outlines digitized from digital orthorectified aerial photography from spring 2006	Grand River Conservation Authority (GRCA)	Minimum map unit for calculating livestock density per structure identified as contributing animal nutrient units
HVA (polygon)	Highly Vulnerable Area polygon	Lake Erie Source Protection Region	Reporting unit

Verification of the results through field inspection would be beneficial; however, this has not been completed to date for the Highly Vulnerable Aquifer areas in the Kettle Creek watershed.

Known Limitations and Data Gaps

The property code and farm operation code values used to identify a candidate parcel is a single descriptor assigned by MPAC during the generation of the tax assessment record. It does not necessarily represent the current land use activities on each property. None of the data used as input to the analysis was verified in the field. A quantitative estimate of data accuracy is not known. Therefore, the results should be considered as only an approximation.

The input data layers used to identify the non-managed land areas (wetlands, water bodies, wooded areas, etc.) have spatial and content accuracies of varied and unknown degrees. The NRVIS data is intended to represent 1:10,000 scale hardcopy mapping. The data layers were acquired from Land Information Ontario, and represent the best available data for their thematic content at the time of the analysis.

The values of nutrient unit per square metre of livestock type were generated by the Ontario Ministry of Agriculture, Food and Rural Affairs. The values are meant to approximate the maximum potential nutrient unit production for the size of the livestock barn structure. The livestock nutrient unit calculations were not field verified and therefore the results should be considered as only an approximation.

The estimation of barn size was also approximate, as air photo interpretation cannot decipher between areas of the barn that house livestock and areas that do not. Also, the ability to determine whether the barn had one storey, or two storeys of housing areas was impossible through air photo interpretation and all barns were assumed to be single storey. Interpretation of the imagery was done to the best of the interpreter's ability. Verification of the livestock type and size of actual livestock housing area is suggested for more accurate results.

The ratios for non-agricultural managed lands were done using averages estimated through air photo interpretation. However, each parcel category could show very different percentages of managed land area and should only be used as approximation. Additional information from municipal by-laws on pervious cover requirements may be very useful in refining the estimates.

4.2.3 Percentage of Impervious Surfaces for Highly Vulnerable Aquifers

To determine whether the application of road salt poses a threat to the Highly Vulnerable Aquifer (HVA) areas, the percentage of impervious surface where road salt can be applied per square kilometre in each highly vulnerable aquifer area was calculated using the 2021 Technical Rules. The input data used to calculate the percentage of impervious surfaces per square kilometre are listed in **Table 4-3*.***

Impervious surfaces in highly vulnerable aquifer areas in Kettle Creek watershed constitute less than 8 percent of the total area, as shown in **Map 4-5** which represents a low percentage. Based on these results, the application of road salt does not pose a threat to Highly Vulnerable Aquifers in Kettle Creek watershed.

Methodology

To calculate the percent impervious surfaces, information on land cover classification was used. The Southern Ontario Land Resource Information system (SOLRIS) represents the land surface data, including road and highway transportation routes, as continuous 15 by15 metre grid cells with land cover classifications. All the cells that represent highways and other impervious land surfaces used for vehicular traffic were re-coded with a cell value of 1 and all other land cover classifications were given a 0 value, to identify only the road areas.

Using the Spatial Analyst module of ArcGIS software, the total number of road cells were summed for each square kilometre area in all highly vulnerable aquifer areas. The summed value for each cell in the output equaled the total number of road cells within each 1 kilometre by 1 kilometre window. The value of summed cells was converted to the square kilometre equivalent to determine the percentage of impervious road surface per square kilometre.

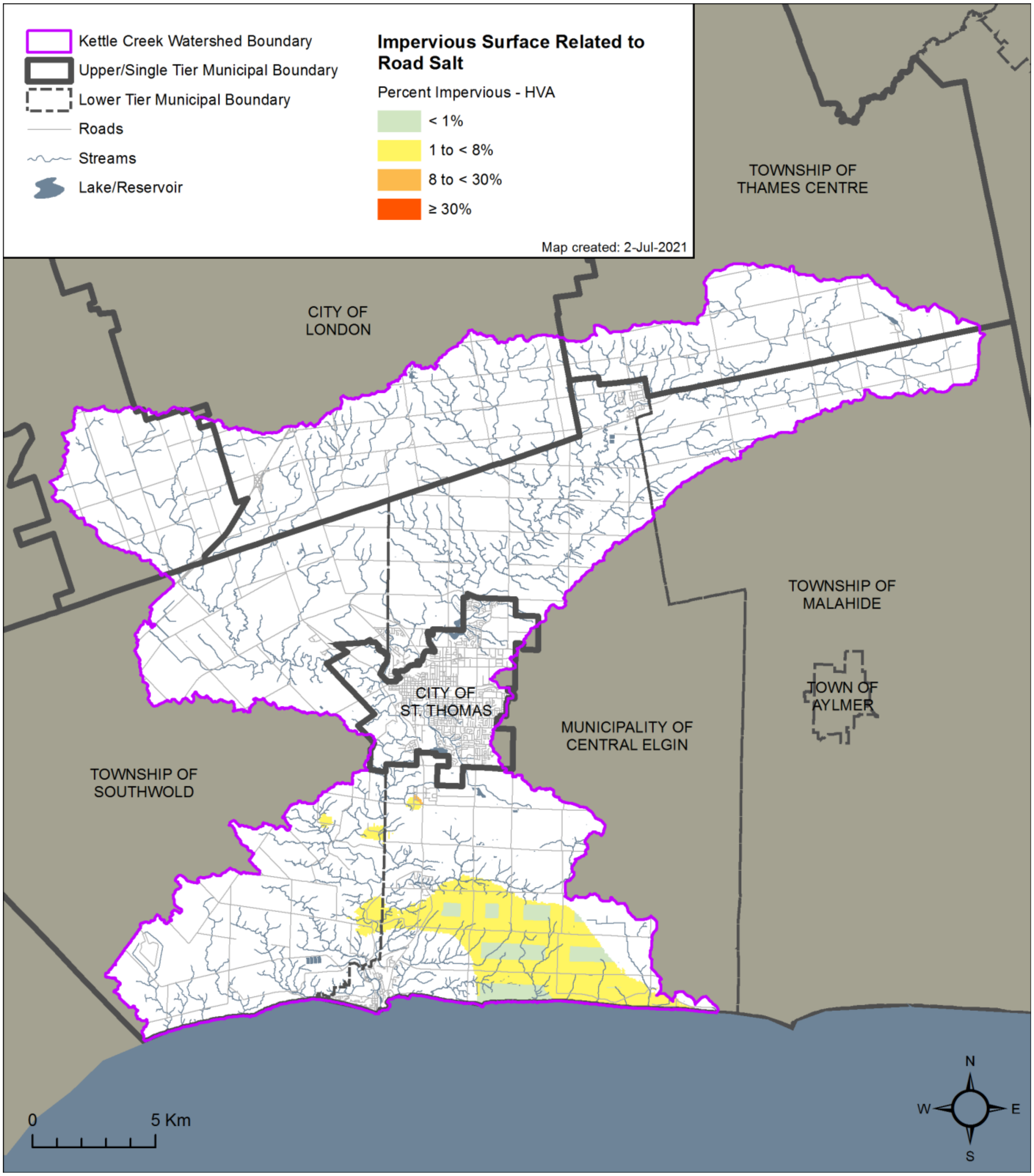
Known Limitations and Data Gaps

Impervious surfaces such as parking lots, pedestrian walkways and other related surfaces that may receive salt application were not considered as data was not available for these features within the study area.

Table 4-3: Input Data for Impervious Surfaces in Highly Vulnerable Aquifers

Data Input	Description	Source	Purpose
Road areas (raster)	Road and highway transportation routes as represented by the Southern Ontario Land Resource Information System (SOLRIS) version 1.2 May 2008, 15 metre raster cell format	Sub-license from Ontario Ministry of Natural Resources (MNR)	Continuous 15 x 15 metre cells represent surface areas of all highways and other impervious land surfaces used for vehicular traffic
HVA (polygon)	Highly Vulnerable Aquifer area polygon	Lake Erie Source Protection Region	Boundary of reporting unit

Map 4-5: Percent Impervious Surfaces in Highly Vulnerable Aquifers in the Kettle Creek Watershed



4.2.4 Drinking Water Threats in Highly Vulnerable Aquifers

Activities and conditions that are or would be drinking water threats in Highly Vulnerable Aquifer areas cannot be significant threats, given that the vulnerability score is 6. However, moderate and low drinking water threats and conditions could be identified within highly vulnerable aquifers.

Table 4-4 indicates the possible levels of threat posed by chemicals, pathogens and dense non-aqueous phase liquids (DNAPL) within the Highly Vulnerable Aquifer areas in Kettle Creek Watershed, which are illustrated on **Map 4-2.** A checkmark indicates that the threat classification is possible; a blank cell indicates that it is not. As indicated in the table by the blank cell, no activities can be classified as a significant threat in the Highly Vulnerable Aquifer areas; whereas some chemicals and DNAPLs are or would be considered moderate and low drinking water threats in the areas illustrated in red on **Map 4-2**.

The level of threat that an activity poses to a drinking water supply depends on the vulnerability scores within a vulnerable area. Since Highly Vulnerable Aquifer areas receive a vulnerability score of 6, even the most hazardous activities are not classified as significant threats.

The Ministry of the Environment, Conservation and Parks produced tables that list all of the threats and associated circumstances that are or would be moderate and low drinking water threats in Highly Vulnerable Aquifer areas. These tables are no longer in use, but corresponding information is available on the Source Water Protection Threats Tool. This information can be used along with **Map 4-2** and **Table 4-4** to help the public determine where certain activities are or would be significant, moderate and low drinking water threats.

Table 4-4: Identification of Drinking Water Quality Threats in Highly Vulnerable Aquifers (HVAs)

Threat Type	Vulnerability Score in HVA	Threat Classification Level Significant 80+	Threat Classification Level Moderate 60 to <80	Threat Classification Level Low >40 to <60
Chemical Threats	6	No	Yes	Yes
Handling / Storage of DNAPLs	6	No	No	Yes
Pathogens	6	No	No	No

At the time of this report, a drinking water threats analysis is not necessary within the Highly Vulnerable Aquifers, since no significant threats can occur in Highly Vulnerable Aquifer with a vulnerability score of 6. Additionally, no conditions resulting from past activities have been identified in the Highly Vulnerable Aquifer areas in the Kettle Creek Watershed.

4.2.5 Drinking Water Issues in Highly Vulnerable Aquifers

No Issues have been identified in the Highly Vulnerable Aquifers to date. Public Health Units are undertaking risk assessments of all small drinking water systems, and may, through that process, identify possible Issues for a future Assessment Report.

4.3 Significant Groundwater Recharge Areas

Significant Groundwater Recharge Areas (SGRAs) are defined as a specific type of vulnerable area that will be protected under the *Clean Water Act*, 2006. The role of significant groundwater recharge areas is to support the protection of drinking water across the broader landscape.

Groundwater recharge was estimated using the hydrologic model. The hydrologic model results provide an estimate of groundwater recharge based on Hydrological Response Units (HRUs), which are designed to reflect surficial geology and land cover, and climatic conditions over the period 1980 to 2004. Threshold values were calculated as set out in the Technical Rules (2009a), and areas with annual average recharge above those values were labeled as significant. In 2021, vulnerability scoring within SGRAs was removed to align with the updates to the Technical Rules.

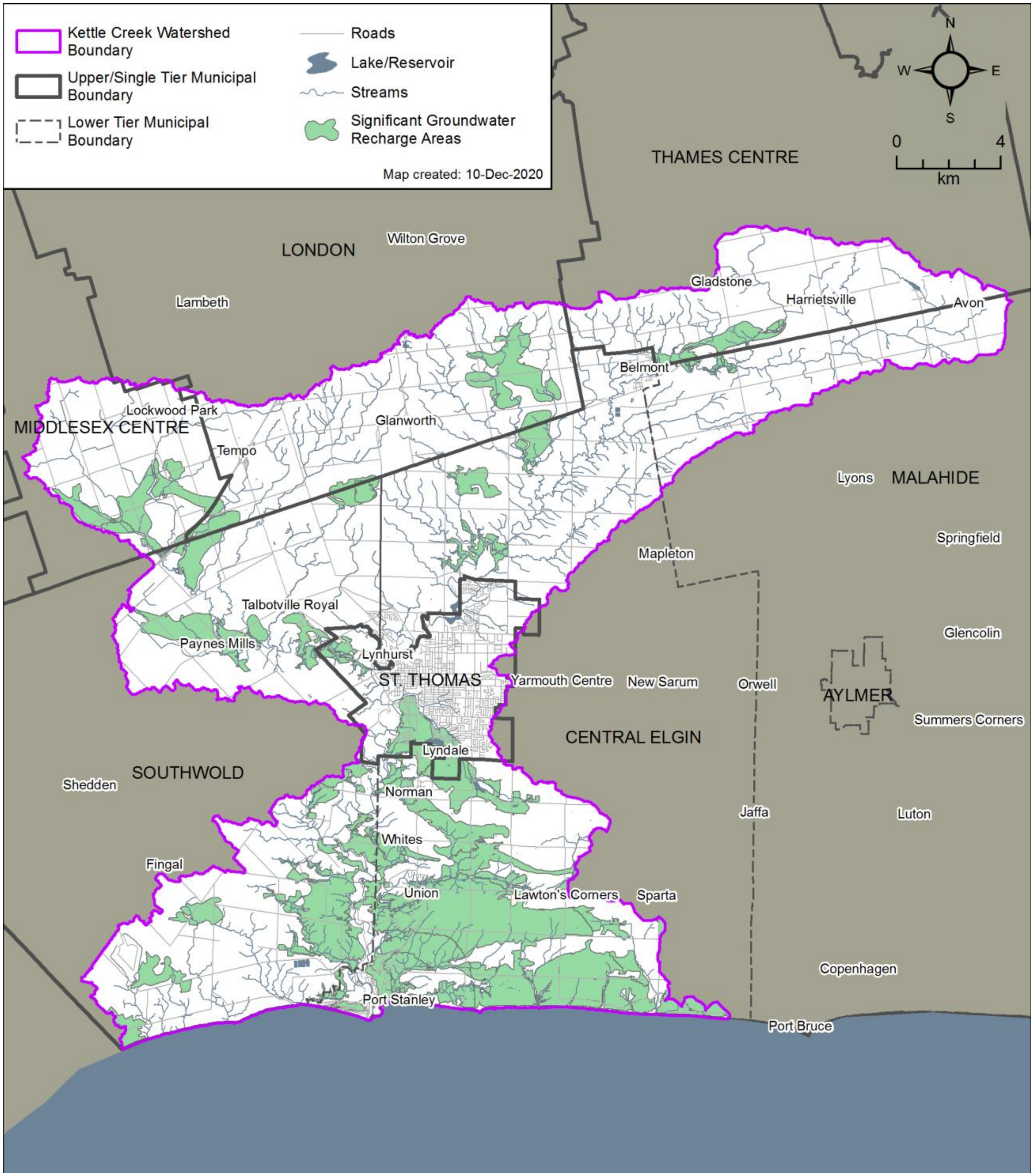
Threshold values for significant groundwater recharge areas were defined by taking 115 per cent of the annual average recharge for the related groundwater recharge area. For the Kettle Creek Watershed area, the “related groundwater recharge area” was taken as the watershed. The average annual groundwater recharge rate for Kettle Creek Watershed is 143 millimetres per year. The threshold, calculated as 115 percent of the average annual rate, is 164 millimetres per year.

After estimating significant groundwater recharge areas, small, isolated areas (<1 km^2) were removed to create mapping that focuses the delineated significant groundwater recharge areas to larger geologic and physiographic features that are considered more representative of mapped Quaternary geology features.

Map 4-6 shows the significant groundwater recharge areas mapped based on the calculated threshold and with isolated polygons of less than 1 km^2 removed. All of the significant groundwater recharge areas mapped within the Kettle Creek Watershed are considered hydrologically connected to groundwater sources used for drinking water because of the extensive cover of domestic overburden wells in the study area (**Map 3-4**).

Delineation of significant groundwater recharge areas is limited by the processes used by the hydrologic model to estimate recharge, the mapping used to create hydrologic response units, and the climate data available. The hydrologic model is a simplification of natural processes. Recharge is based on water that infiltrates through two soil layers and is not lost to runoff or evapotranspiration. This recharge may include interflow as well as true recharge to the aquifer system. The mapping used to create hydrologic response units is landscape based and only represents a point in time. Land cover mapping may change significantly over a short time period and this may not be represented in the land cover mapping used. Finally, only one climate station was used for the hydrologic model. Although over 20 years of data were used to calculate the average annual recharge rate, this rate does not represent changes to the climate due climate change nor focus on the importance of seasonal and annual variability.

Map 4-6: Significant Groundwater Recharge Areas in the Kettle Creek Watershed



4.4 Village of Belmont Water Supply

The village of Belmont is located in the northeastern portion of the Kettle Creek watershed. Belmont lies on a till plain and Port Stanley Till, a clayey silt till, is the surficial unit throughout most of the region. Underlying the Port Stanley Till is the more sandy/silty Catfish Creek Till. Belmont's municipal wells are supplied by groundwater from a confined overburden aquifer located between the Port Stanley and Catfish Creek Till sheets. Both the Port Stanley Till and the Catfish Creek Till act as regional aquitards. There are approximately 80 to 100 metres of overburden overlying the bedrock in the Belmont area. Shallow gravel and sand horizons have been noted in the area, but clay units ranging up to 30 metres or more are not uncommon.

The Municipality of Central Elgin operates a groundwater source water supply and distribution system in the former Village of Belmont. The system collects water from two pumping wells located at 300 Caesar Road, within the former village limits. The system currently supplies, on average, approximately 345 m^3 of water per day to approximately 1,950 residents. The well field has been in operation since 1956. The locations of the well sites and the serviced area are shown on **Map 4-7**.

The system operates under a Permit to Take Water (PTTW No. 4026-A82QSJ) issued by the MECP which expires on May 31, 2026. System characteristics are summarized below.

System characteristics:

- System Maximum Day Permitted Rate (m^3/day) [a] – 3034
- 2020 Average Day Demand (m3/day) [a] – 345
- 2020 Maximum Day Demand (m3/day) [a] – 1,246

Well 1 characteristics:

- MECP Well Number [b] – 2001938
- Date Constructed [b] – December 12, 1956
- Easting [c] - 17-492925
- Northing [c] - 17-47477000
- Screen Depth (m bgs) [b] - 39.6 to 41.2
- Permitted Pumping Rate (m^3/day) [c] – 3034 [d]

Well 2 characteristics:

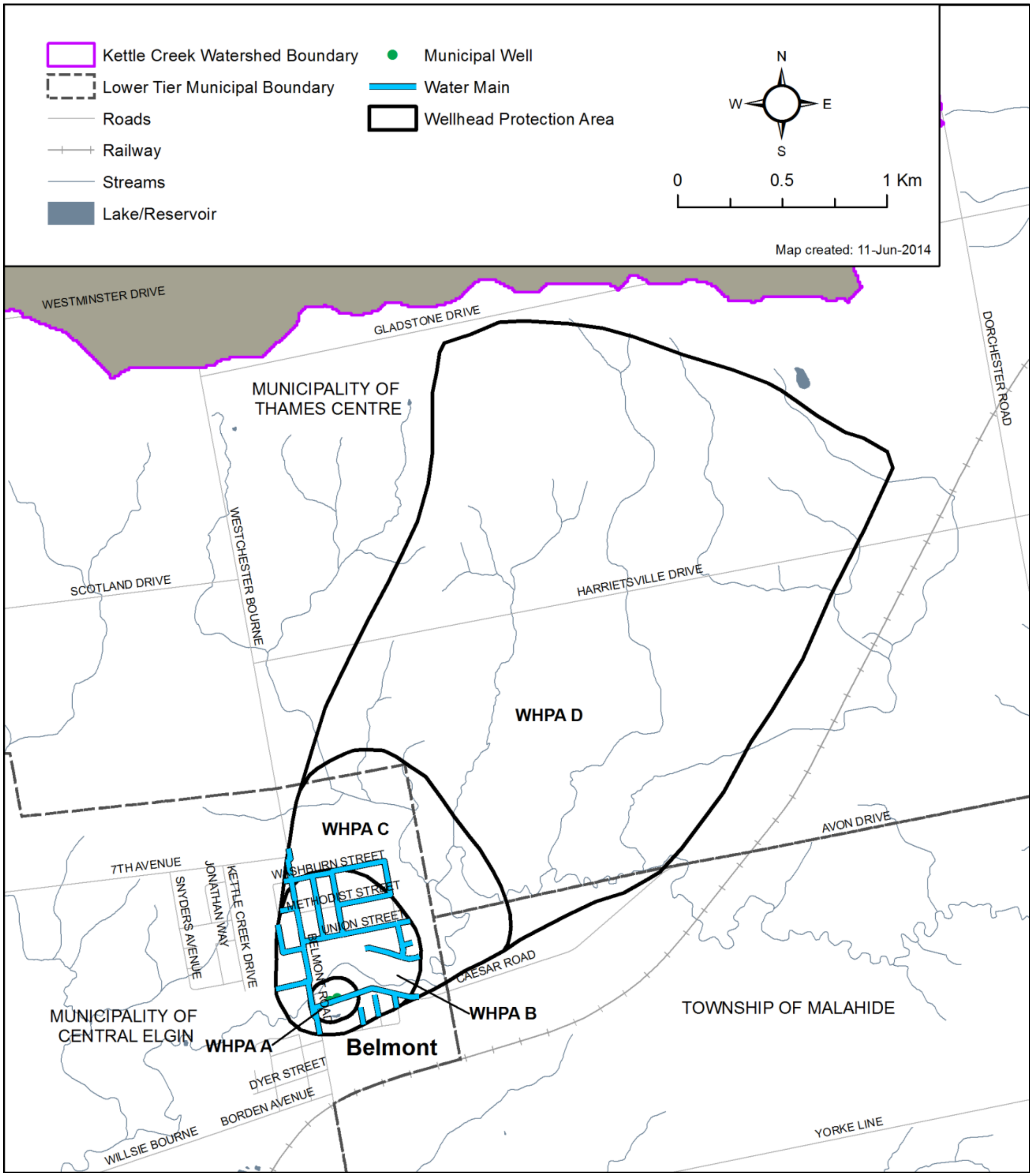
- MECP Well Number [b] – 2002168
- Date Constructed [b] - October 30, 1973
- Easting [c] - 17-492955
- Northing [c] - 17-47477000

- Screen Depth (m bgs) [b] - 39.9 to 41.8
- Permitted Pumping Rate (m3/day) [c] - 3034[d]

Notes:

- A :2020 Summary Report, Belmont Water System
- B: GUDI Study; Dillon, 2002
- C: PTTW No. 2261-6PQHMY, 2006
- D: Well 1 and Well 2 cannot pump more than 3034 m^3/day combined
- m bgs is short for metres below ground surface
- m^3/day is short for cubic metres per day

Map 4-7: Belmont Water Supply Distribution System in the Kettle Creek Watershed



4.4.1 Belmont Water Supply Wellhead Protection Areas

Wellhead Protection Areas (WHPAs) associated with the municipal water supply represent the areas within the aquifer that contribute groundwater to the well over a specific time period. According to the Technical Rules (MECP, 2021), four Wellhead Protection Areas are required, one a proximity zone and the three others time-related capture zones:

- WHPA-A 100 metre radius from wellhead
- WHPA-B 2-year Time of Travel (TOT) capture zone
- WHPA-C 5-year TOT capture zone
- WHPA-D 25-year TOT capture zone

The approach taken for the village of Belmont was to estimate the capture zones using a finite-difference numerical groundwater flow model (MODFLOW) calibrated to available hydrogeological data. The groundwater flow model was developed based on local and regional hydrogeological conditions observed during previous hydrogeological studies (Dillon, 2002, 2003, 2006). The modelling is described in Capture Zone Modelling, Belmont Water Supply System (Dillon, 2008).

Prior to undertaking the numerical modelling, a conceptual groundwater flow model was developed from a review of available hydrogeological data contained in previous studies and the MECP WWIS well records.

The Belmont water supply aquifer is a 10 metre thick overburden aquifer overlain by approximately 30 metres of low permeability silt and clay soil. The aquifer is under artesian pressure with a piezometric head of approximately 3 metres above the ground surface at the well. Although no formal investigation was completed on the conditions below the aquifer, based on regional data, the aquifer is underlain by a low permeability till which in turn is underlain by limestone bedrock (Dundee Formation).

The surficial till deposit in the vicinity of Belmont is the Port Stanley Till, which is underlain by the older Catfish Creek Till. It is assumed that the Belmont water supply aquifer is situated between these two till units. The Dillon (2008) modelling study assumed the aquifer to be continuous and of consistent thickness throughout the study area.

A numerical model was developed based on the conceptual model. For the flow model, a 12-kilometre (west-east) by 6 kilometre (north-south) domain boundary was chosen. Ten layers were specified in the model. The aquifer was assumed to be 10 metre thick based on the thickness of the aquifer at the municipal wells. The surface of the aquifer was determined through the examination of the MECP WWIS well records and the development of cross-sections.

The groundwater model boundaries consist of "constant head", "river", and "general head" boundaries that correspond to Kettle Creek and its tributaries and estimated groundwater heads on the north, south, east, and west limits of the area, respectively. The lower limit of the aquifer (representing the lower till or at a few locations bedrock) was assumed to be impermeable (the base of the model).

Static water elevations from the water wells located within the well field aquifer were also reviewed. Static water levels indicate the direction of groundwater movement in the aquifer and therefore have a significant influence on model development and wellhead protection area delineation. In addition to static water well elevations, the elevations of major water bodies (river and constant head boundaries, e.g., Kettle Creek and the Jenkins Drain), were used in the model.

Existing Pumping (Steady-State)

Initially, the model was run and calibrated to steady-state pumping conditions (500 m^3/day) as the production well has been in operation since the 1950's. Recharge and hydraulic conductivity values were adjusted within pre-set minimum and maximum values as presented in **Table 4-5.** Four different hydraulic conductivity zones were used in the model. The surficial weathered till unit was assigned an order-of-magnitude higher hydraulic conductivity than the unweathered till overlying the aquifer to reflect a more hydraulically active surficial zone due to weathering and fracturing. The aquifer was divided into two hydraulic conductivity zones: an overall hydraulic conductivity for the majority of the aquifer, and a lower hydraulic conductivity zone in the upper reaches of the model to reflect higher water levels near Gladstone and south of Derwent. This hydraulic conductivity zone is fairly removed from the Belmont well field and only affected the extreme part of the 25-year capture zone. The hydraulic conductivity ranking of the four hydraulic units was maintained throughout. The "best fit" hydraulic conductivity of the main aquifer (0.0002 m/s) translates to an aquifer transmissivity of 170 m^2/day (a 10 metre thick aquifer was used in the model) which coincides closely to the transmissivity determined in the recent pumping tests (200 m^2/day).

The final calibrated non-pumping steady state model resulted in a calibration with a correlation coefficient of 0.978 and a normalized root mean squared (RMS) of 7.3 percent (models with normalized RMS values below 10 percent are generally considered to be well calibrated). The model has a standard error of 0.32 metres.

Table 4-5: Belmont Aquifer Hydrogeological Parameters

Parameter	Minimum Value	Maximum Value	Calibrated Value
Weathered till*	1.0×10^{-7}	1.0×10^{-6}	5.0×10^{-7}
Unweathered till	1.0×10^{-8}	1.0×10^{-7}	5.0×10^{-8}
Main aquifer	0.00005	0.0004	0.0002
'Gladstone' aquifer	1.0×10^{-5}	5.0×10^{-5}	2.0×10^{-5}
Recharge (mm/yr)	50	125	100

*horizontal hydraulic conductivity was assumed to be isotropic. Vertical hydraulic conductivity was assumed to be 50 percent of the horizontal hydraulic conductivity for the unweathered till unit and 100 percent for the other units.

Forecasted Pumping

A critical step in delineating WHPAs is estimating the future water demand. The projected future water demand for the water supply system was determined using information provided by Mr. Lloyd Perrin, Director of Physical Services for the Municipality of Central Elgin. Annual water usage data for the period between 2003 and 2008 was used to calculate historical per capita average annual water demand. Using this estimate and information provided by the municipality on the planned future build-out condition of the village, a predication was made on the future annual average water demand on the water supply system. Details are presented below.

Current 2008 conditions:

- Current (2008) Served Population[1] – 1630
- 2003-2008 Average Day Demand (m^3/day)[2] – 429
- Calculated Average Water Demand per capita (L/day)[2] – 263

Future conditions:

- Maximum Build-out Population[1] – 3353
- Predicted Future Per Capita Use[2] (L/day)[2] – 263
- Predicted Future Annual Average use at Build-out[3] (m^3/day)[2] – 883

Notes:

- provided by the Municipality of Central Elgin
- calculated by Dillon, using water usage data provided by the municipality

Based on this calculation, the predicted maximum future demand based on planned build-out conditions is 883 m^3/day. However, the average demand value for 2020 calculated as part of the Class Environmental Assessment Environmental Screening Report (Dillon, 2003) is 1517 m^3/day, which is considerably higher. It was decided, in consultation with the municipality, to use a pumping rate of 1500 m^3/day, essentially the more conservative estimate calculated as part of the Environmental Assessment in the numerical model.

The long-term pumping rate simulation was used to provide time-of-travel estimates for particle tracking. Groundwater velocities were calculated using simulated water level data, hydraulic conductivity, and porosity for each cell. An “effective porosity” of 0.15 was used in the travel time estimated by MODPATH.

Backward tracking particles originating at the well were used to map the 2-year, 5-year, 10-year and 25-year time-of-travel capture zones. In addition to these zones, Zone A was set as the area within 100 metres of the two pumping wells.

The resulting 25-year WHPA extends from the well field to the northeast and is approximately 3.5 kilometres in length and 2.0 kilometres in width. The 5-year and 2-year WHPAs are confined mainly to the community of Belmont. Zone A is limited primarily to the well field. The Wellhead Protection Areas are depicted on **Map 4-8.**

Capture Zone Delineation Uncertainty and Limitations

The delineation of wellhead protection areas comprises a number of assumptions and estimates based on point data such as lithology described in water well records and hydrogeological information provided from reports.

The most significant limitation for the Belmont model was the assumption that the aquifer is continuous over the entire model area. Confined overburden aquifers in the area are known to be discontinuous and coincide with the depositional environment that occurred in the interstadial periods in which the aquifers were formed. It is doubtful that the aquifer is continuous over the entire 25-year time-of-travel area. The certainty of the model increases in the area in the immediate vicinity of the well.

Since the hydraulic head levels used for the observation wells used during model calibration were taken at different times of year and over several decades, a more recent and comprehensive survey of hydraulic head levels would provide for a more accurate basis to compare calibration with. The hydraulic head levels used for calibration, while useful for comparison if still relevant, could be offset by as much as 2 to 3 metres due to seasonal fluctuation or other influences. The heterogeneity of the overburden aquifer hydraulic conductivity could not be evaluated and, since hydraulic conductivity and other parameters can vary by as much as two orders of magnitude within the same hydraulic unit, it is likely that significant variation exists within the Belmont system that could not be accounted for based on the data available for the development of this model.

In terms of meeting uncertainty criteria for the *Clean Water Act*, 2006, since forecasted pumping rates and current acceptable numerical modelling methods were used to delineate WHPAs, the uncertainty rating is low.

Vulnerability Scoring in Wellhead Protection Areas

The vulnerability calculated within the vicinity of Belmont is low. These results are considered an appropriate estimate for the municipal aquifer, given the confined groundwater conditions in Belmont and the presence of the thick, low permeability clay aquitard. Vulnerability results are shown on **Map 4-9**.

Determining the vulnerability score within the Wellhead Protection Areas is performed by overlaying the mapped Wellhead Protection Areas with the Aquifer Vulnerability. Vulnerability scores were determined from areas of intersection between the Wellhead Protection Areas and the vulnerability, as outlined in **Table 4-6**.

Table 4-6: Vulnerability Scoring Matrix using SAAT

WHPA	SAAT Times 0 to 5 years (High)	SAAT Times 5 to 25 years (Medium)	SAAT Times > 25 years (Low)
Zone A (100m radius)	10	10	10
Zone B (0- 2 year)	10	8	6
Zone C (2 - 5 year)	8	6	2
Zone D (5 - 25 year	6	4	2

Note: Scoring based on MOE Technical Rules: Assessment Reports, November 16, 2009.

The results of vulnerability scoring are shown on **Map 4-9**. As indicated, the majority of the vulnerability scores are low, with scores of 10 only in Zone A. Zone B has a vulnerability score of 6. Zone C and Zone D have vulnerability scores of 2.

Limitations and Uncertainty

The SAAT approach to vulnerability analysis is deemed to have less uncertainty than other approaches that are allowed within the Technical Rules. Nevertheless, given that the SAAT method only differentiates between time-of-travel to the aquifer of 25 years or less and the travel times from the water table to the well are expected to be much longer, the influence of uncertainty and limitations of the SAAT method are not considered significant. Overall, the uncertainty is considered low, considering that the hydrogeological properties of the relatively thick aquitard that overlies the aquifer is relatively simple, and that the results of the SAAT analysis confirm observations made in other hydrogeological studies conducted in the area (Dillon and Golder 2004, Dillon 2009b).

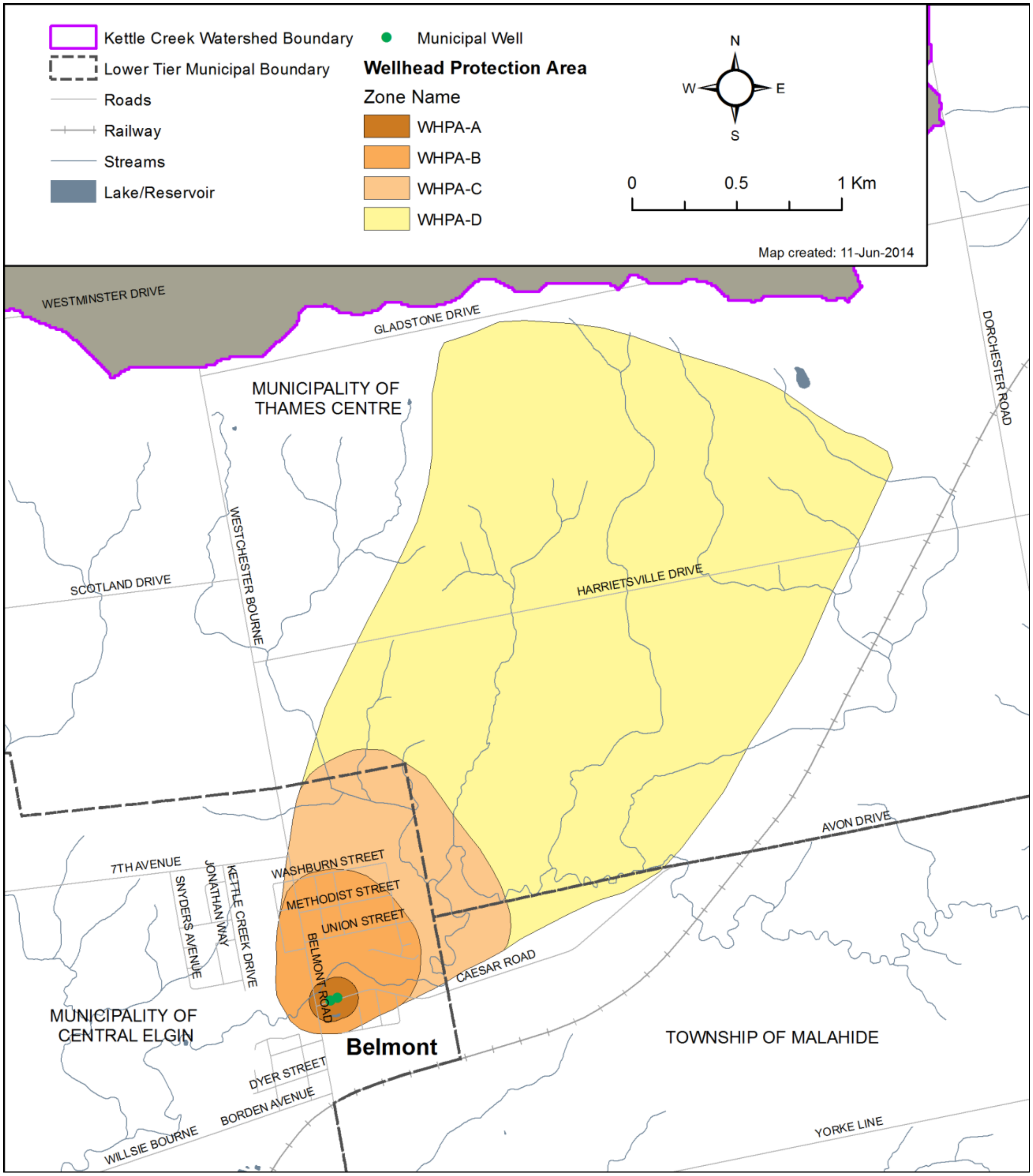
Peer Review of WHPAs and Vulnerability

A peer review of the report Belmont Village Source Protection Study: Vulnerability Analysis Report #1 (Dillon Consulting Limited, 2009a) was completed by Chris Neville of S.S. Papadopulos & Associates Inc. The overall impressions of the report by the peer reviewer are as follows:

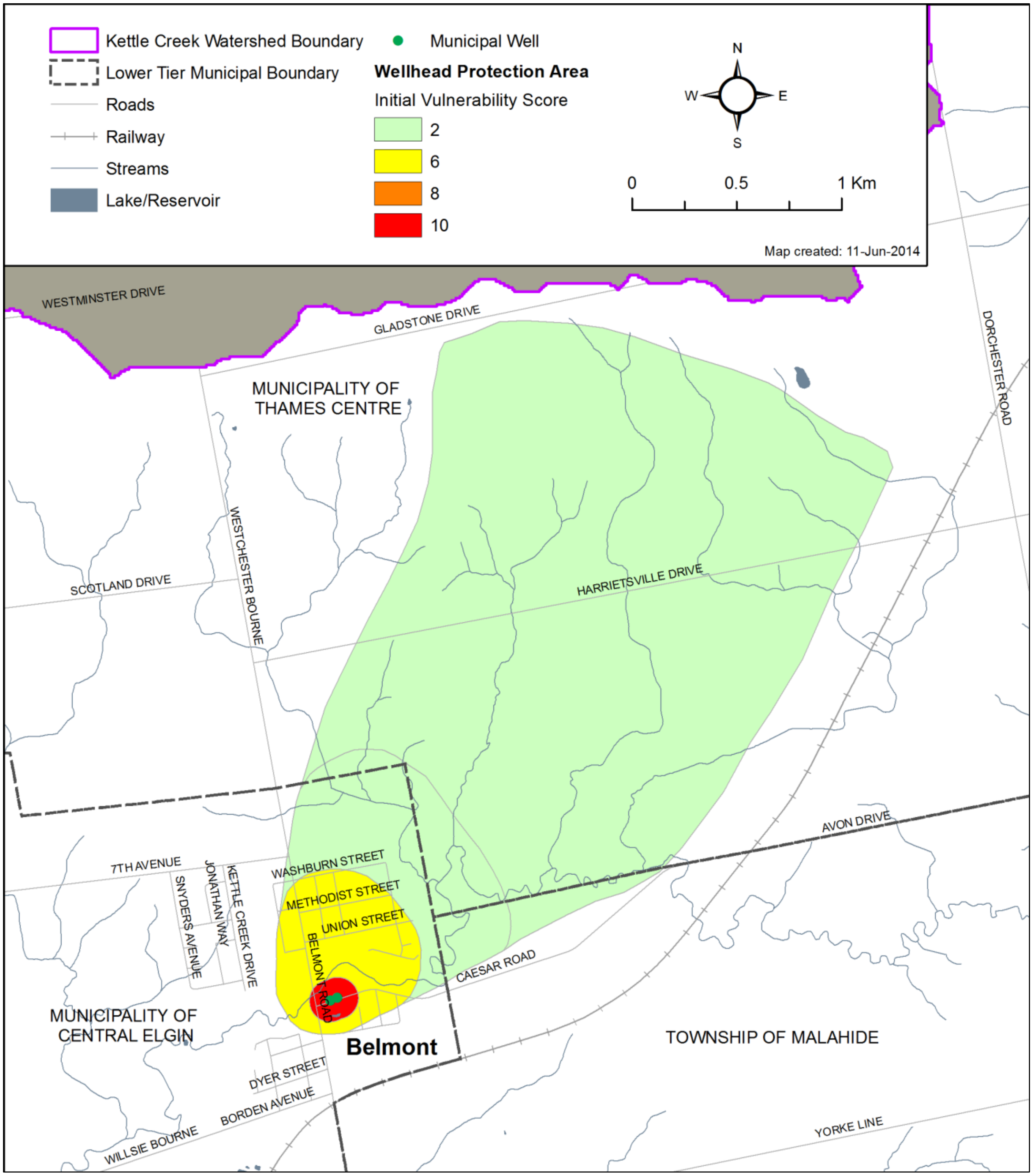
"In our opinion, the study is a solid, defensible effort. In our opinion, the approach is consistent with the Clean Water Act Technical Rules (December 12, 2008) and the Ontario Ministry of the Environment Source Water Protection Guidance Documents. We concur with the general methodology, but we do have a concern regarding its implementation for this particular study. In our opinion, our concern does not affect the overall results of the study. The report is a model of clarity and concision. The text and maps are clear. In general, the report is complete and self-contained."

Responses to peer review comments were incorporated into the final Vulnerability Analysis Report (Dillon, 2009b). The responses to the peer review comments enhanced the overall defensibility of the report but did not impact the outcome of the WHPAs or vulnerability scoring.

Map 4-8: Village of Belmont Wellhead Protection Area



Map 4-9: Belmont Wellhead Protection Area Initial Vulnerability Scoring



4.4.2 Identification of Transport Pathways and Vulnerability Adjustment

Transport pathways are features that may increase the aquifer's vulnerability. The following transport pathways are those that the MECP has highlighted as being of concern.

- Existing Wells
- Abandoned Wells
- Pits and Quarries
- Mines
- Construction Activities
- Storm Water Infiltration
- Septic System
- Water Mains and Sewer Infrastructure

A description of the methodologies used to identify each of the main categories of constructed pathways is presented in the following sections.

Existing Wells

Existing wells are defined as any water well that is currently being used to supply water for potable, agriculture, or commercial/industrial uses. As the locational accuracy of wells in the MECP's WWIS is generally low, the approach taken in Belmont was to also identify land parcels that have a high probability of containing a water well. To do so, areas within the Belmont WHPAs that are not serviced were identified through a review of municipal infrastructure records and through discussions with municipal staff. Any property with an identified building that fell in a non-serviced area was considered to have a water well.

Abandoned Wells

Abandoned wells are defined in this study as water wells, observation wells, or test holes that are no longer in service and may, or may not, have been decommissioned. Land parcels that may contain abandoned wells were identified through the review of historical air photography, settlement maps, and infrastructure servicing information. In general, a land parcel was identified as having, or potentially having, an abandoned well if any of the following conditions applied:

- All farmsteads;
- Municipal wellfields;

- Property that is currently serviced but was occupied by a structure prior to servicing in 1956;
- Non-serviced areas.

Further elaboration on these particular scenarios and rationale for their evaluation is discussed below.

Farmsteads

Farmsteads may have several wells, including sand points, dug, and drilled wells. The number of wells on a given farmstead will vary; however, a general guideline is that one well will be drilled per habiting generation. For agriculture properties, it is also common to have wells in fields for either irrigation or livestock watering purposes. For Belmont, farmsteads were identified from air photography and the windshield survey.

Municipal Wellfields

Municipal wellfields were treated as a special case, as it is common that numerous observation holes, test holes, or former pumping wells may be positioned on the property or adjacent lands. Investigation involved review of available municipal reports (i.e., Engineer Reports, wellfield development reports, GUDI studies, etc.) to identify the potential location of past wells.

Serviced Areas

Areas that were developed prior to the provision of municipal servicing in 1956 are potential locations for abandoned wells. Mapping of pre-serviced developed areas was based on a review of 1950 aerial photography. Also included in the review were farmsteads that are no longer present within the town footprint. Based on information provided by the municipality, it is believed that, prior to municipal water services, many of the homes were serviced by privately owned communal wells, where each well would service several properties. The locations of these wells are not known.

Buildings in Non-Serviced Areas

Areas where buildings once existed, or are currently present, were identified as potential abandoned well locations. In addition to the above, the MECP Water Well Information System was reviewed to determine whether any water wells were located within the Study Area.

Pits and Quarries and Mines

Pits and quarries can act as a direct conduit for contamination if material extraction has removed protective geological layers. Pits and quarries were identified through the review of current and historical air photography, NDMNRF aggregated databases, and conversations with people familiar with the history of the area.

Construction Activities

Construction activities related to current and relatively short duration disturbances of land may act as temporary transport pathways. Investigation was performed via windshield surveys.

Storm Water infiltration and Drainage

By design, storm water infiltration is a potential transport pathway. Infiltration systems were identified through review of air photography. Areas identified as potential infiltration areas include ponds and flooded gravel pits. The Municipality was also questioned on their knowledge of any infiltration systems within the WHPAs. In addition to identifying storm water infiltration features, areas of ponded water near the well heads were also identified as potential sources of contaminant impacts. GUDI reports were reviewed to aid in determining if any nearby water features would act as potential threats to source water.

Septic Systems

Septic systems act as transport pathways as they direct sewage directly into the subsurface. Septic systems were identified within the Belmont WHPAs using air photos to map the location of residences, businesses, or industrial operations that are not in municipally serviced areas. Older buildings that may predate municipal services were also identified.

Water Mains and Sewer Infrastructure

The installation of water mains and sewers may decrease the protective material overlying the aquifer of interest, possibly reducing their natural protection. Further, coarse grained material may be used to backfill the trenches, allowing these features to facilitate the horizontal movement of contaminants into the WHPAs from outside areas. The location of water mains and sewer infrastructure was mapped based on engineering information provided by the municipalities. The location of the infrastructure was limited to identifying their general alignment along roads/easements.

Identified Transport Pathways

The results of the transport pathway assessment are presented graphically on **Map 4-10.** A summary of the identified pathways grouped by MECP pathway class is summarized below.

Existing Potable Water Wells - Existing potable water wells are located along Avon Road, east of the village limits, and north of Seventh Street along Westchester Bourne Road. Private wells are also located at farmsteads and residential properties along Harrietville Drive and Gladstone Drive.

Monitoring Wells - No monitoring wells were inventoried/observed.

Exploration Wells - There is no knowledge of exploration wells in the Study Area.

Abandoned Wells - A high potential for abandoned wells exists at farmsteads and areas that were developed prior to the construction of the municipal system in 1956. The footprint of the developed portion of the town prior to servicing (as depicted in a 1950 air photo) is shown on **Map 4-10** and reflects areas where abandoned wells may be present.

Pits and Quarries - No pits or quarries were identified during the inventory.

Mines - No mines were identified during the inventory.

Construction Activities - No significant construction activities observed.

Storm Water Infiltration/Ponds - No storm water ponds were identified within the capture zones.

Septic Systems - Known buildings serviced by septic systems are shown on **Map 4-10**.

Water Mains and Sewers - The majority of the village is fully serviced, with the exception of a few homes along Caesar Road, near the boundary between the Municipality of Central Elgin and Malahide Township. The depth of the services is relatively shallow (<3 metres) relative to the thickness (>30 metres) of the overlying clay aquitard; therefore, the buried services are not expected to significantly decrease the protective capacity of the aquitard.

Field Drains - Several of the fields in the vicinity of Belmont are tile drained, as shown on **Map 4-10**. Note that the limits of the tile drain do not totally conform to the field position as indicated on the orthophotograph. The discrepancy is attributed to the lower resolution of the tile drain information relative to the orthophotograph.

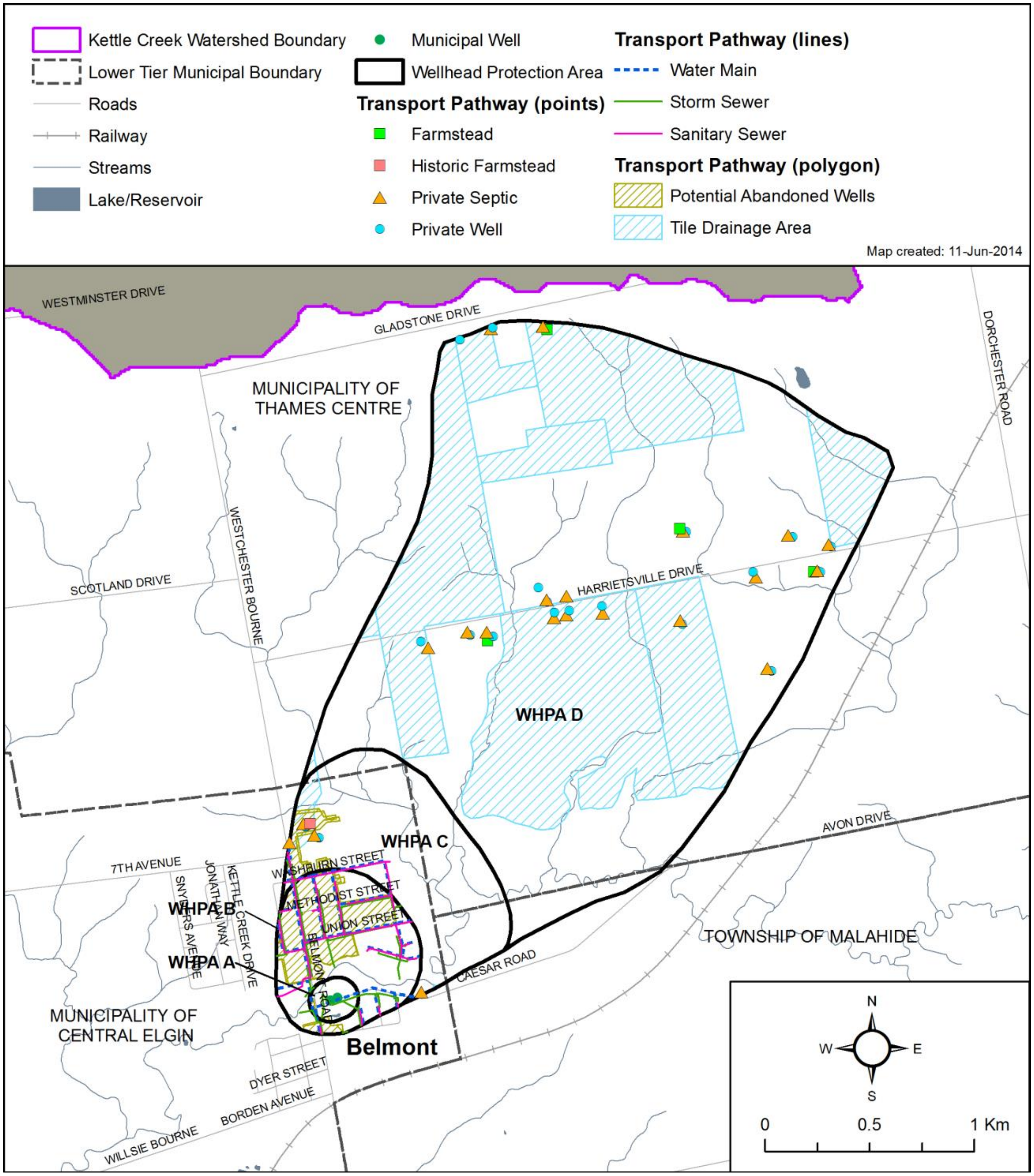
4.4.3 Adjusted Vulnerability Scoring

The Technical Rules allow investigators to modify the vulnerability scoring if there is a concern that the identified transport pathways within the Wellhead Protection Areas may increase the vulnerability of the aquifer beyond that represented by the intrinsic vulnerability. Modification of the vulnerability score is performed by increasing the vulnerability of the underlying aquifer vulnerability map from either a low to moderate value or moderate to high value. An initial aquifer vulnerability value of high cannot be increased.

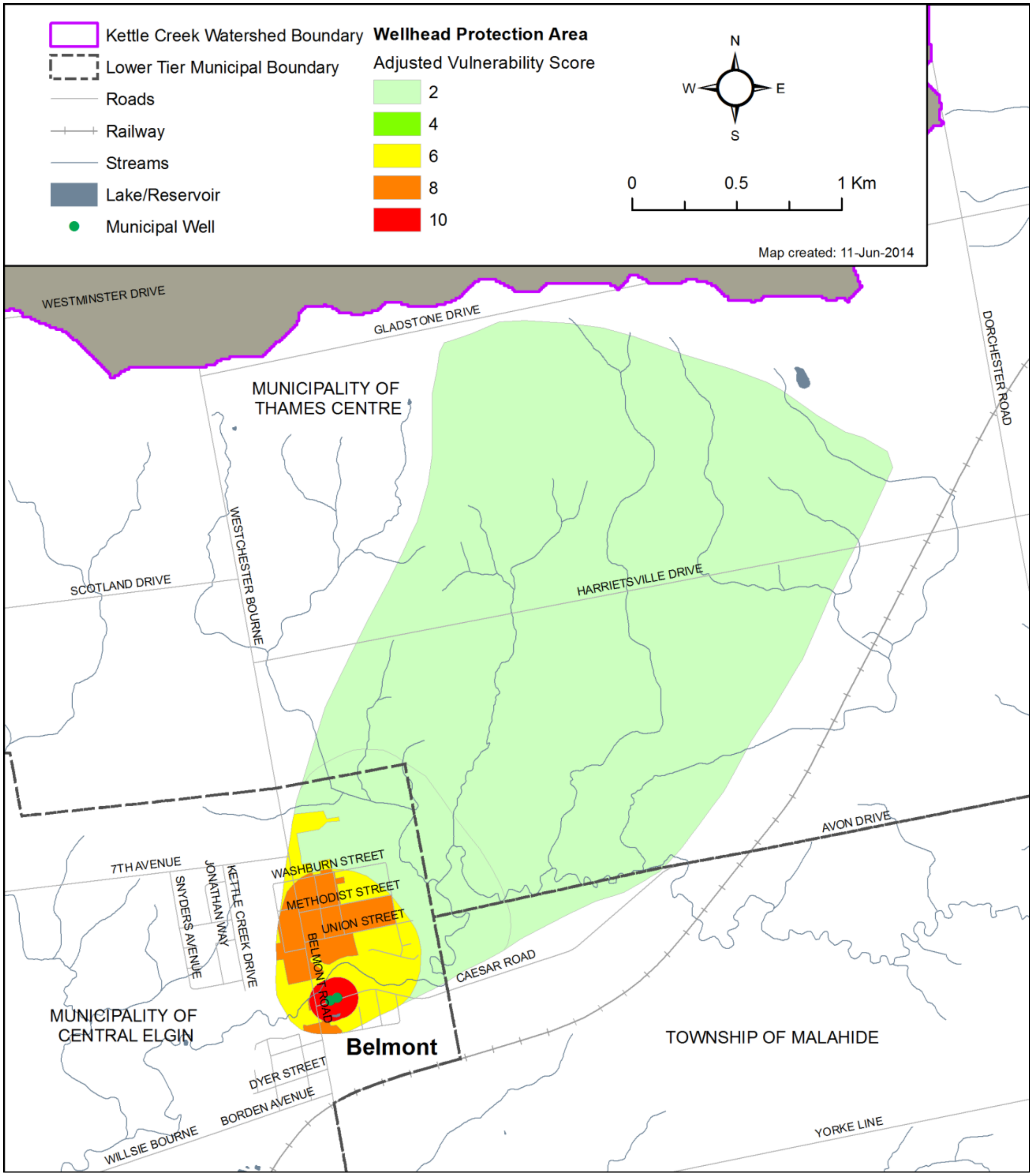
For the Belmont village system, the vulnerability of the aquifer was increased only in those areas where private wells may potentially exist at relatively high concentrations. The approach taken was based on discussions with the municipality, and involved increasing the vulnerability within the area of the village from low to moderate in areas that were developed prior to the installation of the municipal system in 1956. The rationale for this decision was that land parcels in this area have a higher risk of having an older private well that may or may not be maintained. These wells would penetrate the clay causing a potential transport pathway for contaminants through the aquitard if the wells are in poor condition.

The results of the final vulnerability score modification are shown on **Map 4-11.** Most of the vulnerability score increases occur within the 2-year WHPA (WHPA-B), where there is an increase from a score of 6 to an 8 in the area north of the well field along Main Street, Union Street, and Church Streets. North of Washburn Street, and along Main Street, the vulnerability score of several parcels increases from 2 to 6.

Map 4-10: Belmont Wellhead Protection Area Transport Pathways



Map 4-11: Belmont Wellhead Protection Area Final Vulnerability Scoring



4.4.4 Managed Lands and Livestock Density

Managed Lands are lands to which nutrients are applied. Managed lands can be categorized into two groups: 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 land includes golf courses, sports fields, lawns, and other built-up grassed areas that may receive nutrients (primarily commercial fertilizer). Determining the location and percentage of managed lands, the location of agricultural managed lands, and the calculation of livestock density were used to determine whether the application of agricultural source material (ASM), non-agricultural source material (NASM), and fertilizer were significant threats within the Belmont WHPAs.

All parcels that intersect each vulnerable area boundary were included in the calculation. Assessment parcels and Municipal Property Assessment Corporation (MPAC) property codes were used to identify parcels that belong to the agricultural managed lands category. Satellite imagery interpretation was then used to adjust this area to exclude features within each parcel not considered managed lands, such as buildings, driveways, and forests. Using a similar approach, features belonging to the non-agricultural managed lands category were identified, such as residential lawns. The percentage of managed land within a vulnerable area was calculated by summing the total land area within the vulnerable area, dividing it by the vulnerable area, and multiplying by 100.

The livestock density analysis determines the probable number of livestock animals present and is the surrogate measure of the potential for gathering, storing, and applying ASM as a source of nutrients within the vulnerable area. Assessment parcels and MPAC property codes were used to identify parcels that have the potential to house farm animals in barns. The buildings were then assessed to determine which buildings were likely used for livestock rather than another use, such as implementation storage. The sizes of the buildings used to house livestock were estimated using satellite imagery. The number of nutrient units (NU) supported by the building was estimated using the relationship table provided by the MOE (2009), which provides an average m^2/NU ratio for each animal type. Livestock density is expressed in NU/acre by summing the total NU for all categories, divided by the total area of agricultural managed lands for the vulnerable area. The results of the analyses are summarized in **Table 4-7, Map 4-12** and **Map 4-13.**

Table 4-7: Managed Lands and Livestock Density Calculation Results in the Belmont Wellhead Protection Areas

WHPA	Agricultural Managed Lands Area (acres)	Agricultural Managed Lands Percent	Non-Agricultural Managed Lands Area (acres)	Non-Agricultural Managed Lands Percent	Total Managed Lands Area (acres)	Total Managed Lands Percent	Nutrient Units (NU)	Livestock Density (NU/acre)
WHPA-A	0.0	0.0%	14.7	70%	14.7	70%	0.0	0.00
WHPA-B	6.6	5.0%	61.4	47%	68.0	52%	0.0	0.00
WHPA-C	289.4	63.5%	49.6	11%	339.0	74%	46.2	0.16
WHPA-D	1618.1	87.0%	25.3	1%	1643.4	88%	343.2	0.21

Threats associated with managed lands and livestock density are limited to the following prescribed drinking water threats:

- Application of ASM to Land,
- Application of Commercial Fertilizer to Land, and
- Application of NASM to Land.

Identification of potentially significant threats was performed based on the circumstances outlined in the Technical Rules for each PDWT listed above. Based on this analysis, none of the prescribed drinking water threats were identified as significant threats.

4.4.5 Percentage of Impervious Surface Area in Belmont Wellhead Protection Areas

Mapping of the percent imperviousness within the WHPAs (Zone A though Zone D) was performed by dividing the Belmont WHPAs into 1 kilometre by 1 kilometre grid squares, with the node of the grid positioned at the centroid of the zones. Using GIS, a percentage impervious area was calculated for each grid square. Considering that this map will be used during future threats inventory work as it relates to salt loading, only those surfaces where salt is likely to be applied were identified as impervious. Therefore, for this analysis, all mapped parking lots, roadways, and sidewalks were considered impervious, while all other areas are considered pervious.

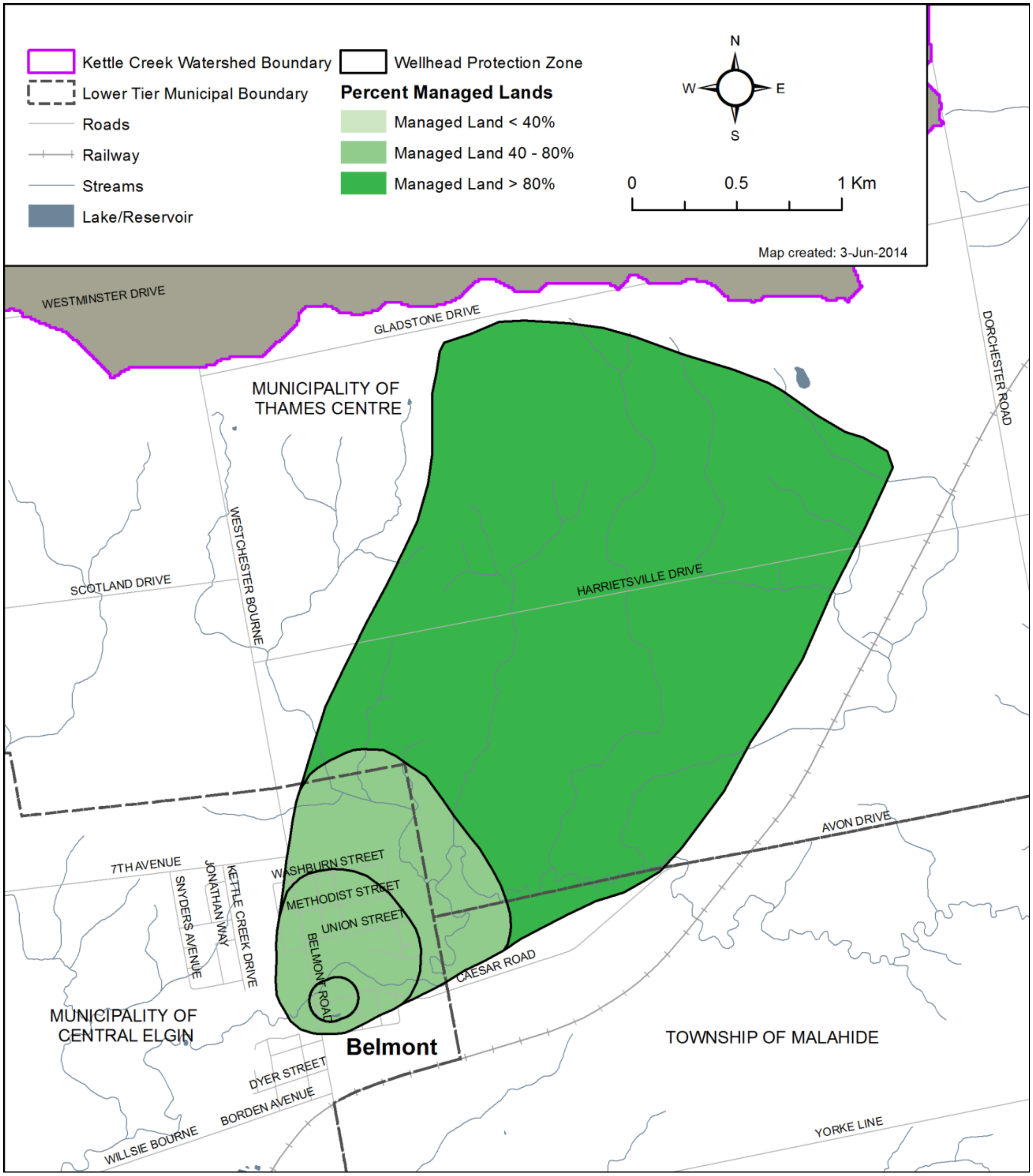
It should be noted that Technical Rule 17 was removed in the amended December 2021 update to the Technical Rules allowing flexibility in methods used to calculate impervious surfaces.

The results of the assessment are presented in **Map 4-13.** The areas are grouped into classes that correspond with the 2021 Technical Rules threat tables. These classes include <1 percent, >1 to 8 percent, >8 to <30 percent, and >30 percent. As shown in **Map 4-14,** most of the grids have a calculated imperviousness of <1 percent, with 6 of the 16 grid squares being between >1 to 8 percent. One grid square was calculated to be 15 percent impervious.

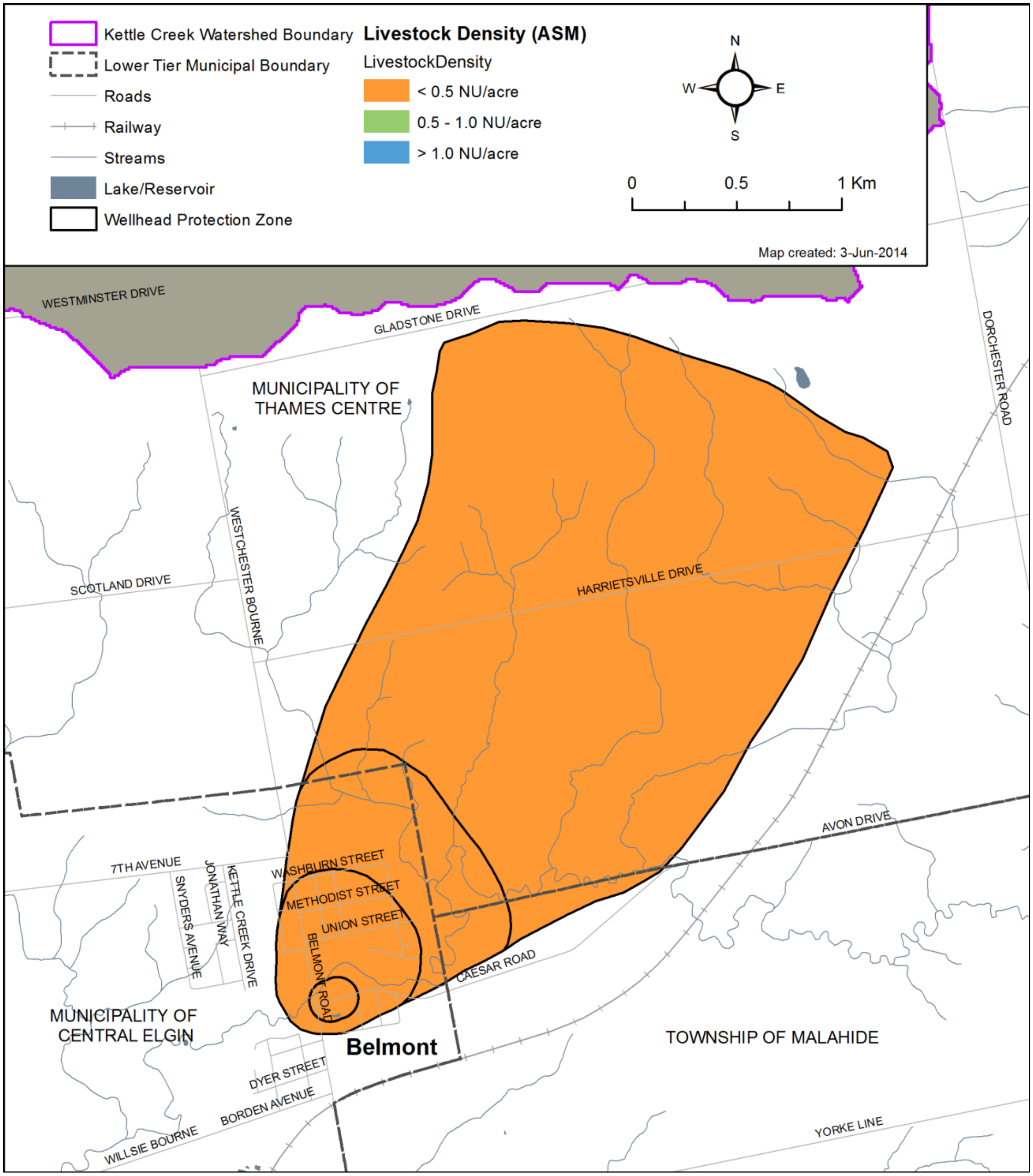
Limitations and Uncertainty

Uncertainty associated with this analysis is almost solely associated with the gridding approach, rather than error associated with accurately identifying the areas of roads, sidewalks, and parking lots. Grids that span both urban and rural areas will have the most uncertainty using this method. Overall, the error associated with Grid Zone 1 (which incorporates most of the urban area) is considered low, while Grid Zones 2, 6, and 5, which encompass a small portion of the urban area but include mainly rural lands, generate a percentage value that underestimates the imperviousness in the urban area, and overestimates the imperviousness of the rural portion of the grid. An improved estimate might be achieved by increasing the grid discretization.

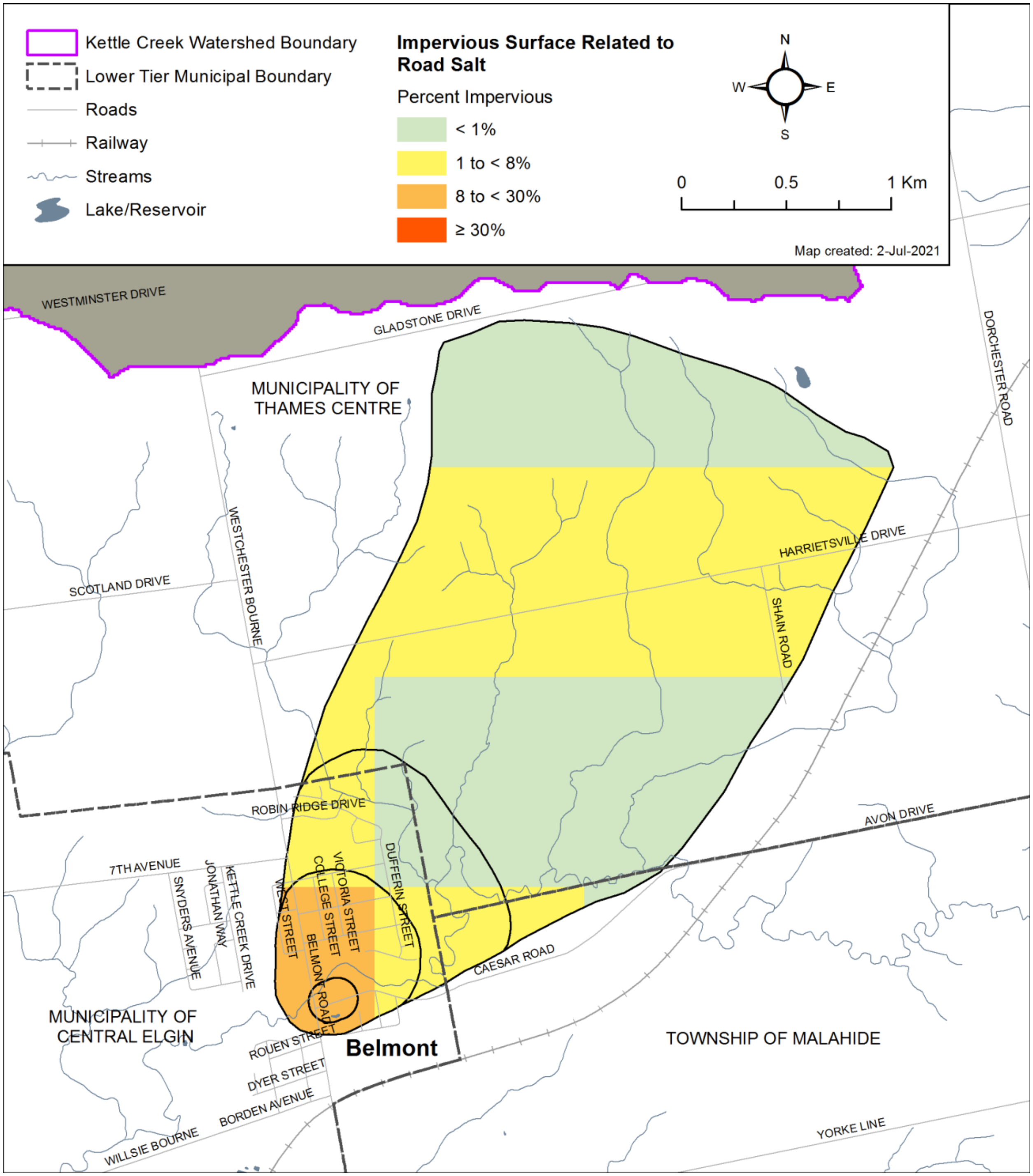
Map 4-12: Percent Managed Lands in the Belmont Wellhead Protection Areas



Map 4-13: Livestock Density in the Belmont Wellhead Protection Areas



Map 4-14: Percent Impervious Surfaces in the Belmont Wellhead Protection Areas



4.5 Village of Belmont Drinking Water Quality Threats Assessment

The Ontario *Clean Water Act*, 2006 defines a Drinking Water Threat as “an activity or condition that adversely affects or has the potential to adversely affect the quality or quantity of any water that is or may be used as a source of drinking water and includes an activity or condition that is prescribed by the regulation as a drinking water threat.”

The Technical Rules (MECP, 2021), list five ways in which a threat to a drinking water source can be identified, as follows:

a) through an inventoried activity prescribed by the Act as a Prescribed Drinking Water Threat;

b) through an activity identified by the Source Protection Committee as an activity that may be a threat and (in the opinion of the Director) a hazard assessment confirms that the activity is a threat (local threat);

c) through a condition that has resulted from past activities that could affect the quality of drinking water;

d) through an activity associated with a drinking water Issue; and

e) through an activity identified through the events-based approach.

Significant threats to the Belmont groundwater supply were assessed through the calculation of impervious surfaces, the development of a desktop land use inventory, and the calculation of managed lands and livestock density within the WHPAs for the original 2010 version of the assessment report. Since that time, threat assessments have relied on different sources of information. Threats are currently assessed through a combination of windshield surveys and local knowledge / field verification.

Prescribed Activities that Are or Would be Drinking Water Quality Threats in the Wellhead Protection Areas

Table 1-3 lists the activities that are prescribed drinking water quality threats. Listed beside the drinking water quality threats are the typical land use activities that are associated with the threat.

Identification of Significant, Moderate and Low Drinking Water quality Threats for the Belmont Water Supply

The identification of a land use activity as a significant, moderate, or low drinking water threat depends on its risk score, determined by considering the circumstances of the activity and the type and vulnerability score of any underlying protection zones, as set out in the 2021 Technical Rules. The information above can be used with the vulnerability scores shown in **Map 4-11** to help the public determine where certain activities are or would be significant, moderate and low drinking water threats.

Table 4-8 provides a summary of the threat levels possible in the Belmont Well Supply for Chemical, Dense Non-Aqueous Phase Liquid (DNAPL) and Pathogens. A checkmark indicates that the threat classification level is possible for the indicated threat type under the corresponding vulnerable area / vulnerable score; a blank cell indicates that it is not.

Table 4-8: Identification of Drinking Water Quality Threats in the Belmont Wellhead Protection Areas

Threat Type	Vulnerable Area	Vulnerability Score	Significant 80+	Moderate 60 to <80	Low >40 to <60
Chemicals	WHPA-A	10	Yes	Yes	Yes
Chemicals	WHPA-B	8	Yes	Yes	Yes
Chemicals	WHPA-B/C	6	No	Yes	Yes
Chemicals	WHPA-C/D	2	No	No	No
Handling / Storage of DNAPLs	WHPA-A/B/C	Any Score	Yes	No	No
Handling / Storage of DNAPLs	WHPA-D	2	No	No	No
Pathogens	WHPA-A	10	Yes	Yes	No
Pathogens	WHPA-B	8	No	Yes	Yes
Pathogens	WHPA-B	6	No	No	Yes
Pathogens	WHPA-C/D	Any Score	No	No	No

4.5.1 Conditions Evaluation

Conditions are drinking water threats that are a result of past activities. Part XI.5 of the Technical Rules (MECP, 2021) defines the following groundwater situations (as they apply to the Belmont system) as condition-related drinking water threats:

- The presence of a non-aqueous phase liquid in groundwater in a highly vulnerable aquifer, significant groundwater recharge area or wellhead protection area.

- The presence of a contaminant in groundwater in a highly vulnerable aquifer, significant groundwater recharge area or a wellhead protection area if the contaminant is listed in Table 2 of the Soil, Ground Water and Sediment Standards and is present at a concentration that exceeds the potable groundwater standard set out for the contaminant in that Table, and the presence of the contaminant in groundwater could result in the deterioration of the groundwater for use as a source of drinking water.

For the original 2010 version of the assessment report, no documentation of either of these scenarios was uncovered in the Belmont wellhead protection areas; therefore, no condition-related drinking water threats have been identified. In an interview, Lloyd Perrin, Director of Physical Services for the municipality of Central Elgin, confirmed that they are not aware of any condition-related threats. It is possible that condition-related drinking water threats do exist; however, no data is available to either confirm or refute this possibility.

4.5.2 Limitations and Uncertainty for Conditions Evaluation

No significant data gaps were encountered during the identification of significant drinking water conditions. There was a general lack of information on the presence/absence of contamination associated with historical land uses. As a result, no condition-related drinking water threats (if present) were identified. In addition, the type and amounts of chemicals stored at the commercial operations within the is unknown.

4.6 Drinking Water Quality Issues Evaluation

The *Clean Water Act*, 2006 Technical Rules (MECP, 2021) requires that Issues associated with the drinking water quality for the municipal system be identified. The activities that contribute to identified Issues that have an anthropogenic origin are deemed a significant drinking water threat.

The Issues evaluation for Belmont, completed in 2008, focused on the water quality parameter groupings outlined in the Ontario Drinking Water Quality Standards (ODWQS) identified in Ontario Regulation 169/03 under the Safe Drinking Water Act and the related technical support document. These parameters include: a) Pathogens, b) Schedule 1 parameters, c) Schedule 2 and 3 parameters and, d) Table 4 parameters. A brief description of each grouping is provided in the following paragraphs. In addition to these parameters, the Source Protection Committee may identify other parameters that are to be evaluated; however, to date, no additional parameters have been identified.

Pathogens – A pathogen is described as a disease-causing bacteria, viruses or protozoa, other than Escherichia coli (E.coli) and coliforms (which are assessed as Schedule 1 parameters). They can cause severe or fatal waterborne illness in humans. Some are resistant to commonly used disinfectants at water treatment plants. Reliable laboratory detection methods for pathogenic protozoa are yet to be established. There are no established Canadian water quality guidelines for these microbiologic organisms. The presence of these pathogens is a cause for concern and, as per the Safe Drinking Water Act, a microbial risk assessment must be completed to determine what Issues may be caused by these pathogens.

Schedule 1 Parameters – Schedule 1 parameters include E. coli and Total coliform. E. coli is a fecal coliform that can be detected by numerous laboratory tests. E.coli is present in fecal matter and is prevalent in sewage and is a strong indicator of recent fecal pollution, suggesting the presence of pathogenic bacteria and viruses. Its presence can also indicate the presence of more tolerant pathogens such as Giardia and Cryptosporidium. Total coliform includes the species of the genera Escherichia, Klebsiella, Enterosiella, Enterobacte, Citrobacter, Serratia and many others.

Schedule 2 and 3 Parameters – Schedule 2 and 3 parameters are a combination of Chemical Parameters (Schedule 2) and Radionuclides (Schedule 3), both natural and artificial. The parameters are known to be, or are, potentially toxic, and may adversely affect human health. Some of these parameters occur naturally in the environment, while others are the results of human activities. The ODWQS identifies maximum acceptable concentrations (MAC) values or Interim MACs for these parameters.

Table 4 Parameters – Table 4 parameters consist mostly of parameters that may impair the taste, odour or colour of the water or may interfere with good water quality control practices. The parameters may also affect the effectiveness of the treatment, disinfection, and distribution of the water. The ODWQS identifies either aesthetic objectives (AO) or operational guidelines (OG) for these parameters.

Assessment of the possible Issues related to the raw water quality at the Belmont municipal water system was conducted following a two-step screening and evaluation process. This process involved the comparison of available water quality information to water quality benchmarks and other comparison criteria. The first step was a screening evaluation, where parameters were flagged for further scrutiny based largely on their concentration relative to the ODWQS and whether the operator identifies the parameter as a concern. Flagged parameters were then further evaluated relative to degree, duration, and frequency of ODWQS exceedances, water treatment capacity, and opinion of operating authority.

4.6.1 Data Sources

Numerous sources of data were used for this analysis to review the current and historical water quality for the Belmont system. Available Annual Drinking Water System

Reports which summarize the results of testing during the year for each municipal system were reviewed and scrutinized. Reported parameters include Schedules 1, 2, and, 3, and Table 4 parameters, along with other parameters that may be individually important to a specific well. Additional information such as treatment method, system improvements, and any breakdowns in the treatment equipment are also available in the annual reports.

The reviewed information consists of the following:

- Annual 2005 to 2007 summary reports for raw and treated water. Parameters included turbidity, inorganics, microbiological data, volatile organic data, pesticides, and PCBs,

- 2003-2004 and 2006-2008 MECP Annual Inspection Sample Reports.

4.6.2 Drinking Water Quality Issues Evaluation for the Belmont Water System

Pathogens

Screening

Based on the available data for this well, and the operators' opinion, no known pathogens have been reported as detected from the available test results for the Belmont wells. The referenced documents were reviewed for test results concerning pathogens. Since no pathogens were reported as detected in the available data, no parameters were flagged for further evaluation.

Issue Identification

Since no pathogens were reported as detected in the available data, no Issues were identified.

Schedule 1 Parameters

Screening

Between the period of 2003 and 2008, there were 587 reported raw water samples collected and analyzed for E. coli, total coliforms, and background colonies. Only the number of samples and the maximum and minimum concentrations are reported. As such, there are a limited number of conclusions that can be drawn from the data.

E. coli – E. coli was found to be present in the raw water only in 2005. The highest reported level in 2005 was 3 cfu/100 millilitres. There was no available data for treated water in 2005.

Total Coliforms – Positive test results for total coliforms occurred in both 2005 and 2007. The highest recorded level of total coliforms was 11 cfu/100 millilitres in 2007 and 6 cfu/100 millilitres in 2005. The total coliform levels should not cause concern with proper disinfection at the water treatment plant.

Issue Identification

Although E. coli and Total coliforms were found present in some sample results, since this system incorporates disinfection, these parameters were not identified as an issue. The current disinfection system, when dosing at the proper rate, should be able to address the observed *E. coli* and Total coliform concentrations.

Schedule 2 and 3 Parameters

Screening

Fluoride – Fluoride has been identified in the 2003-2004 and 2006-2008 MECP annual reports as being greater than 50 percent of the MAC of 1.5 mg/l. A concentration range of 0.76-0.90 mg/L and an average of 0.832 mg/l have been reported. The reported range of fluoride concentrations falls partly between the 0.5-0.8 mg/l range that is deemed optimal to prevent tooth decay.

Issue Identification

Fluoride – Fluoride concentrations have exceeded 50 percent of the MAC five of the last six years yet have never exceeded the MAC itself. Since no obvious rising trend has emerged, the fluoride concentrations are not considered an issue, but should continue to be monitored closely, and therefore this parameter is flagged as a concern.

Schedule 4 Parameters

Screening

Sodium – there are two reported water samples that contained sodium above 50 percent of the 20 mg/l Medical Officer of Health notification level since 2005. However, there are no reported samples above the 200 mg/l ODWQS aesthetic objective. The maximum reported concentration was in 2006 with a reported concentration of 18.1 mg/l. Other than these two reported samples, there have been no other reported results above 50 percent of the 20 mg/l Medical Officer of Health notification level.

Iron – water produced from the Belmont wells has historically been high in iron. The reported levels of iron range from a low of 258 µg/l to a high of 433 µg/l between 2003 and 2008. The ODWQS aesthetic objective for iron is 300 µg/l. The average of the reported samples is 384.8 µg/l. The reported iron concentration for the past three years appears to be declining, but the limited number of samples reviewed cannot adequately confirm this trend.

Turbidity – based on the historical data, the raw water turbidity for the Belmont wells ranges between 0.02 and 22 NTU. The maximum reported values for the ranges reported in 2004-2007 all exceed the aesthetic objective of 5 NTU (as measured at point of consumption).

Issue Identification

Sodium – Sodium has not been in excess of the 20 mg/l guideline that requires notification to the local Medical Officer of Health. The sodium concentrations are therefore not considered an issue or even flagged as a concern.

Iron – the identified iron levels exceed the 0.3 mg/l ODWQS aesthetic objective. The system uses sodium silicate for iron sequestration. The sequestering system is shown to adequately remove iron and hence iron is determined to be naturally-occurring and not an issue.

Turbidity – the identified range of turbidity in the well can be considered above the aesthetic objective of 5 NTU (as measured at point of consumption). Turbidity is regularly reported as >1 NTU and, therefore, the possibility exists for interference with the disinfection. Ontario Regulation 170/02 states that water prior to disinfection should be <1.0 NTU. This parameter should continue to be monitored, as there is no filtration incorporated in this water system, and increasing turbidity can potentially interfere with the disinfection process. The source of the turbidity can likely be partially attributed to naturally high natural iron content in the water. As such, turbidity in the well is deemed a natural-based issue.

Other Parameters

No other parameters of note have been identified in the samples results reviewed for this system.

4.6.3 Summary of Water Quality Issues Evaluation for the Belmont Water System

Issues and concerns (flagged parameters) that have been identified based on the assessment methodology are iron and fluoride. Overall, one issue, turbidity, which has a natural source, was identified. There are no issues that meet Technical Rule 114 for the Belmont Water Supply.

4.6.4 Limitations and Uncertainty for the Drinking Water Quality Issues Evaluation

The results of the Issues assessment for Belmont are based on the review of the available data, which is generally limited to water system annual reports and MECP inspection reports. Sampling and analysis were not conducted. Consequently, the analysis and conclusions can only be based on previous data obtained as part of other programs. This analysis can also not comment on the method by which these samples were obtained or the laboratories used in the analysis or errors in data reporting or laboratory analysis that could be unknowingly carried forward through this analysis.

Data for the years between 2003 and 2008 were reviewed; the potential to review any trends in the data is limited to this time span. Sample data obtained during well commissioning could be useful to determine long term trends. Nevertheless, the reviewed data is deemed adequate for the purpose of this assessment and no significant data gaps are identified.

4.6.5 Enumeration of Significant Drinking Water Quality Threats

Currently there are no existing significant drinking water quality threats for the Belmont Water Supply, as per the 2021 Technical Rules.

Land Use Inventory Methodology

Inventorying land use activities that may be associated with prescribed drinking water threats for the original 2010 version of the assessment report 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. No site-specific information was collected; therefore, all drinking water threats were considered potential threats and required further site specific assessments to confirm their presence.

Details on the types of information collected for Belmont and used in the threats evaluation are presented in **Table 4-9**.

Table 4-9: Drinking Water Threats Data Sources for the Belmont Water System

Category	Primary Data Source
Road Salt Application	Municipal Survey
De-icing Activities	Municipal Survey
Snow Storage	Municipal Survey
Storm Water Management Systems	Municipal Survey, Windshield Survey
Cemeteries	Municipal Survey, Windshield Survey
Landfills – Active	Waste Disposal Site Inventory (MECP)* Municipal Survey
Landfills – Closed	Anderson’s Waste Disposal Sites* Municipal Survey
Organic Soil-conditioning	Municipal Survey/Conservation Authorities

Category	Primary Data Source
Septage Application	Municipal Survey/Conservation Authorities
Hazardous Waste Disposal	MECP Waste Disposal Site Inventory (ERIS) Municipal Survey
Liquid Industrial Waste	Waste Disposal Site Inventory (MECP)* Municipal Survey
Mine Tailings	Municipal Survey Ministry of Natural Resource Reports
Agricultural Operations	Windshield Surveys
Historical Activities	Municipal Survey
Fuels/Hydrocarbons	Retail Fuel Storage (TSSA)* Private Fuel Storage (TSSA)* Municipal Survey, Windshield Survey
Dense Non-Aqueous Phase Liquids (DNAPLs)	Business Directories Windshield Surveys O. Reg 347 Waste Generators (MECP)*
Organic Solvents	Business Directories Windshield Surveys O. Reg 347 Waste Generators (MECP)*
Agricultural Operations Pesticides/Fertilizer/Manure	Windshield Surveys
Transportation Corridors (Roadways, railways)	Municipal Mapping
Infrastructure Corridors (sanitary sewers, storm sewers)	Municipal Mapping
Pipelines	Review of Ontario Base Map topography maps (1:10,000 scale)

Notes:

- *Data provided through third party (EcoLog ERIS)
- MECP: Ministry of the Environment, Conservation and Parks
- TSSA: Technical Standards & Safety Authority

A description of the primary data sources for each drinking water threat category is presented below.

Previous Reports

A contaminant inventory was prepared for the study area as part of the Middlesex-Elgin Groundwater Study (Dillon and Golder, 2004). Data was obtained through a combination of interviews, surveys, and collection of government and commercial databases. This information was used as a starting point for the collection of contaminated sites information.

Municipal Surveys

Local information was provided by the municipality through their completion of a questionnaire on their knowledge of land uses and features that are potential drinking water threats. The survey was the primary source of information for road salt application and de-icing practices, and was also used to confirm information provided through other databases. Areas where potential fuel oil tanks and septic systems may be located were identified through input from the municipality and from assumptions used in the threat inventory methodology. More specifically, it was assumed that fuel oil tanks and septic systems are located at all properties unless the municipality indicated otherwise. In general, the likelihood of fuel oil tanks is greatest for rural properties and in areas that were developed prior to natural gas servicing. Similarly, the likelihood of septic systems is greatest in areas that were constructed prior to municipal servicing and in rural areas.

Windshield Surveys

Windshield surveys were conducted to gain information on current land uses and to confirm the land use and location of potential drinking water threats identified from other data sources. The survey was conducted in the fall 2007, and involved viewing land parcels from public thoroughfares to visually identify potential threats. Windshield surveys were the main source of data for identification of threats related to agriculture (manure, fertilizer, and pesticide use), type of farm, cemeteries, and storm water management ponds. For agricultural, farmsteads were highlighted as fuel, pesticide, fertilizer, and/or manure storage may occur at these locations.

Government and Commercial Databases

Information on historic and existing land uses that involved the storage of potential contaminants were obtained primarily from Provincial, Federal, and commercial databases. These databases were provided through a third-party vendor, EcoLog ERIS. A description of these government and commercial databases is provided below.

Federal Contaminated Sites June 2000-Sept 2002 – The Treasury Board of Canada Secretariat maintains an inventory of all known contaminated sites held by various Federal departments and agencies. This inventory does not include properties owned by Crown Corporations but does contain non-federal sites for which the Government of Canada has accepted some or all financial responsibility. All sites have been classified through a system developed by the Canadian Council of Ministers of the Environment.

The database provides information on company name, location, site ID#, property use, classification, current status, contaminant type and plan of action for site remediation.

MECP Spills Database (Occurrence Reports) – Spill data was provided for contaminant releases to air, land or water in the study area between 1988 and 2006. This database includes the location (street address or legal description), quantity, type and affected media of the spill.

Ontario Inventory of PCB Storage Sites – The MECP Waste Management Branch maintained an inventory of PCB storage sites within the province between 1987 and 2000. During these years, the MECP required that facilities storing or disposing of inactive PCB storage equipment and/or PCB waste register with the Waste Management Branch. This database contains information on waste quantities, major and minor sites storing liquid or solid waste, and a waste storage inventory.

O. Reg 347 – Waste Generators Summary – Regulation 347 of the Ontario Environmental Protection Act (EPA) defines a waste generation site as “any site, equipment and/or operation involved in the production, collection, handling and/or storage of regulated wastes”. A generator of regulated waste is required to register the waste generation site and each waste produced, collected, handled, or stored at the site. This database contains the registration number, company name and address of registered generators, including the types of hazardous wastes generated. This information is a summary of all years from 1986, including the most currently available data.

O. Reg 347 – Waste Receivers Summary – Part V of the Ontario EPA regulates the disposal of regulated waste through an operating waste management system or a waste disposal site operated or used pursuant to the terms and conditions of a Certificate of Approval or a Provisional Certificate of Approval. Regulation 347 of the Ontario EPA defines a waste-receiving site as any site or facility to which waste is transferred by a waste carrier. A receiver of regulated waste is required to register the waste receiving facility. This database represents registered receivers of regulated wastes, identified by registration number, company name and address. This information is a summary of all years from 1986, including the most currently available data.

Private Fuel Storage Tanks (TSSA) – The Fuels Safety Branch of the Ontario Ministry of Consumer and Commercial Relations maintained a database of all registered private fuel storage tanks. Public records of private fuel storage tanks are only available since the registration became effective in September 1989. The Technical Standards and Safety Authority (TSSA) now collects this information.

Inventory of Coal Gasification Plants (MECP) – The Inventory of Coal Gasification Plants was maintained by the MECP up to 1988. The database includes all known and historical coal gasification sites that produced or used coal tar and other related tars. The locations of these sites were cross-referenced with the study area and were incorporated into the database of potential contaminant sources.

Pesticide Register (MECP) – The Pesticide Register is an MECP database that includes all manufacturers and vendors of registered pesticides. The locations of these sites were cross-referenced with the Study Area and were incorporated into the database of potential contaminant sources.

Wastewater Discharger Registration Database (MECP) – The Wastewater Discharger Registration Database is a conglomerate of two programs maintained by the MECP between 1990 and 1998. Original data included in the database were collected under the MECP Municipal/Industrial Strategy for Abatement (MISA). The data have included all direct dischargers of toxic pollutants within nine sectors including: Electric Power Generation; Mining; Petroleum Refining; Organic Chemicals; Inorganic Chemicals; Pulp & Paper; Metal Casting; Iron & Steel; and Quarries. All information is now collected and stored within the Sample Result Data Store (SRDS). The locations of these sites were cross-referenced with the Study Area and were incorporated into the database of potential contaminant sources.

Sewage Treatment Plants (MECP) – The MECP maintains the Sewage Treatment Plant SRDS to provide detailed information pertaining to municipal sewage treatment plants. In particular, data includes design specifications and performance. The performance data for the municipal systems within the Kettle Creek area were reviewed and locations were incorporated into the database of potential contaminant sources.

Certificates of Approval (MECP) – This database contains the following types of approvals: Certificates of Approval (Air) issued under Section 9 of the Ontario EPA; Certificates of Approval (Industrial Wastewater) issued under Section 53 of the Ontario Water Resources Act (“OWRA”); and Certificates of Approval (Municipal/Provincial Sewage and Waterworks) issued under Sections 52 and 53 of the OWRA. Because of the poor addressing in this database, the data could not be geo-referenced, but is presented within the digital database.

Waste Disposal Site Inventory (MECP) – The MECP Waste Management Branch maintains an inventory of known active, inactive and closed disposal sites in the Province of Ontario. Active sites maintain a Certificate of Approval and are approved to receive and are receiving waste. Inactive sites maintain Certificate(s) of Approval but are not receiving waste. Closed sites have no Certificate of Approval and are not receiving waste. Information from this dataset was merged with the Anderson Waste Disposal site inventory.

Record of Site Condition Registry (MECP) – Sites that have been cleaned up to O.Reg.153/04 requirements and where a Record of Site condition has been issued are registered by the MECP. Sites that have been issued as RSC have either been cleaned up to a generic O.Reg.153/04 soil and/or groundwater quality standard, or to a site specific standard that is supported by an approved Site Specific Risk Assessment. The RSC process does not necessarily address source protection threats; therefore, this information is interpreted to only identified properties where contamination above background conditions was once suspected, or currently remains.

Retail Fuel Storage Tanks – Until 1996, the Fuels Safety Branch of the Ontario Ministry of Consumer and Commercial Relations (MCCR) maintained a database of licensed retail fuel outlets. Historic information was obtained from the MCCR and current information, for the ERIS database, was collected from private sources. This database includes an inventory of retail fuel outlet locations that have on their property gasoline, oil, natural gas, waste oil and/or propane storage tanks.

Anderson's Waste Disposal Sites – The Anderson database uses historical documentation to locate and characterize the likely positions of former waste disposal sites in Ontario. It aims to identify those sites that are missing from the MECP's Waste Disposal Site Inventory (also included in EcoLog ERIS). The Anderson database also provides revisions and corrections to the positions and descriptions for sites listed in the MECP database. In addition to historic waste disposal facilities, the database also identifies certain auto wreckers and scrap yards that have been extrapolated from documentary sources.

Scott's Manufacturing Directory – Scott's Directories is a data bank containing information on over 20,000 manufacturers in Ontario. Even though Scott's listings are voluntary, it is the most comprehensive database of Ontario manufacturers available. Information concerning a company's address, plant size and main products are included in this database. This database begins with 1992 information and is updated annually. The database was used to identify industries that may store or handle chemicals that, if released, could impact groundwater.

Automobile Wrecking & Supplies – This database provides an inventory of all known locations that are involved in the scrap metal, automobile wrecking/recycling, and automobile parts and supplies industry. Information is provided on the company name, location, and business type.

The 2021 Technical Rules list detailed circumstances set forth for each prescribed drinking water threat that may result in the threat being classified as posing a low, moderate, or significant risk, based on the vulnerability scores of the area in which they occur. The circumstances often involve factors associated with the type of contaminant, its volume, and consideration of the likelihood of release.

The evaluation for Belmont followed a multistep process including identifying land use activity names, assigning vulnerability scores, relating the land use activity to the threat category, relating the land use activity to the prescribed drinking water threat, and applicable circumstances.

Assign Land Use Activity Names

Land Use Activity Names, provided by the MECP and based loosely on North American Industrial Classification System (NAICS) codes, were applied to activities during the collection exercise. The Land Use Activity name was then used to link identified activities to the list of prescribed drinking water threats from Ontario Regulation 287/07. As an example, a "day care" inventoried during the windshield survey would receive, from a list of 546 possibilities, the Land Use Activity name "Child Day-Care Services". In some cases, difficulty arose in selecting an appropriate Land Use Activity name, and therefore professional judgment was used in the selection. Where appropriate, the applied Land Use Activity name was updated to reflect the most recent version of the MECP's database (February 2009).

Assign Vulnerability Scores

Once the Land Use Activity names were selected, vulnerability scores were assigned to each activity based on their location within the Belmont WHPAs. In the case where the activity straddled more than one WHPA or area of equal score, the shape was divided proportionally between the overlapping areas and scores, and applied to each parcel. For example, if a soy bean crop straddled two vulnerability scores, the activity would be split into two pieces.

Relate Land Use Activity names to Threat Subcategories

Using the MECP database, Land Use Activity names were related to Threat Subcategories.

Relate Threat Subcategory to Prescribed Drinking Water Threats

Prescribed drinking water threats are listed in Part X and XI of the 2021 Technical Rules. The February 2009 version of the database was used to relate specific Land Use Activities to the list of Prescribed drinking water threats by way of the Threat Subcategory. While any of the prescribed threats could pose a drinking water threat, the MECP recognizes that only under certain circumstances would the threat be considered significant. Further query filters compared the vulnerability scores associated with each Land Use Activity (subsequently related to the prescribed drinking water threat) to the Technical Rules (MOE, 2009a). The outcome is a short list of Land Use Activities linked to Prescribed drinking water threats, and a summarized list of circumstances that must be validated to determine if the activity is to be identified as a potentially significant risk.

Determine Applicable Circumstances

Lastly, the circumstances from Table 1 and 2 of the Technical Rules (MOE, 2009a) were reviewed to determine if the Land Use Activity is a significant drinking water threat. In general, there are two to three types of circumstances that are applied to the identified Drinking Water Threat, including the following (although in some cases, the circumstance types are combined):

1. Circumstances related to a legal definition taken from definitions of other acts and regulations.
2. Circumstance associated with a quantity or likelihood of release based on a physical situation (e.g., location of a tank relative to ground surface, etc.). The applicability of this circumstance is based on professional judgment in the absence of site-specific data.
3. Circumstance associated with the specific chemical parameter. The applicability of this circumstance is based on professional judgment in the absence of site-specific data.

Professional judgment is applied in each unique case. Although only one circumstance in a list of several may trigger a significant risk for a given prescribed drinking water threat, it is prudent to evaluate all circumstances.

Selection of the applicable circumstances is key to the implementation of the Water Quality Risk Assessment for a given threat. Determining the applicable circumstance 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 is considered. In many cases, selection of the relevant circumstance is based largely on professional opinion on the likelihood of a circumstance being applicable, as site investigations have not been conducted.

4.7 Elgin Area Water Supply System

The Elgin Area Water Supply System is an existing large municipal drinking water system, and as such is a Type I system as defined by the Technical Rules (MECP, 2021) under the Clean Water Act,*2006*.

The Elgin Area Water Treatment Plant (WTP) is located in the Municipality of Central Elgin in Elgin County, along the north shore of Lake Erie approximately 2 kilometres east of Port Stanley. The Elgin Area WTP services part of the City of London’s water demand as well as about 54,000 people from area municipalities including City of St. Thomas, Municipality of Bayham, Municipality of Central Elgin, Township of Malahide, Township of Southwold and the Town of Aylmer. The area serviced by the Elgin Area Water supply system is illustrated on **Map 4-15.**

The Elgin Area WTP has an existing rated capacity of approximately 91 million litres per day (MLD) with a current average day demand (2018) of 44.2 MLD treated and 45.2 MLD raw water.

4.7.1 Intake Classification

The Elgin Area WTP has a single, type A (Great Lakes) intake located in Lake Erie. The intake crib is located 1,200 metres offshore and 7.9 metres below the Low Water Datum for Lake Erie (**Map 4-16**)**.**

4.7.2 Intake Protection Zone – 1

Intake protection zones (IPZ) 1 and 2 were delineated for the intake using Part VI of the Technical Rules set by the MOE (November 2009).

An IPZ-1 is defined as a circle that has a radius of 1000 metres centred on the crib of the intake. An IPZ-1 represents the most vulnerable and immediate area around an intake. The Elgin Area Water Supply System IPZ-1 does not intersect the shoreline and therefore an upland IPZ-1 delineation was not required.

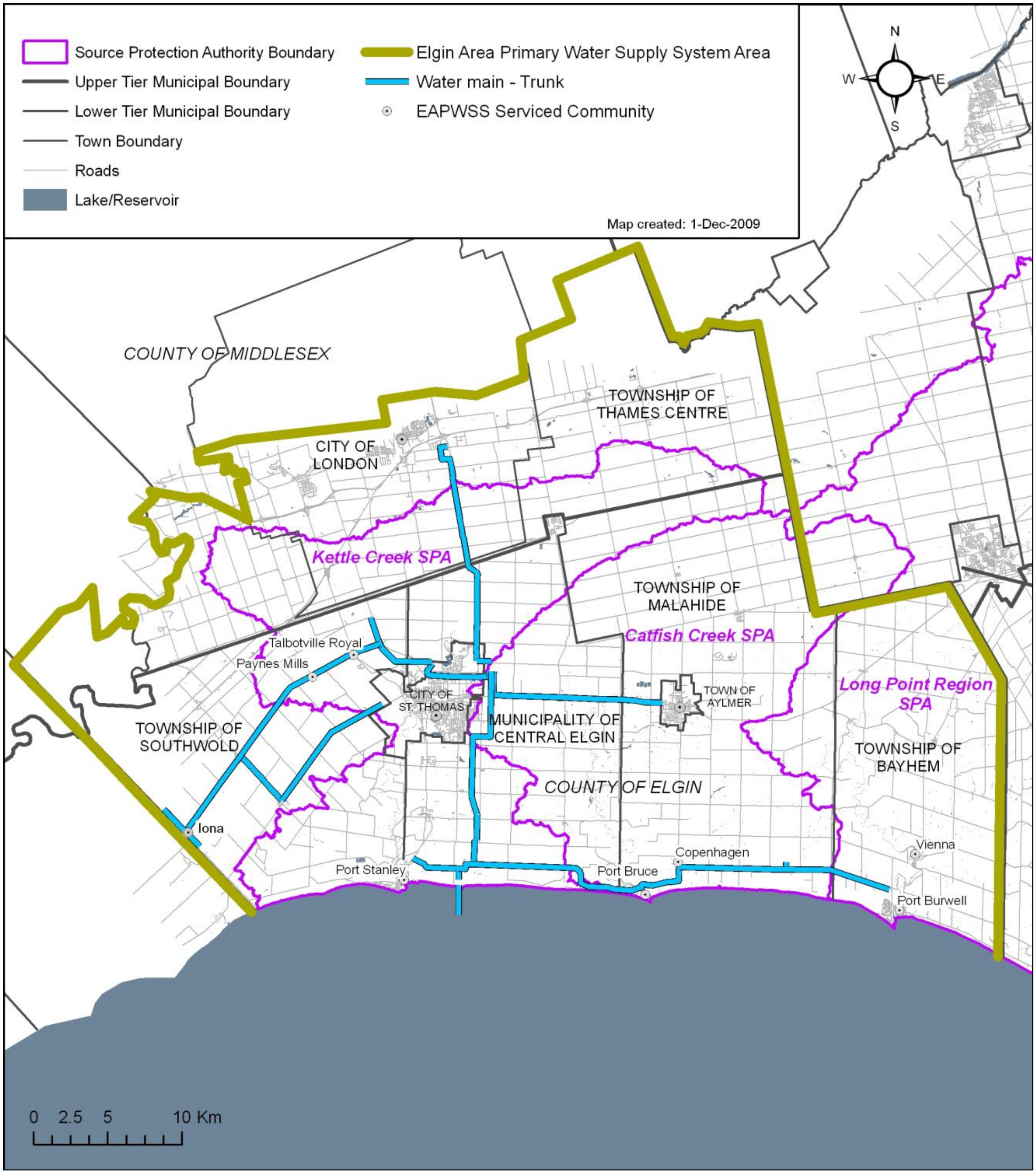
4.7.3 Intake Protection Zone – 2

An IPZ-2 is defined as an area surrounding the intake that takes into account characteristics of the local conditions including local water currents, shoreline features and local tributaries. An IPZ-2 accommodates the following:

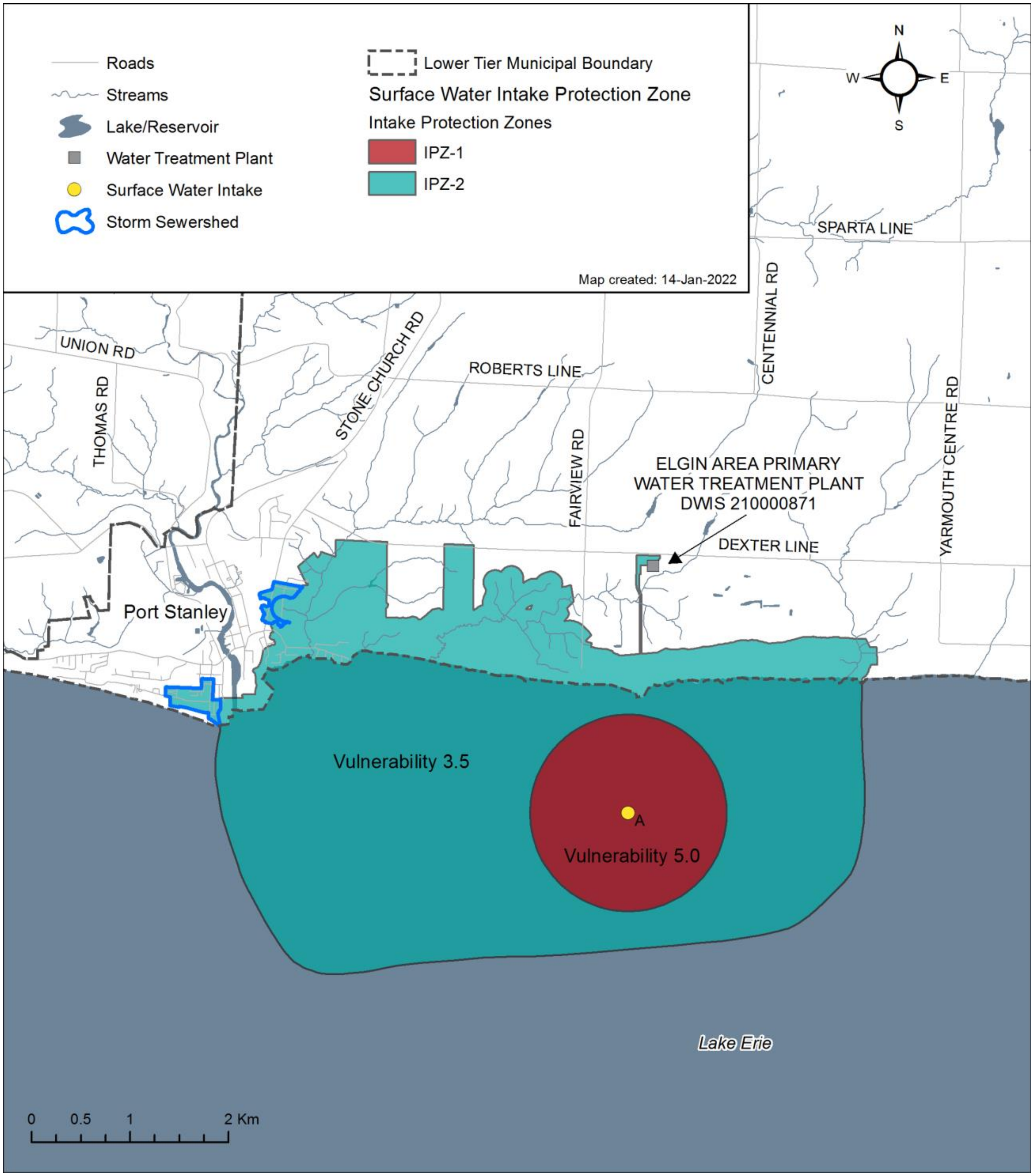
- The area within each surface water body that may contribute water to the intake where the time of travel to the intake is sufficient for operator response to an adverse condition; the minimum time of travel requirement is 2 hours;
- Areas within storm sewer sheds and other drainages that drain toward the intake; and
- A setback of not more than 120 metres inland or the regulated area, whichever is greater if the area abuts land.

An IPZ-2 was delineated for the Elgin Area Water Supply intake using a time of travel of 2 hours. The 2 hour time of travel was deemed appropriate by Elgin Water Supply System staff for sufficient operator response. Operators stated in interviews that the intake could be shut down within 2 hours without negative impact to ongoing plant operations upon notification or awareness of an imminent threat that could impair the quality of water supply at the intake or negatively affect the water treatment plant's ability to produce safe water.

Map 4-15: Elgin Area Water Supply Distribution System



Map 4-16: Elgin Area Water Treatment Plant Intake Protection Zones



A variety of information was synthesized to determine the best suitable approach for determining both the in-water extent, shoreline extent and up-tributary extent of the IPZ 2 and includes:

- Bathymetric information for the nearshore area was derived from Canadian Hydrographic Service navigational charts and field sheets
- Bathymetric information for the off-shore area was derived from the National Geophysical Data Centre (NGDC) of the US National Oceanic and Atmospheric Administration (www.ngdc.noaa.gov).
- Shoreline was derived from the Ministry of Natural Resources Ontario Base Map theme
- Wind and wave data for Lake Erie was obtained from land-based atmospheric stations (Marine Environmental Data Service) and offshore wave buoys and from the Wave Information Study hindcast model input from the National Oceanic and Atmospheric Administration (www.ngdc.noaa.gov) and wave hindcast data from the Ministry of Natural Resources
- Water levels for Lake Erie at Port Stanley was obtained from the Canadian Hydrographic Service;
- Current data was obtained from the deployment of an Acoustic Doppler Current Profiler in the vicinity of the Elgin Area Water Supply intake at a depth of approximately 9 metres; and
- Relevant literature on Lake Erie circulation /currents

Most of the uncertainty in the approach used in this analysis is the prediction of the combined offshore and alongshore conditions. Further evaluation with the 3-D model would be required to provide a more comprehensive result. However, the modelling work completed for the delineation of the IPZ 2 was generally a conservative approach and is typical of planning level investigations.

Off-shore, In-water Extent

The offshore in-water lateral extent of the IPZ 2 boundary was based on output from the 2-D ADCIRC hydrodynamic model while the shoreline intersects and the nearshore extent are based on the output from the ADCIRC model that was updated to be 3-Dimentional. A 10-year return period for wind and wave events was used to describe the in-water area for the IPZ 2.

Along-shore Extent

Particle back-tracking was also used to determine the shoreline extent that would be included in the IPZ 2 area.

The results of the modelling illustrated the in-water IPZ 2 for the Elgin Area Water Supply intake to extend approximately 4.0 kilometres west, 2.5 kilometres east and 1.5 kilometres south (offshore) of the intake crib.

Up-tributary Extent including Transport Pathways

Where the IPZ-2 abutted shore and was not impacted by a tributary or transport pathway (e.g., drain), it was extended upland to include the area of the Regulation Limit with the exception of the land between Kettle Creek and Hawk Cliff Creek where the IPZ-2 extends instead to the area where overland flow drains into the surface water body (height of land). Where the in-water IPZ-2 was impacted by tributaries or transport pathways, the IPZ-2 area was extended to include these areas.

A total of 12 storm sewer outfalls in the community of Port Stanley outlet to either the in-water IPZ-2 area or the up-tributary extent of Little Creek. Information on the location of storm sewers was obtained by the Municipality of Central Elgin and Southwestern Ontario Orthophotography Project (SWOOP) 2006 data provided by Kettle Creek Conservation Authority. A detailed drainage assessment commissioned by the Elgin Area Water Board of the property where the Water Treatment Plant is located confirmed that a storm drain (i.e. pipe) directs drainage and the process wastewater from the water treatment plant from the property and a small portion of Dexter Line directly into Lake Erie (Stantec 2010). A discharge outlet is located in Lake Erie within the IPZ-2 but in very close proximity to the IPZ-1. This drainage assessment indicated that the drainage from this property to the lake is less than a 2-hr TOT and therefore is included in the IPZ-2 delineation as a transport pathway. More detailed information is included in a technical memorandum “Technical Memorandum for the Elgin Area WTP” (Stantec April 2010). Tile drainage areas that appear to outlet to the tributaries in the 2-hr TOT were also included in the IPZ-2 delineation. Tile drained area is based on the percent land artificially drained as indicated by the Tile Drainage Areas GIS dataset (OMAFRA, 2009). The IPZ-2 delineation was extended to the parcel boundary in areas where tile drains were considered transport pathways as in the ‘U’ shaped segment of IPZ-2.

For the purposes of determining an up-tributary extent for each watercourse, a residual time of travel was determined from the in-water IPZ-2 modelling using average in-lake current velocities and distance between the intake and the tributary confluence. A 10-year stream flow return period was used to extend the IPZ-2 up each watercourse (Kettle Creek, Little Creek, Hawk Cliff Creek, and Dexter Creek). A 120 metres setback was applied to each watercourse for the length of the up-tributary extent for all creeks with the exception of Little Creek and Hawk Cliff Creek were the IPZ area was extended to the Regulation Limit.

4.7.4 Intake Protection Zone – 3

Modelling was used to determine the need and extent of the delineation of an IPZ-3 for the Elgin Area Water Supply Intake under Technical Rule 68. A Contaminant release was simulated at three control points of interest, a landfill located in the upper Dodd Creek; wastewater sewage lagoons located in upper Kettle Creek; and a wastewater treatment plant located in the middle Kettle Creek region **(Map 4-17**). The modeled contaminant plume from these contaminant releases was analyzed to predict the concentration and level of dilution of the contaminant along the flow path and at the mouth of Kettle Creek.

The Cornell Mixing Zone Expert System (CORMIX, version 3.2) software was used to predict the concentration of the theoretical pollutant discharges at the mouth of Kettle Creek. This software system is for the analysis, prediction and design of aqueous toxic or conventional pollutant discharges into water bodies. The major emphasis is on the geometry and dilution characteristics of the initial mixing zone, but the system also predicts the behavior of the discharge plume at larger distances. The basic CORMIX methodology relies on the assumption of steady ambient conditions as well as a continuous discharge of the contaminant. Assumptions regarding the volumetric release rate of the contaminant were made to approximate the behavior of a control point contaminant release to Kettle Creek. Specifically, the modeled spill volumes were discharged at a continuous rate over a one half-hour time period. The following factors were applied to the modelling runs:

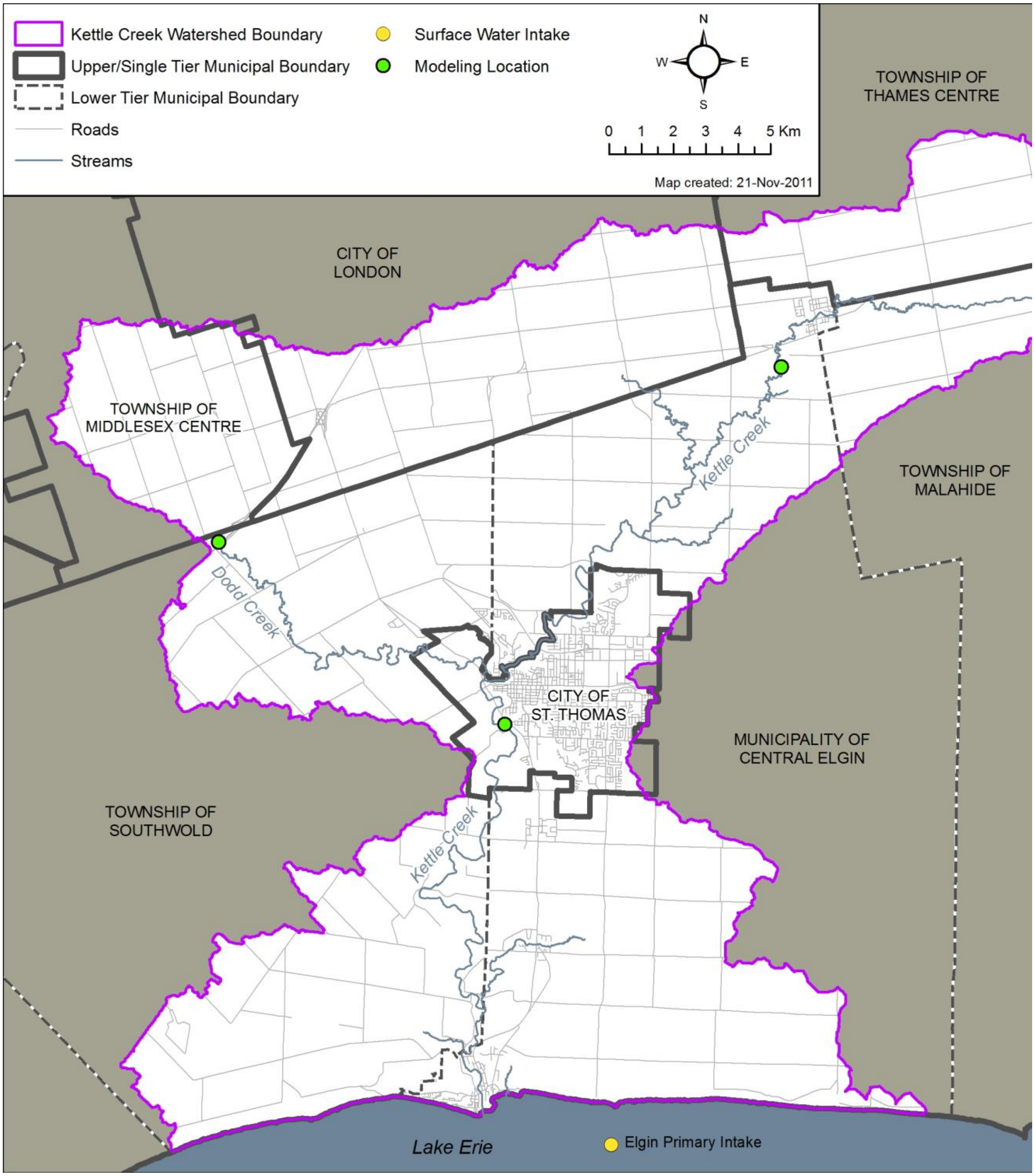
- Three general contaminants were considered to simulate chemicals with densities (1) heavier; (2) lighter; and (3) equal to that of water
- Simulations were performed for the 2-year return period flow and the 100-year return period flow; and
- Two spill volumes were considered per control point release – 2,500L and 10,000L

The modelling of the contaminants at the three control points illustrated a near-instantaneous rate of dilution to 1 percent or less that reached no more than 2,000 metres downstream of the discharge point. Since the three discharge control points are located a great distance from the mouth of Kettle Creek (e.g. 21, 43 and 48 kilometres upstream from the mouth of Kettle Creek) there would be a very high dilution factor of the contaminant. The dilution factor was estimated to be a minimum of 4 to 5 orders of magnitude. It is assumed that there would be further dilution of the theoretical contaminant in Lake Erie due to lake-based processes and the distance from the mouth of the creek to the intake.

The modelling completed to determine the extent of an IPZ-3 illustrated that an IPZ-3 was not applicable to the upper Dodd and upper/lower Kettle Creeks.

A complete description of the methodology for the IPZ-3 upper Dodd and upper/lower Kettle Creeks modelling for the Elgin Area Water Supply is provided in a technical memorandum, EAPWSS Source Protection Planning Surface Water Vulnerability Analysis: IPZ-3 Component (Stantec 2009).

Map 4-17: Modelling locations for determining an IPZ-3 for the Elgin Area Water Treatment Plant



4.7.5 Vulnerability Assessment

Vulnerability analysis of the IPZ-1 and 2 includes consideration for both the area and the source as described in the Technical Rules. The area vulnerability factor for an IPZ-1 is prescribed to be 10 in the Technical Rules while the area vulnerability factor for an IPZ-2 can range from 7 to 9.

The area vulnerability for an IPZ-2 takes into account three sub-factors: the percentage of the IPZ-2 area that is land; land characteristics (land cover, soil type, soil permeability and percent slope); and transport pathways (storm catchment area, tile drain area and number of storm outfalls / drains / watercourses). The Area Vulnerability score for the IPZ-2 for the Elgin Area Water Supply was determined to be 7.0 based on the following considerations:

- less than 1/3 of the IPZ-2 consists of land;
- land characteristics that describe moderate to low runoff potential; and
- limited storm catchment and tile drain area despite a number of storm outfalls, small watercourses and drains.

According to the Technical Rules (2021), the source vulnerability factor for a Great Lake intake (type A) can range from 0.5 to 1.0. When determining the source vulnerability factor consideration is given to intake characteristics, such as the depth of the intake, the distance the intake is offshore and whether there have been any identified water quality concerns at the intake. The source vulnerability was determined to be 0.5 considering that the intake is quite deep (7.9 metres); it extends out 1,200 metres from shore; and there have been few water quality concerns identified at the intake. The update to the Technical Rules in 2021 allow for the division of the IPZ-2 into multiple vulnerability scoring areas and for the source vulnerability factor of the intake to be increased as the updated range of source vulnerability factor is 0.5 to 1.0, compared to the previous range of 0.5 to 0.7. The updated Technical Rules were considered for the Elgin Area Water Supply System, however, it was determined that no changes to the IPZ-2 or source vulnerability factor were necessary.

Based on combining the area and source vulnerability scores, the overall vulnerability score for the Elgin Area Water Supply IPZ-1 was 5.0 and IPZ-2 was 3.5 (**Table 4-10**).

Table 4-10: Vulnerability score summary for the Elgin Area Water Supply Intake Protection Zone

Intake Type	Area Vulnerability Factor			Source Vulnerability Factor	Vulnerability Score		
Type A	IPZ-1	IPZ-2	IPZ-3	0.5	IPZ-1	IPZ-2	IPZ-3
Type A	10	7	N/A	0.5	5	3.5	N/A

A complete description of the methodology for the determination of the vulnerability score for the Elgin Area Water Supply Intake Protection Zones is provided in the report entitled Elgin Area Water Supply System Source Protection Planning Technical Study Update (Stantec, 2009).

4.7.6 Percentage of Impervious Surfaces within Intake Protection Zones

The Intake Protection Zone 1 is entirely within Lake Erie and does not have impervious surfaces. The vulnerability scores in the Intake Protection Zone 2 for the Elgin Area Water Supply is less than the vulnerability score necessary for the related activities to be considered a threat in the Tables of Drinking Water Threats. As such, the percentage of impervious surface area where road salt can be applied has not been calculated for this Assessment Report.

4.7.7 Managed Lands and Livestock Density within Intake Protection Zones

The Intake Protection Zone 1 is entirely within Lake Erie and does not have land for which to calculate per cent managed land and livestock density. The vulnerability scores in the Intake Protection Zone 2 for the Elgin Area Water Supply are less than the vulnerability score necessary for the related activities to be considered a threat in the Ministry of the Environment's Table of Drinking Water Threats. As such, the percentage of managed lands and livestock density were not calculated for this Assessment Report.

4.8 Elgin Area Water Supply Threats Assessment

The identification of a land use activity as a significant, moderate, or low drinking water threat depends on its risk score, determined by considering the circumstances of the activity and the type and vulnerability score of any underlying protection zones, as set out in the 2021 Technical Rules. The information above can be used with the vulnerability scores to help the public determine where certain activities are or would be significant, moderate and low drinking water threats.

Table 4-11 provides a summary of the threat levels possible in the Elgin Area Water Supply Intake Protection Zones for Chemical, Dense Non-Aqueous Phase Liquid (DNAPL) and Pathogens. A checkmark indicates that the threat classification level is possible for the indicated threat type under the corresponding vulnerable area / vulnerable score; a blank cell indicates that it is not.

Table 4-11: Identification of Drinking Water Quality Threats in the Elgin Area Water Supply Intake Protection Zones

Threat Type	Vulnerable Area	Vulnerability Score	Significant 80+	Moderate 60 to <80	Low >40 to <60
Chemicals	IPZ-1	5	No	No	Yes
Chemicals	IPZ-2	3.5 & 5	No	No	No
Handling / Storage of DNAPLs	IPZ-1	5	No	No	Yes
Handling / Storage of DNAPLs	IPZ-2	3.5	No	No	No
Pathogens	IPZ-1	5	No	No	Yes
Pathogens	IPZ-2	3.5 & 5	No	No	No

Threats assessment was completed in two capacities:

- based on the vulnerability attributed to the intake protection zones; and
- based on existing land use activities.

Based on the vulnerability score of 5 for the IPZ-1, the number of possible threats identified for the original 2010 version of the assessment report, was 570 low level threats; however, since there is no land in the IPZ-1, these threats were not applicable.

Based on the existing land use activities and that the IPZ-2 vulnerability score is 3.5, of the 458 properties identified in the IPZ-2, there were no land use activities identified as significant, moderate or low drinking water threats.

4.8.1 Event Based Drinking Water Threats

Under the 2021 Technical Rules an activity can also be identified as a significant drinking water threat following the event based approach, if within an Intake Protection Zone the activity could result in the release of a chemical parameter or pathogen that would be transported to the intake and result in the deterioration of the water for a drinking water source (Rule 130).

At the time of the investigation (2012), two significant drinking water threat events based investigations were completed.

- the handling and storage of 5,000 m^3 or more of commercial fertilizer and,
- the handling and storage of 6,000 Litres or more of fuel.

In recent years, the bulk storage tanks of fertilizer were removed, and the previous industrial lands are being rezoned as part of the Secondary Plan for the Port Stanley Harbour area. The Events Based Area and associated IPZ-3 for the Urea Ammonium Nitrate (UAN) fertilizer threat have been removed as part of the 2024 assessment report update.

For the diesel spill scenario, a 2-D approach was used to approximate the extent to which the diesel spill would impact the intake. A spill volume of 6,000 L of diesel was spilled over a period of 24 minutes into a drain located at the Water Treatment Plan. This drain extends from the Water Treatment Plan property to the Lake Erie nearshore. The spill concentration (spill loading rate/flow rate) was increased from 0 at the start of the spill, increasing linearly to a maximum at 12 minutes, and then falling linearly again to 0 at 24 minutes. A generic maximum concentration of 100 mg/L was assumed in the analysis, and the resulting concentration at the intake was assumed to represent the dilution factor that would be applied to a contaminant concentration at the plant drain outfall. For the scenario, a moderate event was deemed to have the greatest potential to cause adverse effects at the intake and be consistent with the definition of an ‘extreme event’ as defined in the Technical Rules. An offshore windspeed of 5 m/s was used in a cropped 2-D hydrodynamic model with flux boundaries.

Table 4-12: Modelled concentration of Diesel fuel from 6000 L spill over 24 minutes

Category	Scenario1	Scenario 2
Turbulent Diffusion (m^2/s)	1	7
Initial Concentration	100 mg/L	100 mg/L
Concentration at Intake	0.32 mg/L	0.24 mg/L
Dilution Factors	0.0032	0.0024

Table 4-12 outlines the turbulent diffusion factors, concentrations and dilution factors used in the two modeled scenarios for the diesel spill. The resulting dilution factors were used to determine the potential concentration of benzene at the intake under the modeled conditions. The concentration of benzene in diesel fuel is approximately 76 mg/L depending on refining methods. Using this concentration and the dilution factor of approximately 0.0024, the resultant concentration at the intake is 0.1824 mg/L which is greater than the 0.005 mg/L Ontario Drinking Water Quality Standards limit.

It is important to note that this modelling scenario is a 3-D problem given the buoyancy of the contaminant and the fact that the critical hydrodynamic condition in the lake may be a strong offshore surface current. This current would move the upper portion of the plume towards the intake, or possibly an onshore wind which would generate setup, and move the lower portion of the plume offshore via the downwelling current. It is a condition that is not well represented by the 2-D modelling. Therefore, a number of assumptions were used to apply the current 2-D model to this scenario including the modification and cropping of the boundary conditions to represent the area of concern (intake); applying empirical estimates of wind-generated currents; and the direction of the trajectory of the plume. These assumptions and the limited 2-D approach suggest that these results are preliminary and have a high level of uncertainty. However, the study team felt that the high estimate of pollutant concentration (0.1824 mg/L) relative to the Ontario Drinking Water Quality Standards (0.005 mg/L) and the extremely close proximity of the discharge of the WTP storm drain to the IPZ-1 necessitates the inclusion of this activity as a significant drinking water threat. Further study is required to refine this modeled significant drinking water threat.

A complete description of the methodology of the events based approach for identifying significant drinking water threats for the Elgin Area Water Supply is provided in the report entitled Elgin Area WTP Source Protection Planning IPZ-3 Analysis (Stantec, 2012).

Modelling shows that under certain environmental conditions, a spill of diesel fuel from the Water Treatment Plant could result in a deterioration of the water used as a source of drinking water at the intake. **Map 4-18** illustrates the areas where modelling supports the designation of fuel as a significant drinking water threat for the Elgin Area Water Treatment Plant. **Table 4-13** lists the fuel threat and its associated circumstance. The urea ammonium nitrate fertilizer significant drinking water threat, Events Based Area and IPZ-3 have been removed from the map and table as it is no longer a significant drinking water threat due to the removal of the storage tanks and the rezoning of the lands.

Map 4-18: Areas where modelling supports the designation of significant drinking water threats for the Elgin Area Water Treatment Plant

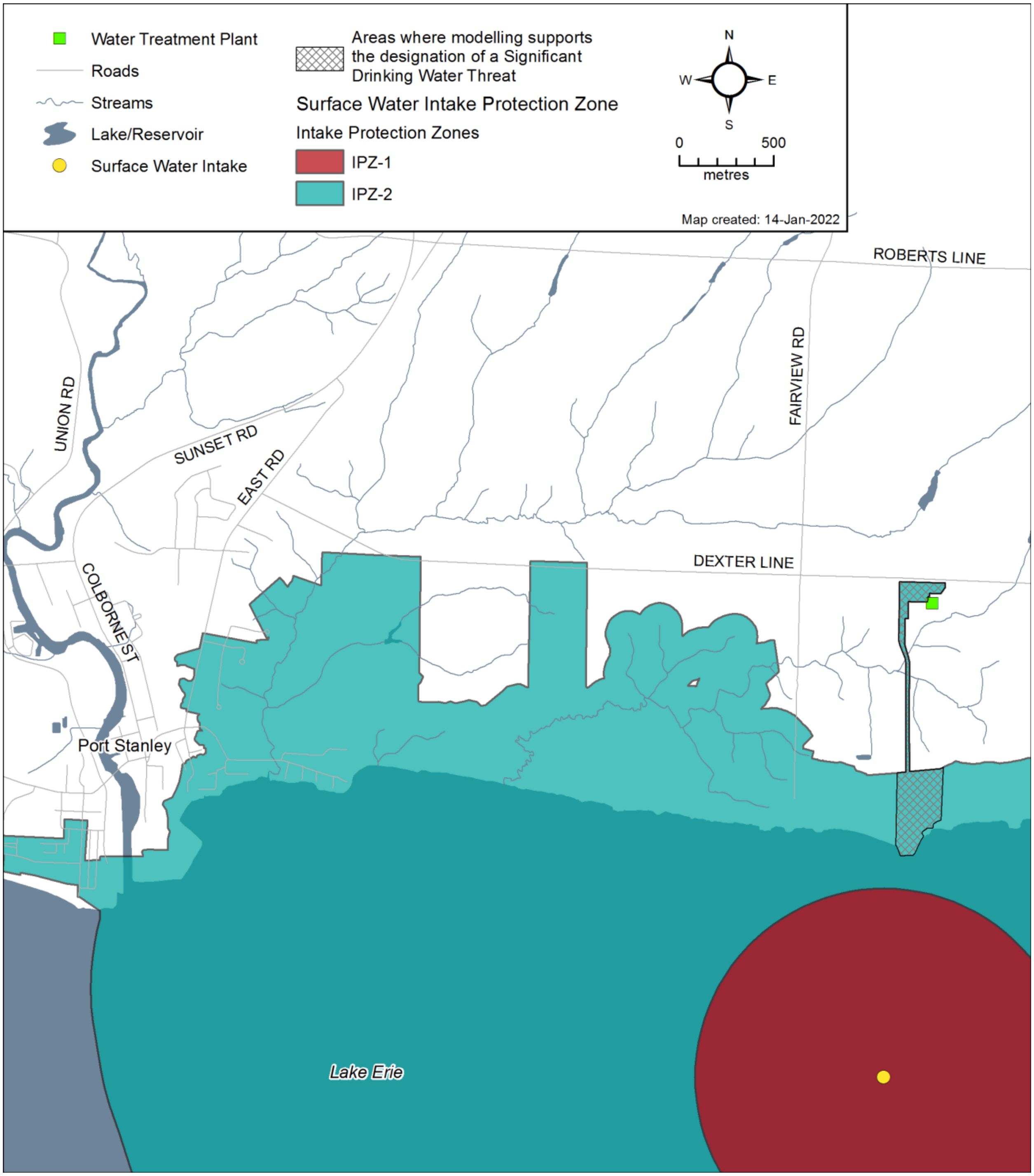


Table 4-13: Significant Drinking Water Quality Threats in the Elgin Area Water Supply Intake Protection Zones – current as of March 2022

PDWT[1] #	Threat Subcategory	Number of Activities	Vulnerable Area
15	The handling and storage of fuel	1	IPZ-2

Total number of properties: 1.
Total number of activities: 1.
Total number of conditions: 0.
1: The Prescribed Drinking Water Threat Number refers to the prescribed drinking water threat listed in O.Reg.287/07 s.1.1.(1).

4.8.2 Conditions Evaluation

As stated in the 2021 Technical Rules, conditions may exist in a vulnerable area if the presence of a single mass of more than 100 litres of one or more dense non-aqueous phase liquids (DNAPLs) occurs in the surface water of an IPZ and/or if there is the presence of a contaminant in the surface soil or sediment. Consequently, the conditions assessment for the IPZ-2 completed as part of the original 2010 version of the assessment report, included the evaluation of soil and sediment quality data from the Port Stanley Harbour and Pier from available technical reports.

From the review of the technical reports, arsenic, chromium, copper, lead, mercury, nickel, PCBs, silver and zinc are sediment contaminants that are conditions within the IPZ-2 vulnerable area. Additionally, antimony, arsenic, lead, selenium, toluene, and PAH's are soil contaminants that are conditions for the IPZ-2 vulnerable area.

Technical Rule 139 prescribes the hazard rating to be 10 for all conditions that result from past activities where there is evidence of off-site contamination. Given that the vulnerability score for the IPZ-2 was 3.5, the maximum risk score for the activities that resulted from past land uses was calculated to be 35. This score is below the threshold that constitutes a low level threat (e.g. risk scores between 40 and 60). Therefore, no conditions were identified as drinking water threats.

4.9 Elgin Area Water Supply Issues Identification and Parameters of Concern

In 2009, historic water quality data from the MECP's Drinking Water Information System (DWIS) and Drinking Water Surveillance Program (DWSP) were reviewed to determine whether any parameters exceed Ontario Drinking Water Standards (ODWS). ODWS are instruments to be applied to treated water only; however, they were applied to raw water samples for the purposes of this assessment to determine whether any parameters should be flagged for further review. Nine water quality parameters in raw water samples were identified to have regularly exceeded ODWS for aesthetic objectives or operational guidelines: aluminium, colour, hardness, iron, manganese, organic nitrogen, pH, temperature, and turbidity.

All nine parameters do not directly impact human health. Most of the parameters are attributed to naturally occurring processes and characteristics and therefore not considered drinking water Issues at this time.

The Elgin Area Water Supply preliminary Issues identification and parameters of concern was completed at the time of the intake protection zone delineation in 2009. The information presented in the following section describes the current (2022) water quality concerns at the Elgin Area Water Supply Intake.

4.10 Current Water Quality Concerns at the Elgin Area Water Supply Intake

Enhanced monitoring strategies at the Elgin Area Water Supply System for the nine parameters identified as preliminary Issues or parameters of concern have been developed.

Regular monitoring continues for all nine parameters identified. In some cases, the monitoring strategy has been enhanced since the last assessment report, through storm sampling or additional baseline monitoring. The Elgin Area Water Supply System continues to look for additional opportunities for enhanced monitoring.

Below is the current sampling program for the 9 parameters:

- Since 2009, pH, temperature, and turbidity are continuously monitored (online analyzers in SCADA) as well as tested in the on-site lab daily.
- Since 2009, aluminium and colour are tested in the on-site lab daily.
- Hardness, organic nitrogen, and iron are tested annually for baseline monitoring.
- Since 2011, storm samples are taken during seasonal weather events. The purpose of this monitoring is to better understand raw water quality during peak events, and assess the Water Treatment Plant performance during these events. Iron and manganese are included in the storm sampling.
- From 2017 to 2022, the sampling frequency of manganese was increased to monthly. Effective in 2022 manganese sampling is increased to a daily monitoring frequency during the period August 1st to November 30th. This ties in with the details of the manganese event sampling discussed below.

Harmful Algal Bloom (HAB)

In recent years, Lake Erie has experienced severe blue-green algal (cyanobacteria) blooms. Algal blooms can create challenges for the Elgin Area Water Supply System by producing unpleasant taste and odours, interfering with treatment plant performance, and producing cyanotoxins which can impact human health.

Several monitoring programs are in place to keep drinking water safe from potential impacts of overgrowth of aquatic algal bacteria (i.e. cyanobacteria) that produce or have the potential to produce toxins (i.e. cyanotoxins). Toxins can be released in the surrounding water when the algal cells are damaged or die. These toxins, which include microcystins, can be harmful to people.

For operational purposes, the Elgin Area Water Supply System has developed a Harmful Algal Bloom (HAB) Monitoring and Sampling Program. A Standard Operating Procedure (SOP) is in place to guide operational response. The procedure includes visually monitoring the lake and shoreline conditions, monitoring incoming raw water quality for changing conditions that may indicate the presence of a HAB (e.g., Low dissolved oxygen), and monitoring operational parameters such as taste and odour. The Elgin Area Water Supply System performs weekly microcystin sampling on a seasonal basis, from June through the end of October.

Through the Ministry of the Environment, Conservation and Parks' Drinking Water Surveillance Program (DWSP), the Elgin Area Water Supply System has also participated in an algal toxins monitoring program since 2014. The purpose of the MECP research is to monitor algal toxins to determine the levels of microcystins in drinking water. Participation takes place seasonally, typically June through November, and the samples are submitted to the MECP laboratory for analysis. The MECP algal toxins monitoring program was suspended in 2019 but may resume at a future date.

The test results received to date through both monitoring programs indicate that microcystin has occasionally been detected in raw water at relatively low concentrations, however no microcystin has been detected in the treated drinking water.

Low Dissolved Oxygen and Manganese

Lake Erie is prone to experiencing seiches, which are typically caused by strong wind blowing the warmer surface water to one end of the lake. The colder water of the hypolimnion (the lower layer of a stratified lake) then moves in waves causing the mixing of the hypolimnion. This lower water is typically anoxic. In an anoxic zone, microorganisms that are deprived of free oxygen will scavenge oxygen from chemical compounds that contain oxygen, including iron and manganese compounds. As the chemical compounds are scavenged for their oxygen, the metals are released into the water column resulting in appreciably higher concentrations of those metals. Along with those metals, low dissolved oxygen and lower pH values will be evident.

Storm events, seiches, seasonal lake turnover events, algal biomass degradation, and other factors can all contribute to low dissolved oxygen events in Lake Erie. This leads to high levels of soluble manganese which when not adequately oxidized can pose treatment plant issues and potential for discoloured water, staining, and taste concerns in treated drinking water.

The Elgin Area Water Supply System has developed a SOP to assist operations in dealing with low dissolved oxygen and manganese events.

In addition to the routine continuous monitoring of raw water, a new seasonal sampling program has been implemented in which operations will sample for manganese daily during the period August 1st to November 30th. In the event that manganese levels start increasing, operations will initiate a more comprehensive sampling program that includes testing of various parameters at each stage within the water treatment process and distribution system.

The Elgin Area Water Supply System experienced a low dissolved oxygen and manganese event in September 2021. This was the most challenging manganese event experienced to date. The highest value of manganese in the incoming raw water was 0.636 mg/L on September 11, 2021.

4.10.1 Technical/Peer Review Process

Technical/Peer review for the surface water vulnerability was completed, iteratively, by Sandra Cooke, Senior Water Quality Supervisor, Grand River Conservation Authority throughout the process of drafting the Surface Water Vulnerability report for the Elgin Area Water Board to ensure the consistent application of the Ministry of the Environment, Conservation and Parks' *Clean Water Act*, 2006 Technical Rules. Comments on draft reports were formally prepared in memo format and submitted to the project manager, Brian Lima, City of London and their Consultant, Stantec Consulting Ltd., for consideration. Less formal comments were sent via email.

The City of London and their consultant included all technical/peer review comments and their responses in their final report in Appendix 1.2: Client Comments.

4.10.2 Uncertainty Ranking

Uncertainty was assessed by the Consultant for the delineation of the IPZ's and the vulnerability scoring for the Elgin Area Water Supply intake. Uncertainty was considered for the (1) data that was used in the analysis; (2) modelling; (3) quality assurance and quality control; (4) calibration and validation; and (5) accuracy of the vulnerability factors. Overall, the delineation of the IPZ1 was considered 'low' while the delineation of the IPZ2 and IPZ3 was considered 'high'. Inherent uncertainty associated with large in-lake modelling resulted in a 'high' score for the IPZ2 delineation and the assumptions that were used to identify the extent of the IPZ3 should also contribute to a 'high' uncertainty score. Sufficient data and information were gathered to assign a 'low-level uncertainty' for the vulnerability score for both the IPZ1 and IPZ2.

Given the inherent vulnerability with modelling, the project team felt that there was sufficient information and analysis completed to ensure that the intent of the Technical Rules to delineate and score vulnerability areas for the Elgin Area Water Supply intake was met. Therefore, the vulnerability assessment for the Elgin Area Water Supply intake, at the time of this report, is classified as having a low uncertainty.

4.11 Climate Change Vulnerability Assessment on Elgin Area Water Supply System

The Technical Rules (MECP, 2021), under the *Clean Water Act*, 2006*,* include the consideration of climate change in source water quality risk assessments. Technical Rule 15.3 allows local source protection authorities to consider climate change information, data, and analysis as part of the local assessment report and source protection plan.

Climate change impacts on water quantity have been recognised in the Technical Rules as part of the water quantity water budget assessment. Technical Rule 19(13) requires the inclusion of climate data in the conceptual water budget where climate change projections and modelling are completed.

Climate change impact assessment results may inform local discussions and decision-making on how to address climate change impacts. The climate change impact assessment results do not alter the delineation or the scoring of vulnerable areas, nor do they affect the risk level of drinking water threats outlined in the local source protection plan and assessment report.

In July 2021, the Elgin Area Water Supply System utilized the Climate Change Vulnerability Assessment Tool for the intake and area level sensitivities related to climate change. The goal of the assessment was to aid in the evaluation of the current and predicted states of the Elgin Area Water Supply System and identify which components of the system may be most susceptible to climate change impacts.

4.11.1 Overview of Climate Change Vulnerability Assessment Tool

A Climate Change Vulnerability Assessment Tool (Assessment Tool) was developed to assess groundwater well and surface water intake sensitivities and vulnerabilities due to climate change. The information pertaining to the Assessment Tool in this section references the document 'Climate Change Vulnerability Assessment Tool for Drinking Water Source Quality (2020)' which was created by Conservation Ontario (Milner et al., 2020).

The Assessment Tool's main purpose is to provide science-based guidance to governing bodies on how to assess climate change vulnerabilities to source water quality at a macro-level, related to drinking water. The Assessment Tool assesses both water supply intake sensitivity and area level sensitivity, as well as the overall adaptive capacity of the system, to identify climate change vulnerabilities that are specific to the area surrounding the drinking water system.

The Assessment Tool utilizes a series of linked Excel worksheets to assess climate change exposure, evaluate climate change sensitivity at the intake, and assess the adaptive capacity and climate change vulnerability of the area and intake. It also provides a qualitative climate change vulnerability rating and examines how it relates to existing drinking water quality threat risk assessments.

The results of the climate change vulnerability assessment are intended to be used in adaptation and risk mitigation strategy planning, capital planning and process optimization. The assessment can also indicate how resilient the system is to climate change risks.

4.11.2 Assessment Approach

The assessment approach used to evaluate climate change impacts on water quality includes the scale of the study area, the type of approach (i.e., qualitative or quantitative) and the concept of the approach (i.e., top-down or bottom-up). The assessment approach for the climate change vulnerability assessment on the Elgin Area Water Supply System is discussed below.

Scale of Assessment

The Assessment Tool uses worksheets to evaluate the components of climate change vulnerability at different scales.

The Climate Change Exposure worksheet evaluates exposure at a larger geographic scale. Kettle Creek Source Protection Area was chosen as the scale for the study area in the Climate Change Exposure worksheet for the Elgin Area Water Supply System climate change vulnerability assessment. The Kettle Creek Source Protection Area was chosen as the scale because climate data was readily available at the watershed scale and not the water supply system scale but assumed to be similar given their relative location and size.

The Climate Change Sensitivity, Climate Change Impacts and Adaptive Capacity worksheets evaluate the components at both the study area and system scales and combine information from these two scales to determine the final climate change vulnerability. As mentioned above, the study area scale is the Kettle Creek Source Protection Area. The system scale was chosen as the Elgin Area Water Supply System's service area.

The Source Water Quality Risks worksheet reviews risk to source water quality at the IPZ or WHPA scale. The vulnerable area scale was chosen as the Intake Protection Zones of the Elgin Area Water Supply intake.

Type of Approach

The assessment of climate change impacts on water quality can be done quantitatively, qualitatively, or a combination of both. The quantitative approach uses numerical modelling and analytical tools to understand the relationships between climate indicators (e.g., temperature, precipitation) and hydrological characteristics of the drinking water sources (e.g. surface water levels, aquifer water tables). The qualitative approach depends on local expert/traditional knowledge and experience, historical information on specific climate events that may have impacted the quality of water, and a literature review of studies conducted for a specific drinking water system.

A combination of both a quantitative and qualitative approaches were used for the climate change vulnerability assessment for the Elgin Area Water Supply System. The final results of the climate change vulnerability assessment are in a qualitative term that can inform discussions around climate change adaptation actions and risk mitigation measures.

Concept of the Approach

There are two common concepts to understand climate change impacts on drinking water quality: top-down and bottom-up. The top-down approach concept relies on global climate models, regional downscaling approaches, and hydrologic models to predict climate change impacts and vulnerabilities at a local water system. The bottom-up approach concept relies on a local understanding of past and existing conditions of a topic or theme (e.g., water quality analysis) that helps to estimate the future resiliency and adaptation to climate change (*CCME, 2013*).

The Climate Change Vulnerability Assessment Tool is a bottom-up approach with user inputs that include information from local source protection plans (including the science-based assessment reports), watershed characterization reports, municipal planning documents, municipal water and wastewater master plans, Drinking Water Quality Management reports, climate change studies, journal publications, reliable climate data portals as well as a wealth of local knowledge and expertise from local and cross-jurisdictional organizations, agencies, working groups and committees.

4.11.3 Data Used for the Climate Change Vulnerability Assessment

Selecting a Climate Change Scenario

The assessment tool requires users to obtain certain climate data, the values of which depend on "climate change scenarios" of future projections. The assessment tool allows flexibility for users to choose the climate change scenario as deemed appropriate. These climate change scenarios are called "Representative Concentration Pathways" (RCPs) and are defined by the Intergovernmental Panel on Climate Change (IPCC).

The RCPs represent future total radiative forcing, which is a cumulative measure of human emissions of greenhouse gases from all sources expressed in Watts per square metre, pathways, and level by 2100 (IPCC, 2014). Each RCP represents a different combination of economic, technological, demographic, policy, and institutional futures (IPCC, 2014b).

The climate change scenario chosen for the Elgin Area Water Supply System climate change assessment is RCP 8.5 (high emissions or business as usual scenario) where emissions continue to rise into 2100 and beyond (IPCC, 2014; Riahi et al. 2011). This scenario indicates global average warming levels of 3.2 to 5.4°C by 2090 (ECCC, 2018b).

Obtaining Climate Data

To obtain historical and predicted climate trends, climate data was found in the Climate Atlas of Canada, the Ontario Climate Data Portal and Natural Resources Canada. The historical data from the Climate Atlas was collected from 1950 to 2013, while the modelled future data covered 2014 to 2095. The Climate Change Assessment Tool analyzes ten climatic parameters that are most relevant to source water quality. These specific parameters were selected based on literature review, consultation with subject matter experts, and considerations of data limitations and availability. This data was graphed for each parameter and statistical analysis was used to determine whether the trends were increasing, decreasing, or staying the same over time.

Table 4-14 provides the climate parameters and their annual historical and future climate trend, where available. The sources of data used for each climate parameter is provided. Discussion on the climate trends is provided in the following section.

Table 4-14: Trends and Data Sources for Historical and Future Climate Data

Climate Parameter	Historical Climate Trend	Future Climate Trend	Historical Data Source Used	Future Data Source Used
Minimum Temperature	Increasing	Increasing	Climate Atlas of Canada	Climate Atlas of Canada
Maximum Temperature	Increasing	Increasing	Climate Atlas of Canada	Climate Atlas of Canada
Precipitation	Not Changing	Increasing	Climate Atlas of Canada	Climate Atlas of Canada
Heavy Precipitation	Increasing	Increasing	Climatedata.ca	Climatedata.ca
Very Hot Days (+30°C # of days)	Not Changing	Increasing	Climate Atlas of Canada	Climate Atlas of Canada
Frost Free Season (# of days)	Increasing	Increasing	Climate Atlas of Canada	Climate Atlas of Canada
Freeze-Thaw Cycles (# of days)	Decreasing	Decreasing	Climate Atlas of Canada	Climate Atlas of Canada
Maximum Length of Dry Spell	Not Changing	Not Changing	Ontario Climate Data Portal (OCDP)	Ontario Climate Data Portal (OCDP)
Rainfall	Not available	Increasing	Not available	Natural Resources Canada, 2011
Snowfall	Not available	Increasing	Not available	Natural Resources Canada, 2011

4.11.4 Results of Climate Change Vulnerability Assessment Tool on the Elgin Area Water Supply System

Climate Change Exposure

An assessment of climate trends using historical and future climate data was completed for the Kettle Creek watershed.

The result of the trend analysis is an overall climate exposure rating of high. During the spring and winter months, the climate parameters driving the high exposure rating are minimum/maximum air temperature, precipitation, and heavy precipitation. During the summer and fall months, the climate parameters driving the high exposure rating are minimum and maximum air temperature. On an annual basis, the climate parameters driving the high climate exposure rating are minimum/maximum air temperature, precipitation, heavy precipitation, very hot days, and the frost-free season (Bryans, 2022).

Area and Intake Sensitivity

An assessment of the area level sensitivity was completed for the Kettle Creek Source Protection Area. The Kettle Creek Source Protection Area has an overall Area Level Sensitivity of 71 percent, meaning of all attributes assessed, 71percent were highly sensitive to climate change. Examples of area-level attributes within Kettle Creek Source Protection Area with high area level sensitivity are listed below.

- the size of the area, general information of current and future populations the drinking water system serves,
- current and future land uses (e.g., built-up area, agricultural land, areas drained by storm sewers, etc.) and,
- historical issues with flooding, contamination, or drought events in the past.

The weighted attributes are used to calculate the final climate change impact score.

An assessment of the intake sensitivity was completed for the Elgin Area Water Supply System intake. Examples of intake attributes include the depth below water level, distance from shoreline, percent of intake protection zone (IPZ) on land, slope of land in IPZ, and soil permeability. These characteristics are important to document, as they can help determine the sensitivity of source water quality, which in turn may increase or decrease the system's vulnerability to climate change conditions in the future. Like the area level sensitivity, the weighted attributes are used to calculate the final climate change impact score.

The Elgin Area Water Supply intake had an overall intake sensitivity of 50 percent, which indicates a low intake sensitivity. This means of all the attributes assessed, 50 percent were highly sensitive to climate change (Bryans, 2022).

Climate Change Impact at the Area and Intake Scales

Potential climate change impact is any impact that may occur given projections of changing climate conditions, without any consideration of the system's adaptive capacity. It is a product of exposure and sensitivity.

The results from the climate change exposure rating and the climate change sensitivity rating are used to calculate the climate change impact score. The final climate change impact score for the Elgin Area Water Supply System intake is 6.9/9 or a qualitative impact rating of high. A high rating suggests that the quality of the drinking water source will be affected by climate change, and existing source protection plan policies may not be sufficient to protect it (Bryans, 2022).

Climate Change Adaptive Capacity and Climate Change Vulnerability

Adaptive capacity is the ability of a system to adjust to climate change (including climate variability and extremes) in order to moderate potential damages, to take advantage of opportunities, or to cope with the consequences.

The adaptive capacity calculated for the Elgin Area Water Supply System intake is 82 percent or high adaptive capacity. A high percentage adaptive capacity score implies more adaptive capacity (i.e., greater ability to address impacts and variability from climate change). The high adaptive capacity at the Elgin Area Water System intake can be attributed to the ability of the system to accommodate decreased raw water quality, existing redundancy with the adjoining Lake Huron Water Supply System (intake) and having existing municipal policies and management procedures in place that aid in mitigating climate-related risks. For example, Safe Operating Procedures are available for addressing impacts of climate change such as contamination of raw water, obstruction of intake, and responding to algal blooms (Bryans, 2022).

Climate Change Vulnerability to Source Water Quality

In the context of the assessment tool, climate change vulnerability of source water refers to any drinking water source that will likely be adversely affected by local climate change impacts now and in the future.

The assessment tool determines an overall climate change vulnerability score based on the overall climate change impact and adaptive capacity scores**.** The resulting climate change vulnerability rating for the Elgin Area Water Supply System is low (Bryans, 2022).

Climate Change Vulnerability Assessment and Water Quality Threats Assessment

Elgin Area Water Supply System has one existing significant drinking water threat, the handling and storage of fuel (diesel fuel tanks for backup generators at the water treatment plant). The suggested action through the climate change vulnerability assessment tool for this drinking water threats is to determine if additional actions are needed to account for any climate change impacts. This threat has been addressed through a Risk Management Plan (RMP), so no further action is required at this time (Bryans, 2022).

The results of the assessment tool can be used to help inform discussions around protection, operations, management and adaptation actions at both the municipal and watershed scales. They may serve to further encourage and enhance climate change risk management of drinking water system infrastructure and support local climate change strategies and Climate Action Plans.

4.11.5 Uncertainty Assessment of the Climate Change Vulnerability Assessment

The Assessment Tool allows for the user to determine the uncertainty of their inputs and analyses and assign a level of "high" or "low" uncertainty for each step of the climate change vulnerability assessment.

Uncertainty exists in the accuracy and reliability of climate-related data (both historical and future). This includes instrument error and limitations associated with downscaled global climate models which generally do not consider local attributes and micro-climates (e.g., lake effect snow).

The assessment tool takes a conservative approach to calculate the vulnerability of source water quality to climate change. This is done to account for all possibilities of climate change impacts in the future. For example, the assessment tool takes the maximum climate change exposure rating across all seasons, and multiplies this by the sensitivity scores, making the climate change impact scores the maximum that they can be, given the inputs to the assessment tool.

The uncertainty assessment for the work associated with the climate change vulnerability assessment for the Elgin Area Water Supply System was based on expert judgement. Uncertainty is assessed for the climate change exposure, area sensitivity, intake sensitivity, climate change impact and adaptive capacity worksheets. The information below **Table 4-15** assigns the level of uncertainty for each part of the assessment with a description of what was considered in the uncertainty assessment.

Table 4-15: Uncertainty Assessment for Climate Change Assessment for Elgin Area Water Supply

Worksheet	Uncertainty Level	Considerations for Uncertainty Assessment
Climate Change Exposure	High	• minimum / maximum temperatures, • precipitation, • heavy precipitation (intensity), • very hot days, and • frost-free days.
Area Sensitivity	High	• future percentage of agricultural fields within of the Kettle Creek Source Protection Area for the municipal planning horizon, and • stormwater system capacity.
Intake Sensitivity	Low	• number of intakes, and • threats to water quality.

Intake Impact	High	• Potential for increased vulnerability due to intake type and number • Potential for water quality issues to worsen • Potential for water quality degradation due to presence of discharges near intake • Water quality threats identified through a Drinking Water Quality Management Standard (DWQMS) risk assessment
Adaptive Capacity	Low	• Potential for increased contaminant loadings due to size of the area • Potential for increased contaminant loadings due to percent of agricultural fields • Existence of flood plains and potential for flooding to impact properties and infrastructure • Potential for water quality degradation from sewage • Potential for water quality degradation from storm sewers

4.11.6 Conclusions

From the results of the Climate Change Vulnerability Assessment Tool, the Elgin Area Water Supply system and Kettle Creek source protection area are susceptible to climate change impacts. However, the Tool demonstrated the water system as having a high adaptive capacity and is resilient to climate change impacts. This can be attributed to the existing source protection plan policies, and management policies and procedures currently in place.

Although the overall climate change vulnerability score was qualitatively low, the Climate Change Vulnerability Assessment Tool provided recommendations to be investigated further.

The next steps in utilizing this Tool include collaborating with area source protection committees and municipalities. This will enable the Elgin Area Water Supply System to better adapt to the potential impacts climate change may have on the system. This includes being able to maintain levels of service to the benefiting municipalities by being proactive when it comes to planning for climate change related impacts.

4.12 Section Summary

Regional Aquifer Vulnerability

- Aquifer vulnerability was mapped across the watershed using the Surface to Aquifer Advection Time (SAAT) method.

- Areas of medium and high aquifer vulnerability are located across the southern extents of the watershed, roughly coincident with the shallow, unconfined aquifer of the Norfolk Sand Plain.

- The northern extents of the watershed have been assessed as low vulnerability. This area is generally comprised of the clay-rich Port Stanley Till, which provides protection to the deeper, confined overburden aquifers.

- Areas mapped as having a high aquifer vulnerability are considered Highly Vulnerable Aquifers (HVAs). These areas received a vulnerability score of 6.

- Managed lands were calculated to be between 40 and 80 percent of the total land area within the Highly Vulnerable Aquifers.

- Livestock density was calculated to be <0.5 Nutrient Units per acre within the Highly Vulnerable Aquifers.

- Impervious surfaces as related to road salt application fell into 2 categories: <1 percent and 1 to <8 percent of the total area within the Highly Vulnerable Aquifers.

- Given that the maximum vulnerability score a Highly Vulnerable Aquifer can receive is a 6, significant threats cannot be located within Highly Vulnerable Aquifers.

- To date, no drinking water Issues have been identified in the Highly Vulnerable Aquifers. Public Health Units are undertaking risk assessments of all small drinking water systems, and may, through that process, identify possible Issues for a future Assessment Report.

Significant Groundwater Recharge Areas

- Significant Groundwater Recharge Areas were delineated as part of the water budget studies. Groundwater recharge was estimated using a hydrologic model.

- To date, no drinking water Issues have been identified in the Highly Vulnerable Aquifers. Public Health Units are undertaking risk assessments of all small drinking water systems, and may, through that process, identify possible Issues for a future Assessment Report.

Village of Belmont Groundwater Supply

- The village of Belmont's groundwater supply system collects water from two pumping wells and, on average, supplies approximately 343 m^3 of water per day to approximately 1,950 residents.

- The wells obtain their water from a deep, confined overburden aquifer that is overlain by approximately 30 metres of clay-rich till.

- Four Wellhead Protection Areas were delineated, one a 100 metres proximity zone, and the others time-related (2-year, 5-year and 25-year) capture zones generated through a groundwater model.

- A transport pathway assessment was completed for the Wellhead Protection Areas and resulted in an adjustment (increase) to the vulnerability scoring in areas where private wells may exist in relatively high concentrations. Most of the vulnerability score increases occurred within the 2-year WHPA where there was an increase from a score of 6 to 8 and in the 5-year WHPA where the score was increased from 2 to 6 in several parcels.

- Impervious surfaces as related to road salt application were calculated for the WHPAs. The results concluded that road salt application is not a significant threat to the Belmont municipal water supply.

- A water quality threats assessment was completed for the WHPAs and showed no significant threat within WHPA A.

- An Issues-based threats analysis was also completed through a review of water quality data collected from the municipal well. No issue-based threats were identified within the municipal groundwater system.

Elgin Area Water Supply System

- The Elgin Area Water Supply System is a municipal drinking water system serving approximately 100,000 people in the Cities of London and St. Thomas, the Municipality of Bayham, Municipality of Central Elgin, Township of Malahide, Township of Southwold and the Town of Aylmer.

- The surface water intake is located approximately 1,200 metres offshore of the town of Port Stanley in Lake Erie.

- The Intake Protection Zone (IPZ) 1 is delineated as a circle that has a radius of 1000 metres centred on the crib of the intake. The IPZ-1 does not intersect with land. The resulting vulnerable area of IPZ-1 was given a vulnerability score of 5.0.

- IPZ-2 was delineated by numerical modelling to encompass a two-hour travel time. The delineated area includes both in-water and on-shore areas. The vulnerability of IPZ-2 was found to be low and was given a score of 3.5.

- In 2012, event-based modelling scenarios illustrated that spills of Urea Ammonium Nitrate fertilizer from harbor lands in the vicinity of Kettle Creek and diesel fuel from the water treatment plant via a storm drain pipe that discharges in Lake Erie can result in elevated contaminant concentrations. As a result, the storage of fertilizer and fuel were considered significant drinking water threats.

- In recent years, the bulk storage tanks of fertilizer have been removed and the lands are being rezoned as part of the Secondary Plan for the Port Stanley Harbour area. The Events Based Area and associated IPZ-3 for the Urea Ammonium Nitrate (UAN) fertilizer threat have been removed as part of the 2022 assessment report update.

- As a result, the storage of fertilizer is no longer a significant drinking water threat, however, the storage of fuel remains a significant drinking water threat.

- No activities or conditions were identified as significant threats in either IPZ-1 or IPZ-2, since the areas are considered to be of low vulnerability.

- No Issues were identified.

Climate Change Vulnerability Assessment on Elgin Area Water Supply System

- Within Kettle Creek Source Protection Area, a climate change vulnerability assessment has been completed for the Elgin Area Water Supply System intake.
- The overall assessment results show a low climate change vulnerability rating for the Elgin Area intake.
- Impacts on source water quality can be expected due to climate change; however, with the high adaptive capacity of the Elgin Area Water Supply System, climate change impacts on the source water quality may be reduced

5.0 STATE OF CLIMATE CHANGE RESEARCH IN THE LAKE ERIE SOURCE PROTECTION REGION

Human-induced warming reached approximately 1°C above pre-industrial levels (1850-1900) in 2017, increasing at 0.2°C per decade (Allen et al., 2018). Warming greater than the global average has already been experienced in many regions and seasons, with higher average warming over land than over the ocean (Allen et al., 2018).

Ontario borders four of the five Great Lakes and has more than a quarter of a million inland lakes, over half a million kilometres of rivers and streams, and numerous aquifers (MOECC, 2016a). Overall, climate change is expected to bring a 3.6˚C increase in average annual temperatures by 2050 in Ontario (compared to the period between 1981 and 2010), along with milder and shorter winters, earlier snowmelt, a decline in ice cover on lakes, changes in precipitation intensity and frequency, and more evapotranspiration (MNRF, 2014). These changes can impact both the quantity and quality of water for both surface water and groundwater systems.

Many studies have agreed that greater and more frequent extremes are expected in the Lake Erie region in terms of temperature and precipitation (such as Bruce et al., 2006; Chiotti and Lavender, 2008; Kunkel et al., 2009; Zhang et al., 2000, McDermid et al., 2015). There is evidence and agreement by modeling studies in predictions of increased winter air temperatures, increased frost-free period and growing season, and an increase in air temperature of 1.5˚C to 7˚C by the 2080s in the Great Lakes Basin (McDermid et al., 2015).

Annual total precipitation trends are expected to increase in the Great Lakes basin (McBean and Motiee, 2008 and McDermid et al., 2015), but the distribution throughout the year will be altered. There is evidence and agreement by modeling studies in predictions of a 20 percent increase in annual precipitation across the Great Lakes Basin by the 2080s under the highest emissions scenario (McDermid et al., 2015). Extreme precipitation events will be more intense and higher frequency (McBean and Motiee 2008) with a decrease in rain during the summer months (McDermid et al., 2015).

Warmer winter temperatures will be the most influential change for water resources in the Kettle Creek subwatershed. Some of the changes predicted include more winter precipitation as rain, a smaller snowpack, higher evaporation from open water bodies that no longer freeze and an earlier and weaker freshet in the spring (Barnett et al., 2005; Bruce et al., 2000; Environment Canada, 2004; Jyrkama and Sykes, 2007; Mortsch et al., 2000). Soil moisture will start higher in the spring but drop lower in summer with anticipated higher evapotranspiration, leading to greater demand for water resources for irrigation and more frequent drought occurrence (Brklacich, 1990; McBean and Motiee, 2008). Precipitation trends of more intense storms may be associated with decreased infiltration and groundwater recharge (de Loë and Berg, 2006; McLaren and Sudicky, 1993), higher sediment and nutrient loading in the creeks due to greater erosion (McBean and Motiee, 2008), and a lower number of days with rain or longer dry periods (Mortsch et al., 2000).

Net basin supplies are projected to decrease, following decreases in runoff, infiltration, higher surface water temperatures and greater evapotranspiration (Lofgren et al., 2002; Mortsch et al., 2000). Overall, climate change is expected to shift the means in temperature, precipitation and evaporation which will lead to increased variability, more frequent and intense events (Francis and Hengeveld, 1998; de Loe et al., 2001; McDermid et al., 2015).

5.1 Potential Effects of Climate Change on Water Quantity and Quality

Climate change predictions in the Kettle and Catfish Creek watersheds have implications to both water quality and quantity. In terms of water quality, the increase in air temperature and greater occurrence of extreme precipitation events will lead to degraded water quality, including lower dissolved oxygen rates and higher stream temperatures (Bruce et al., 2000; Chiotti and Lavender, 2008; Cunderlik and Simonovic, 2004). Higher sediment and nutrient loading are expected in surface water due to greater erosion (McBean and Motiee, 2008). Surface water temperature is forecasted to increase as a result of climate change. This may result in increased nutrient loading, increased frequency, duration and severity of algal growth and cyanobacterial blooms, increased variability in the quantity and character of runoff, and increased frequency of floods and wildfires (Health Canada, 2021).

Nutrients (primarily nitrogen and phosphorous) run off from farms into surface waters during intense rain events. These excess nutrients threaten human health both directly (e.g., “blue baby” syndrome) and indirectly by contributing to toxic harmful algal blooms in shallow water bays of the Great Lakes. In 2011, Lake Erie experienced the largest harmful algal bloom in its recorded history, with peak intensity more than three times greater than any previously observed blooms. Algal blooms will likely become more frequent in the future as higher temperatures and heavy precipitation mix heavy nutrient loads with warmer waters. These pollutants have dramatically raised the cost of water treatment (Chiotti and Lavender, 2008; de Loe and Berg, 2006; Environmental Law and Policy Centre, 2019; Hunter, 2003). It will be important for drinking water system owners to understand seasonal trends to allow for process adjustments or additional processes that may be required to manage the impacts of temperature and effectively treat water throughout the year (Health Canada, 2021).

Decreases in runoff and baseflows from climate change are also important changes with respect to the dilution of sewage treatment effluent because less water will be available for waste assimilation (de Loe and Berg, 2006). The problem of reduced waste assimilation capacity is exacerbated by the projected increase in future populations in these areas and the ability of the system to meet wastewater discharge criteria (James Bruce et al., 2000; Cunderlik and Simonovic, 2004).

In terms of water quantity, climate change is expected to shift the timing of seasonal events, including an earlier and lower spring freshet and changing levels in Lake Erie to rise and fall one month earlier, on an annual basis due to increased lake surface temperatures (Lenters, 2001; Brent M. Lofgren et al., 2002; Millerd, 2006). The longer frost-free periods lead to increased potential evapotranspiration and an increase in drought occurrence (Environment Canada, 2004; McBean and Motiee, 2008), meaning that longer, drier and warmer growing seasons will lower soil moisture (more deficit) and increase demand for irrigation (Brklacich, 1990; McBean and Motiee, 2008). Rainfall is expected to fall with more intensity but on fewer days, leaving longer dry spells that may exacerbate seasonal water shortages during low flow periods (Mortsch et al., 2000). Projected reductions in groundwater recharge may require wells to be drilled deeper, increasing costs to land owners and municipalities and could lead to rural domestic and urban water use conflicts (de Loë and Berg, 2006; McLaren and Sudicky, 1993). The reliability of water resources is compromised and unpredictability of the hydrologic cycle will demand more planning and adaptation by water managers (de Loe and Berg, 2006).

5.2 Potential Impacts of Climate Change on Lake Erie Levels

Impacts to Lake Erie will have important consequences with the changing climate. Anticipated changes in Lake levels are a function of the altered water balance of the basin including higher precipitation, a decrease in runoff, higher evapotranspiration and an increase in lake surface temperature (Jones et al., 2006; Lofgren, 2006; Millerd, 2006). Increasing water temperature in both summer and winter are projected for Lake Erie, causing large increases in evaporation especially in winter months as ice cover would minimize these losses. Annual over-lake evaporation has increased for Lake Erie at a rate of 7.8 percent (Great Lakes Climate Change Report, 2016).

The reduction in winter ice formation on Lake Erie is expected to be considerable and perhaps non-existent in some years (Lofgren et al., 2002), whereas Lake Erie would historically nearly freeze over in the months of January and February and limit the lake's influence on snowfall (Kunkel et al., 2009). The number of days with ice cover on Lake Erie greater than 10 percent and 20 percent for the winter-seasons in 1973/74 and 2017/18 have decreased by 23 and 24 days, respectively, based on data from Great Lakes Environmental Research Laboratory (GLERL). Winter ice cover >10 percent now averages about two months a year, and since 1997 there have been 6 years with fewer than 30 days of ice cover exceeding 20 percent (GLERL, 2018). As a consequence of open water in winter months, the lake-effect storm season off Lake Erie will be longer (Mortsch et al., 2000), however more of this precipitation will fall as rain due to a decrease in the frequency of air temperatures within optimal ranges for snow (-10˚C to 0˚C) (Kunkel et al., 2002).

Shoreline erosion is expected to increase with the reduction in winter ice formation on Lake Erie (Chiotti and Lavender, 2008). Field et al. (2007) noted that recent winters with less ice cover have shown an increased coastal exposure to damaging winter storms, as ice cover would generally protect the shoreline from winter storms, and is an effective barrier against wave erosion (Mortsch et al., 2006). Coastal wetlands are also effective in maintaining shorelines and protecting against erosion, but decreases in water levels and increasing temperature have been reducing wetlands and diminishing their effectiveness along the Lake Erie shoreline (Mortsch et al., 2006). The increase in intense precipitation events also has the potential to increase the erosion and entrainment of sediments (Mortsch et al., 2006).

Water levels in Lake Erie have fluctuated since the 1860s. Over the last few decades, water levels have declined for Lake Erie. The past few years, however, have shown notable increases toward the top of the historical range (NOAA, 2021).

5.3 Effect of Projected Climate Changes on Assessment Report Conclusions

Projected climate changes are not expected to affect the assessment report conclusions with respect to the Belmont drinking water supply. The water quantity stress analysis (Section 3) shows that the Belmont wells are in an area with low potential for stress. The aquifer that is the source of the supply is confined and well protected, with low vulnerability to contamination (Section 4).

The location and depth of the Elgin Area Water Supply intake make it less vulnerable to fluctuating Lake Erie levels than other Lake Erie intakes. Increasing nutrient loads and water temperatures have the potential to increase the occurrence of taste and odour problems. Current water quality concerns at the Elgin Area Water Supply are discussed in Section 4. Water quality concerns at the Elgin Area Water Supply include blue-green algal (cyanobacteria) blooms within Lake Erie and low dissolved oxygen and manganese events at the intake.

Consideration of Climate Change Vulnerability Assessment Tool

Revised 2021 Technical Rules, under the *Clean Water Act*, 2006, include the consideration of climate change in source water quality risk assessments. A climate change vulnerability assessment tool, developed by Conservation Ontario in 2018, provides municipalities, source protection authorities, and the Lake Erie Region Source Protection Committee with a practical and consistent approach to consider local climate change impacts in the assessment of drinking water sources/systems.

Lake Huron and Elgin Area Water Supply Systems staff completed a climate change vulnerability assessment for the Elgin Area Water Supply System. Results of the assessment are discussed in Section 4 of this assessment report.

At this time, the Municipality of Central Elgin will not be completing a climate change vulnerability assessment on the Belmont drinking water system.

6.0 CONSIDERATION OF GREAT LAKES AGREEMENTS

Under the *Clean Water Act*, 2006, the following Great Lakes agreements must be considered in the work undertaken in Assessment Reports:

- Canada-United States Great Lakes Water Quality Agreement (GLWQA)
- Canada – Ontario Agreement Respecting the Great Lakes Basin Ecosystem (COA)
- Great Lakes Charter
- Great Lakes – St. Lawrence River Basin Sustainable Water Resources Agreement

The Great Lakes Water Quality Agreement and the Canada – Ontario Agreement generally deal with water quality concerns, while the Great Lakes Charter, the Great Lakes Charter Annex, and the Great Lakes – St. Lawrence River Basin Sustainable Water Resources Agreement provide principles for joint water resources management and water quantity and quality concerns in the Great Lakes Basin.

6.1 Kettle Creek Watershed and Great Lakes Agreements

Kettle Creek watershed drains directly into Lake Erie and has the potential to contribute pollutants to the lake. These pollutants, including sediments and nutrients, as well as organic and inorganic contaminants, contribute to the overall water quality of the nearshore of Lake Erie, including, but not limited to the IPZ 1 and 2 of the Elgin Area Water Supply intake east of Port Stanley. As part of the information used to undertake the threats inventory and Issues evaluation for the Elgin Area Water Supply, data was incorporated from the Great Lakes Surveillance Program, a program conducted by Environment Canada under the Great Lakes Water Quality Agreement between Canada and the United States.

In order to achieve water quality goals and objectives set under the Great Lakes Water Quality Agreement, Canadian and U.S. federal governments are developing Lakewide Management Plans (LaMP) in conjunction with the Province of Ontario and the States within the Great Lake watersheds. Lakewide Management Plans are broad plans to restore and protect water quality in each Great Lake (Environment Canada, 2005). Information compiled as part of the Lake Erie LaMP was incorporated into the technical studies completed for the Elgin Area Water Supply.

The work undertaken and described in this Assessment Report contributes to the achievement of Goal 6 under Annex 3: Lake and Basin Sustainability under the Canada-Ontario Agreement Respecting the Great Lakes Basin Ecosystem (Environment Canada, 2007). The Report addresses two key results identified under Goal 6 of Annex 3 by identifying and assessing the risks to drinking water sources on the Lake Erie (Result 6.1), and developing knowledge and understanding of water quality and water quantity issues of concern to Lake Erie (Result 6.2).

The Great Lakes – St. Lawrence River Basin Sustainable Water Resources Agreement is a good faith agreement between the 8 U.S. Great Lakes States and the Provinces of Ontario and Quebec that is intended to implement the Great Lakes Charter and the 2001 Great Lakes Charter Annex. The Agreement sets out objectives for the signatories related to collaborative water resources management and the prevention of significant impacts related to diversions, withdrawals and loses of water from the Great Lakes basin (MNR, 2005). The Agreement sets out conditions under which transfers of water from one Great Lake watershed into another (intra-basin transfer) can occur. The City of London currently receives water from two surface water intakes: one on Lake Huron and one on Lake Erie at Port Stanley.

Wastewater is discharged into the Thames River, which drains into Lake St. Clair. The Agreement does not specify whether Lake St. Clair, and the tributaries draining into it, are considered part of the watershed of Lake Huron, Lake Erie, or both. This ambiguity has created uncertainty over whether or not either the Lake Huron or Elgin Area water supplies constitute an intra-basin transfer under the Agreement, and whether further action is required on the part of the Joint Board of Management of the water supplies and the municipalities serviced by the Elgin Area Water Supply.

At this time the work described in this Assessment Report has not included considerations of the impact of this agreement on the Elgin Area Water Supply, given the level of uncertainty related to the definition of the Lake Erie and Lake Huron watersheds. Further clarification from the Government of Ontario is required regarding this situation prior to determining whether the water supplies may be impacted in the future.

7.0 CONCLUSIONS

The Kettle Creek Source Protection Area Assessment Report provides a summary of the results of technical studies undertaken to identify the threats to municipal drinking water sources in the Kettle Creek watershed. Assessment Report findings have been used to develop policies for a Source Protection Plan to protect the sources of drinking water for the village of Belmont and Elgin Area Water Supply Systems.

The Kettle Creek Watershed is located in southwest Ontario and covers an area of approximately 520 kilometres squared draining to Lake Erie. Much of the land of the watershed is used for agriculture. The main urban area is the City of St. Thomas, located in the centre of the watershed.

Residents in the Kettle Creek watershed receive drinking water supplies from both private and municipal supplies. Two municipal sources provide water to the majority of the population in the watershed. The village of Belmont in the Municipality of Central Elgin is serviced by two municipal groundwater wells. The Elgin Area Water Supply provides water to a number of communities in the watershed, as well as neighbouring watersheds, from a surface water intake in Lake Erie, near the town of Port Stanley.

The geology of the Kettle Creek watershed varies from north to south. The upper portions of the watershed are characterised by high runoff and little recharge from tight soils and agricultural lands. The lower portions of the watershed have sandy soils and more moderate runoff and recharge rates with a fairly steep and deeply incised river valley. Numerous Lake Erie tributaries form small gullies along the Lake Erie shoreline.

Surface water quality within the Kettle Creek watershed appears to be negatively affected by increasing summer temperatures, decreasing baseflows, potentially low levels of dissolved oxygen, and extensive nutrient and sediment concentrations. Lower Kettle Creek and Dodd Creek have the most impaired water quality, while Beaver Creek has the least impaired within the watershed. Phosphorus loading is a serious concern across the entire watershed. Warm water temperatures have limited aquatic habitats to warm water fish species throughout most of the watershed. Both the nutrient and sediment issues within the Kettle Creek watershed are primarily the result of runoff and erosion. These conditions are amplified by land-use practices, such as agriculture and urbanization, and the dramatic elevation change within the watershed.

Water demands in the Kettle Creek watershed are low. The Groundwater and Surface Water Subwatershed Stress Assessment completed in conjunction with water budget studies classified Kettle Creek as having low potential for stress under existing, future and drought scenarios. Since the Belmont drinking water supply is located in an area with low potential for stress, further study (i.e., Tier 3 Water Quantity Risk Assessment) is not required.

Aquifer vulnerability was assessed across the watershed using the Surface to Aquifer Advection Time (SAAT) method. The resulting analysis shows areas of medium and high aquifer vulnerability in the southern extents of the watershed, roughly coincident with the shallow, unconfined aquifer of the Norfolk Sand Plain. The northern extents of the watershed were assessed as low vulnerability. This area is generally comprised of the clay-rich Port Stanley Till, which provides protection to the deeper, confined overburden aquifers.

Given that the maximum vulnerability score a Highly Vulnerable Aquifer can receive is a 6, activities cannot become significant threats within Highly Vulnerable Aquifers. To date, no drinking water Issues have been identified in the Highly Vulnerable Aquifers.

Significant Groundwater Recharge Areas were delineated using water budget tools. Groundwater recharge was estimated using a hydrologic model.

The village of Belmont obtains its water supply from two wells that supply approximately 500 m^3 of water per day to 1,950 residents. The wells obtain their water from a deep, confined overburden aquifer that is overlain by approximately 30 metres of clay-rich till. Four Wellhead Protection Areas were delineated for each well: a 100 metre proximity zone, and three time-related (2-year, 5-year, and 25-year) capture zones generated through a groundwater model. The wells are located in an area of low vulnerability, which results in medium to low vulnerability scores in most of the wellhead protection areas, and an area of high vulnerability within the 100-metre area around the wells.

A transport pathway assessment was completed for the Wellhead Protection Areas, and resulted in an adjustment (increase) to the vulnerability scoring in areas where private wells may exist in relatively high concentrations. Most of the vulnerability score increases occurred within the 2-year WHPA where there was an increase from a score of 6 to 8 and in the 5-year WHPA where the score was increased from 2 to 6 in several parcels.

A water quality threats assessment was completed for the WHPAs and showed no significant threats within the wellhead protection area. An Issues-based threats analysis was also completed through a review of water quality data collected from the municipal wells. No issue-based threats were identified within the municipal groundwater system.

The Elgin Area Water Supply System is a municipal drinking water system serving approximately 100,000 people in the Cities of London and St. Thomas, the Municipality of Bayham, Municipality of Central Elgin, Township of Malahide, Township of Southwold and the Town of Aylmer. The surface water intake is located approximately 1,200 metres offshore of the town of Port Stanley in Lake Erie.

The Intake Protection Zone (IPZ) 1 was delineated as a circle that has a radius of 1000 metres centred on the crib of the intake. The IPZ 1 does not intersect with land. The resulting vulnerable area of IPZ 1 was given a vulnerability score of 5.0. IPZ 2 was delineated by numerical modelling to encompass a two-hour travel time. The delineated area includes both in-water and on-shore areas. The vulnerability of IPZ 2 was found to be low and was given a score of 3.5.

A water quality threats assessment was completed in the IPZ 1 and IPZ 2 for the Elgin Area Water Supply. No activities or conditions were identified as potential significant threats in these areas, since the areas are considered to be of low vulnerability. An

Issues-based threats analysis was also completed through a review of water quality data, and no Issues were identified.

Under the Technical Rules (MOE, 2009a) an activity can be identified as a significant drinking water threat under the event based approach, if within an Intake Protection Zone the activity could result in the release of a chemical parameter that would be transported to the intake and result in the deterioration of the water for a drinking water source (Technical Rule 130). Modelling was used to determine whether the delineation of an IPZ-3 for the Elgin Water Supply Intake under Technical Rule 68 was warranted. Spills from specific contaminant sources in the upper portions of Kettle and Dodd Creek, a landfill site, and two wastewater treatment sites, were investigated. Three general contaminants were considered with densities heavier, lighter, and equal to that of water. The modelling results indicated that under 100-year flow conditions a very high level of dilution was identified at the mouth of the Kettle Creek for all modeled scenarios. Contaminant transport from the mouth of Kettle Creek to the intake was not modeled for these scenarios, but concentrations may be further reduced by Lake Erie processes before reaching the intake. Therefore, there was no justification to include those sites in the delineation of an IPZ-3.

In 2012, spills from two locations within the IPZ-2 were also modeled. Results found that urea ammonium nitrate fertilizer and diesel fuel containing benzene could be spilled from the west pier and east harbour land of Port Stanley and the nearshore area adjacent to IPZ-1, respectively, could reach the intake during extreme event conditions that could result in a deterioration of the water used as a source of drinking water.

The bulk storage tanks of fertilizer have been removed and the previous industrial lands are being rezoned as part of the Secondary Plan for the Port Stanley Harbour area. The Events Based Area and associated IPZ-3 for the Urea Ammonium Nitrate (UAN) fertilizer threat have been removed as part of the 2022 assessment report update. As a result, the storage of fertilizer is no longer a significant drinking water threat, however the storage of fuel (6,000 Litres or more) remains a significant drinking water threat.

Current water quality concerns for the Elgin Area Water Supply System include blue-green algal (cyanobacteria) blooms and low dissolved oxygen and manganese events. Elgin Area Water Supply System has monitoring programs and Standard Operating Procedures in place to keep drinking water safe from potential impacts of overgrowth of aquatic algal bacteria (i.e., cyanobacteria) and low dissolved oxygen and manganese events.

Within Kettle Creek Source Protection Area, a climate change vulnerability assessment has been completed for the Elgin Area Water Supply System intake. The results of the assessment tool show an overall low climate change vulnerability rating for the intake. This result is the combination of a high climate change exposure rating for all seasons and annually, high area (Kettle Creek watershed) level sensitivity and intake (Elgin Area Water System intake) level sensitivity and high adaptive capacity (i.e., greater ability to address impacts from climate change). The results of the assessment tool can be used to help inform discussions around protection, management and adaptation actions at both the municipal and watershed scales. They may serve to further encourage climate change risk management of drinking water system infrastructure and support local climate change strategies or Climate Action Plans.

Climate change is not expected to affect the assessment report conclusions with respect to the Belmont drinking water supply. The water quantity stress analysis shows that the Belmont wells are in an area with low potential for stress. The aquifer that is the source of the supply is confined and well protected, with low vulnerability to contamination.

The results of the technical studies were used to develop policies to protect sources of municipal drinking water. Policies were developed by municipalities, conservation authorities, property and business owners, farmers, industry, health officials, community groups and others working together to develop a fair, practical and implementable Source Protection Plan.

Public input and consultation played a significant role throughout the process. Formal public comment periods were held on the draft and proposed Assessment Report and Source Protection Plan before the respective documents were finalized and submitted to the Minister of the Environment.

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9.0 MAP REFERENCES

Maps prepared by the Grand River Conservation Authority for the Lake Erie Source Protection Region.

These maps are for information purposes only and the Grand River Conservation Authority takes no responsibility for, nor guarantees, the accuracy of the information contained thereon.

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Additional references for specific maps are given below:

Map 2-3: Physiography of Kettle Creek Watershed
Physiography of Southern Ontario, Ontario Geological Survey dataset MRD228, Chapman, L.J. and Putnam, D.F. 2007. Ministry of Northern Development and Mines, Copyright © Queen's Printer, 2010.

Map 2-4: Hummocky Topography
Various Authors, 1967-1993, Quaternary and Pleistocene Geology, Southern Ontario, Ontario Geological Survey. Ministry of Northern Development and Mines, Copyright © Queen's Printer, 2010.

Map 2-7: Bedrock Geology
Paleozoic Geology of Southern Ontario, Ontario Geological Survey dataset MRD219, Armstrong, D.K., Dodge, J.E.P., 2007. Ministry of Northern Development and Mines, Copyright © Queen's Printer, 2010.

Map 2-8: Quaternary Geology
Various Authors, 1967-1993, Quaternary and Pleistocene Geology, Southern Ontario, Ontario Geological Survey. Ministry of Northern Development and Mines, Copyright © Queen's Printer, 2010.

Map 2-9: Overburden Thickness
Strynatka, S., Pitcher, J., and Dragunas, P. 2006. Draft Report on the Groundwater Resources of the Catfish Creek Conservation Authority and Kettle Creek Conservation Authority. Ontario Geological Survey.

Mapping based partially on data contained within the Ontario Ministry of the Environment, Conservation and Parks' electronic water well database.

Map 2-10: Water Table Surface
Strynatka, S., Pitcher, J., and Dragunas, P. 2006. Draft Report on the Groundwater Resources of the Catfish Creek Conservation Authority and Kettle Creek Conservation Authority. Ontario Geological Survey.

Mapping based partially on data contained within the Ontario Ministry of the Environment, Conservation and Parks' electronic water well database.

Map 2-11: Overburden Potentiometric Surface
Strynatka, S., Pitcher, J., and Dragunas, P. 2006. Draft Report on the Groundwater Resources of the Catfish Creek Conservation Authority and Kettle Creek Conservation Authority. Ontario Geological Survey.

Mapping based partially on data contained within the Ontario Ministry of the Environment, Conservation and Parks' electronic water well database.

Map 2-12: Bedrock Potentiometric Surface
Strynatka, S., Pitcher, J., and Dragunas, P. 2006. Draft Report on the Groundwater Resources of the Catfish Creek Conservation Authority and Kettle Creek Conservation Authority. Ontario Geological Survey.

Mapping based partially on data contained within the Ontario Ministry of the Environment, Conservation and Parks' electronic water well database.

Map 3-3: Domestic Bedrock Wells
Wells based on data contained within the Ontario Ministry of the Environment, Conservation and Parks' electronic water well database.

Map 3-4: Domestic Overburden Wells
Wells based on data contained within the Ontario Ministry of the Environment, Conservation and Parks' electronic water well database.

Map 3-5: Kettle Creek Watershed Permits to Take Water
Mapping based partially on data contained within Permits To Take Water issued by the Ontario Ministry of the Environment, Conservation and Parks.

Map 3-6: Groundwater Discharge
Waterloo Hydrogeologic Inc., 2007. Draft Final Report: Westward Expansion of the Norfolk FEFLOW Groundwater Model for the Catfish and Kettle Creek Watersheds. Report to the Grand River Conservation Authority.

Map 3-7: Water Quantity Stress Levels by Surface Water Sub-watershed
Waterloo Hydrogeologic Inc., 2007. Draft Final Report: Westward Expansion of the Norfolk FEFLOW Groundwater Model for the Catfish and Kettle Creek Watersheds. Report to the Grand River Conservation Authority

Map 3-8: Water Quantity Stress Levels by Groundwater Sub-watershed
Waterloo Hydrogeologic Inc., 2007. Draft Final Report: Westward Expansion of the Norfolk FEFLOW Groundwater Model for the Catfish and Kettle Creek Watersheds. Report to the Grand River Conservation Authority.

Map 4-15: Elgin Area Water Supply Distribution System
Mapping of the Elgin Area Primary Water Supply System provided by the City of London.

APPENDIX A: PUBLIC CONSULTATION COMMENTS

This appendix provides a summary of each comment received during the public consultation period on the Kettle Creek Source Protection Area Assessment Report from April 5 to May 9, 2023. This section also provides a summary of how the comment was addressed by the Lake Erie Region Source Protection Committee, and if necessary, lists the changes made for the revised Proposed draft Updated Kettle Creek Source Protection Area Assessment Report.

No comments were received during the public comment period from April 5 to May 9, 2023.

Detailed public consultation comments and how they were addressed for previous iterations of the Kettle Creek Assessment Report are available upon request