DRINKING WATER SOURCE PROTECTION
ACT FOR CLEAN WATER

Thames-Sydenham and Region Watershed Characterization Report

Thames Watershed & Region

(Upper Thames River & Lower Thames Valley Source Protection Areas)

Volume 1

December 2008

Prepared by --

Lower Thames Valley Conservation Authority

UPPER THAMES RIVER CONSERVATION AUTHORITY

-- in cooperation with --

St. Clair Conservation

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Conservation Ontario

Watershed Characterization Report
Thames Watershed & Region
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Thames Watershed & Region Maps

Table of Contents - Volume 1

List of Figures - Volume 1

List of Tables - Volume 1

Watershed Characterization Report
Thames Watershed & Region
(Upper Thames River & Lower Thames Valley Source Protection Areas)

1 Introduction

In May of 2000, bacteria entered the drinking water supply of Walkerton, making more than 2000 people sick and resulting in the deaths of seven people. The government of Ontario called an inquiry into the incident. Justice Dennis O'Connor was mandated to determine what caused the deaths and to make recommendations to improve drinking water safety.

In 2002, Justice O'Connor's findings were released in two volumes. Part One[1] presented his findings related to the events. Part Two[2] provided recommendations to safeguard drinking water. He recommended that drinking water be protected by means of a multiple barrier approach including water source protection.

Recommendation 1 of Part 2 of the O'Connor Report recommended "Drinking water sources should be protected by developing watershed-based source protection plans. Source protection plans should be required for all watersheds in Ontario."[3]

Recommendation 2 indicated that "The Ministry of the Environment should ensure that draft source protection plans are prepared through an inclusive process of local consultation. Where appropriate, this process should be managed by Conservation Authorities."

The Lower Thames Valley, Upper Thames River and St. Clair Region Conservation Authorities (LTVCA, UTRCA and SCRCA) formed a partnership in 2005 to share source protection efforts and resources. The CAs in the region saw this as an opportunity to co-ordinate the development of source protection plans for their Source Protection Areas. Under the Clean Water Act, the three Source Protection Areas are designated as the Thames-Sydenham & Region Source Protection Region. The Upper Thames River Conservation Authority is the lead agency to co-ordinate the work.

Since forming the partnership, staff members from the three Conservation Authorities have worked to collect available information. As part of this work, Watershed Characterization Reports have been prepared summarizing the physical characteristics, water quality and water use for the local areas. This Watershed Characterization Report outlines the information for the combined watersheds of the Lower Thames Valley Source Protection Area and the Upper Thames River Source Protection Area. The combined watersheds are referred to as the Thames Watershed & Region. A similar report summarizes information for the St. Clair Region Source Protection Area.

Ultimately, it is expected that the local stakeholders, through their representation on the Source Protection Planning Committee (SPPC) and the associated working groups, will guide the development of the Source Protection Plans. It is anticipated that the role of the Conservation Authorities will be one of facilitation in the development of the plans. Technical expertise will be available to the Source Protection Planning Committee, as well as communications and consultation services.

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[1] Ontario Ministry of the Attorney General. 2002a. Part One. Report of the Walkerton Inquiry: The Events of May 2000 and Related Issues.
[2] Ontario Ministry of the Attorney General. 2002b. Part Two. Report of the Walkerton Inquiry: A Strategy for Safe Drinking Water.
[3] Status of Part Two Recommendations, Report of the Walkerton Inquiry. Ontario Ministry of the Environment website, www.ene.gov.on.ca/envision/water/sdwa/status_part2.htm (May 2006).

Figure 1.0-1: Summary of Components for Source Protection Plans illustrates the "building block" nature anticipated for source protection.

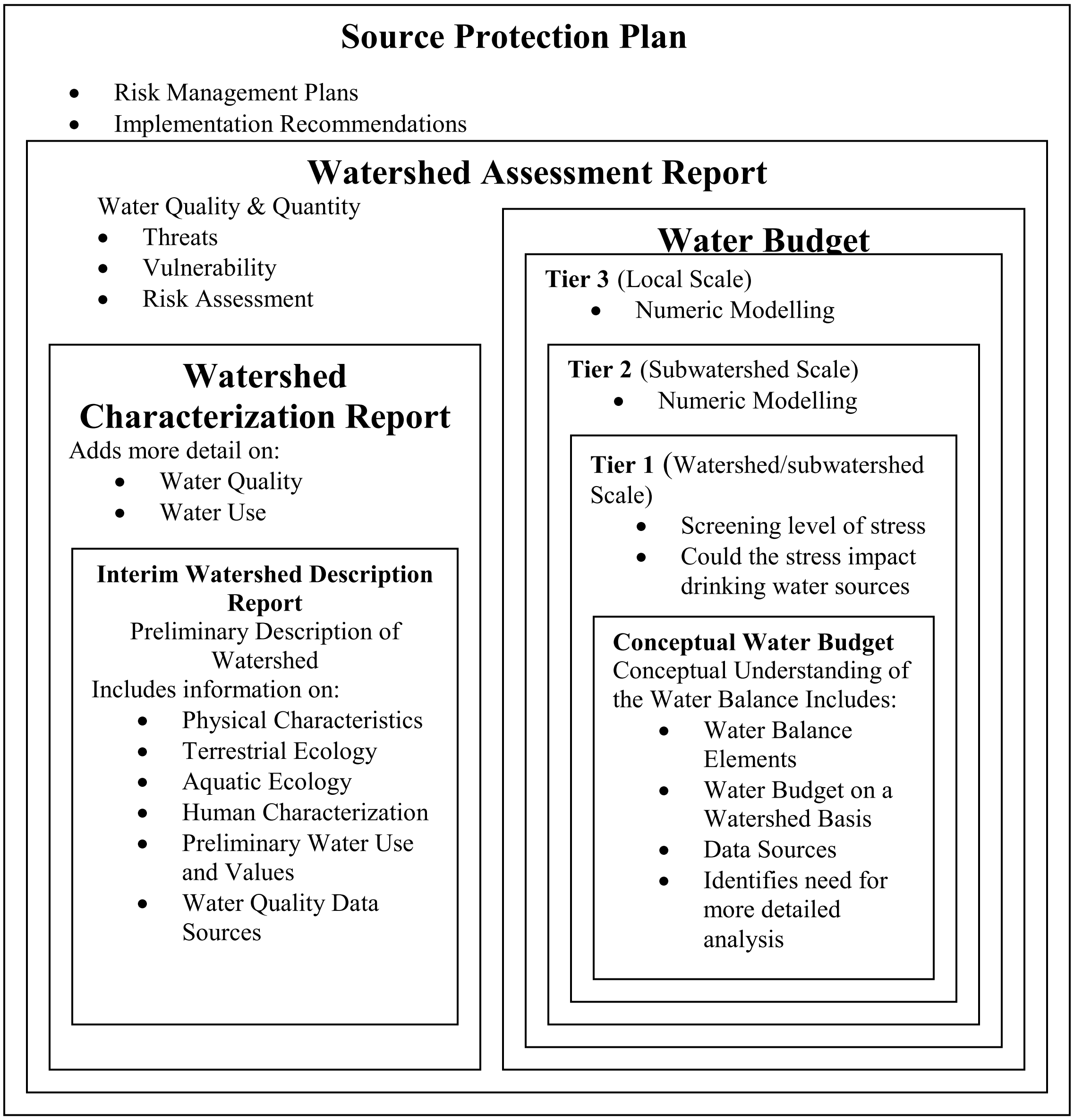

Figure 1.0-1: Summary of Components for Source Protection Plans

The **Interim Watershed Description Report** compiled information on the physical, sociological and economic characteristics of the Thames Watershed & Region (Upper Thames River and the Lower Thames Valley Source Protection Areas). This interim product was circulated to local municipalities for preliminary review and comment.

The Thames Watershed & Region **Watershed Characterization Report** is divided into three volumes. **Volume 1** of the report includes the information collected for the Interim Watershed Description Report with revisions made to address comments received from the municipalities. **Volume 2** provides a summary and review of existing information on surface water, groundwater and drinking water quality for the watershed. **Volume 3** provides a preliminary review of water usage, an outline of known issues pertaining to drinking water sources, and a brief discussion of potential drinking water threats. It also includes a summary of data and knowledge gaps and a list of references. A **Book of Maps** has also been prepared and contains the series of maps that help illustrate the information in the report.

The **Water Budget** focuses on water supply and is being prepared in parallel with the Watershed Characterization Report. A **Draft Conceptual Water Budget Report** has been completed for the Thames-Sydenham & Region Source Protection Region. Work is underway on the next stages of the Water Budget. A Tier 1 Water Budget Report is being prepared for the combined Upper Thames River and Lower Thames Valley Source Protection Areas. A separate Tier 1 report is being prepared for the St. Clair Region Source Protection Area.

The Watershed Assessment Report will be developed using information from the Watershed Characterization Report and the Water Budget.

The Source Protection Plans will be established based on the Watershed Assessment Reports for the Source Protection Areas.

1.1 Data Sources

A wide range of data sources have been used as resources to prepare the Watershed Characterization Report and the accompanying maps.

Water quality data sources include information from the Provincial Water Quality Monitoring Network (PWQMN), the Provincial Groundwater Monitoring Network (PGMN), the Drinking Water Information System (DWIS), the Drinking Water Surveillance Program (DWSP) and water plant operation reports.

References for the information sources used in developing the report are provided as footnotes in the text. The sources of information for the maps are identified in the map legends.

1.2 Data and Knowledge Gaps

During the preparation of the report, some data and knowledge gaps were found due to data being unavailable, incomplete, inadequate or inaccurate.

For the Watershed Characterization Report, the data gaps are discussed in the sections where they are identified. The data and knowledge gaps identified in the report have also been summarized in a spreadsheet in **Volume 3, Appendix A: Data and Knowledge Gaps**.

On the maps, information gaps are identified as part of the map legend.

2 Watershed Description

The Watershed Description Section is intended to provide an assessment of the fundamental natural and human-made characteristics of the Upper Thames River Source Protection Area and the Lower Thames Valley Source Protection Area. The combined areas are referred to as the Thames Watershed & Region. Together with the St. Clair Region Source Protection Area, they form the Thames-Sydenham & Region Source Protection Region.

2.1 Source Protection Region

In 2002, Justice O'Connor recommended that drinking water be protected by multiple barriers. This multi-barrier system includes:

- Source protection
- Treatment
- Monitoring and testing
- Distribution system
- Training

The Province of Ontario made a commitment to implement the recommendations in the O'Connor report. In 2003, acting on the recommendations[4] of the Advisory Committee on Watershed-based Source Protection, the provincial government established two expert committees, the Technical Experts Committee (TEC) and the Implementation Committee (IC). The Technical Experts Committee was asked to produce a set of recommendations[5] related to a "threats assessment framework" while the Implementation Committee was asked to provide advice[6] on tools and approaches to implement watershed-based source protection planning.

In 2004, the government's White Paper[7] on Watershed-based Source Protection Planning provided an opportunity for stakeholder comment and public input on proposed legislation. A Source Water Implementation Group (SWIG) was formed to draft guidance modules[8] for developing assessment reports.

Conservation Authorities (CAs) were recognized by many to be a logical organization to facilitate the development of Source Protection Plans on a watershed basis. They are organized on a watershed basis pursuant to the Conservation Authorities Act (1946).

The White Paper on Watershed-based Source Protection Planning recognized that planning might be developed over an area that was larger than an individual CA's area. Co-ordination of the work to prepare plans would allow for the pooling of resources and the sharing of expertise. In light of this recommendation, many CAs developed partnerships in anticipation of legislation that would support establishing Source Protection Regions.

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[4] OMOE. April 2003. The Final Report: Protecting Ontario's Drinking Water: Toward a Watershed-based Source Protection Planning Framework. Advisory Committee on Watershed-based Source Protection Planning.
[5] Science-based Decision-making for Protecting Ontario's Drinking Water Resources: A Threats Assessment Framework (November 2004)
[6] OMOE. 2004. Watershed-based Source Protection Planning. Science-based Decision-making for Protecting Ontario's Drinking Water Resources: A Threats Assessment Framework. Technical Experts Committee Report to the Minister of the Environment.
[7] OMOE. February 2004. White Paper on Watershed-based Source Protection Planning.
[8] OMOE. April 2006. Assessment Report: Guidance Modules.

The Lower Thames Valley Conservation Authority (LTVCA), Upper Thames River Conservation Authority (UTRCA), and St. Clair Region Conservation Authority (SCRCA) formed such a partnership in 2005.

In 2007, Ontario Regulation 284/07 under the Clean Water Act established the Thames-Sydenham & Region Source Protection Region (SPR) that includes three Source Protection Areas corresponding to the watersheds of the three Conservation Authorities. The Source Protection Region and the three Source Protection Areas are shown in **Map 1: Thames-Sydenham & Region Source Protection Region**.

The main watercourses are the Thames River and the Sydenham River. In addition, the region includes several smaller watersheds that drain directly into Lake Huron, the St. Clair River, Lake St. Clair and Lake Erie.

Thames Watershed & Region

This Watershed Characterization Report will focus on the Thames Watershed & Region, which is the combined watershed area associated with the Upper Thames River Source Protection Area and the Lower Thames Valley Source Protection Area.

The combined watershed stretches from Lake St. Clair in the west to the headwaters of the Thames River in Oxford and Perth Counties in the east. It includes all of the Thames River drainage; a small triangle of land north of the Thames River that drains to Lake St. Clair; and a long narrow strip of land south of the Thames River that drains to Lake Erie.

Map 2: Major Subwatershed Delineations shows the area that drains to Lake St. Clair; the area that drains to Lake Erie; and the Thames River watershed. The Thames River watershed is shown as the area that drains to the main Thames River and the three areas that drain to the branches of the upper Thames River.

Upper Thames River Conservation Authority (UTRCA)

The Upper Thames River Conservation Authority (UTRCA) was established under the Conservation Authorities Act on September 18, 1947 by Order in Council. UTRCA's area of jurisdiction includes all areas draining into the Thames River above the community of Delaware. This covers large parts Oxford, Perth and Middlesex Counties including the City of London. Very small portions of Huron and Elgin Counties also drain into the upper Thames River.

The UTRCA's mission statement is "*Inspiring a healthy environment.*"

The UTRCA watershed area covers approximately 3,423 square kilometres with a total population (2001) of about 472,000. While the area is predominantly agricultural, it includes the large urban centre of London and numerous smaller communities. It is the home of many species at risk and has a variety of natural landscapes including wetlands, forests and Carolinian Canada sites.

The Upper Thames Valley Conservation Report (1952) recommended a series of dams be constructed to provide flood control, along with additional structural measures such as dykes and channels to prevent flood damage. Today, there are three major flood control dams in the UTRCA watershed as well as major dyke systems in London and St. Marys. A channel helps to control flooding in Ingersoll. The Fanshawe Dam and Reservoir was constructed in 1950-52 upstream of the City of London on the north branch of the Thames. It is primarily for flood control. Construction of the Wildwood Dam on Trout Creek, upstream of the Town of St. Marys, began in 1962 and finished in 1965. Water stored in the reservoir from snow melt and/or rain is used to supplement stream flows. The Pittock Dam at Woodstock was started in 1964 and finished in 1967. It is designed for flood control and flow augmentation during low flow conditions.

The UTRCA is actively involved in environmental monitoring and studies to evaluate the overall status of the watershed. The UTRCA has been a partner with the Ontario Ministry of the Environment in the Provincial Water Quality Monitoring Network since the 1960s. There have been a number of studies including the Thames River Water Management Study in 1970 and the Stratford-Avon River Environmental Management Project in 1984 to assess water quality issues. Since 2001, UTRCA has used a system of water monitoring to report on 28 subwatersheds as shown in **Map 23a: Percent Wetland Cover (UTRCA)**.

Lower Thames Valley Conservation Authority (LTVCA)

The Lower Thames Valley Conservation Authority (LTVCA) was established in February 1961. The original boundaries for the LTVCA included only those lands draining into the Thames River from the village of Delaware to Lake St. Clair.

On August 22, 1973, the Authority boundary was enlarged significantly. Simply stated, the Authority acquired jurisdiction over lands that drain into Lake Erie lying south of the lower Thames River watershed and over a small parcel of land north of the mouth of the Thames that drains directly into Lake St. Clair. To the south, the LTVCA watershed includes all streams draining to Lake Erie between the west boundary of the Kettle Creek Conservation Authority in Elgin County and the east boundary of the Essex Region Conservation Authority in Essex County. To the north, the LTVCA watershed includes a triangle of land between the Thames River drainage and the southern boundary of the St. Clair Region Conservation Authority.

The LTVCA's area of jurisdiction includes most of the municipality of Chatham-Kent, the western portion of Elgin County, part of southwestern Middlesex County (including some of the City of London) and a portion of eastern Essex County. The area covers approximately 3,274 square kilometres with a total watershed population (2001) of about 107,000. The area is primarily agricultural with the largest urban area centred on the former City of Chatham.

The LTVCA's Identity and Vision Statement is:
The Lower Thames Valley Conservation Authority is a watershed-based partner, working with the local community, providing services and information to efficiently protect and enhance the environment for present and future generations.

The LTVCA's objectives include:
- Protecting life and property
- Protecting and restoring habitat
- Research and monitoring
- Providing opportunities to enjoy, learn and respect
- Partnering with the local community.

Between 1975 and 1978, the LTVCA constructed over 36 km of dykes to protect low lying farm land from high lake levels and flooding. The dykes were constructed along the shoreline of Lake St. Clair and on the banks of Jeanettes Creek, Baptiste Creek and the Thames River.

Between 1977 and 1980, the Authority focused on the flooding problem associated with the Indian and McGregor Creeks in the Chatham area. LTVCA undertook construction of several channel improvement projects to help alleviate the flooding situation. After an environment assessment that was completed in the mid 1980s, the Authority completed the Indian-McGregor Creek flood control project. The work included the construction of a 3.3 km long diversion channel just east of the Chatham urban area with a dam and pumping station at the mouth of McGregor Creek. The construction of these projects took place between 1988 and 1995.

The LTVCA is actively involved in environmental monitoring and studies to evaluate the overall status of the watershed. The LTVCA has been a partner with the Ontario Ministry of the Environment in the Provincial Water Quality Monitoring Network since the 1960s. There have been a number of studies including the Thames River Water Management Study in 1970s. The LTVCA has developed a monitoring and reporting program for the Lower Thames River, Lake Erie and Lake St. Clair subwatersheds as shown in **Map 23b: Percent Wetland Cover (LTVCA)**.

2.1.1 Stakeholders and Partners

The Source Protection Planning process is intended to be a transparent and consultative process offering a multitude of opportunities for various levels of involvement. The Source Protection Committee (SPC), which has representation from stakeholders within the watershed region, will oversee work on the plan. It is anticipated that a number of working groups will also be formed with stakeholder participation being important in the development of a successful Source Protection Plan (SPP). A number of organizations and individuals will have an interest in Source Protection and may be involved in the committee or the working groups.

Municipalities

The Upper Thames River Conservation Authority includes membership from the following municipalities:

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

The Lower Thames Valley Conservation Authority (LTVCA) includes membership from the following municipalities:

- Municipality of Chatham-Kent
- Town of Lakeshore
- Municipality of Leamington
- City of London
- Municipality of Southwest Middlesex
- Municipality of Strathroy - Caradoc
- Municipality of Middlesex Centre
- Municipality of West Elgin
- Municipality of Dutton/Dunwich
- Township of Southwold

In addition to the member municipalities, there are several upper-tier municipalities that have an interest in source protection. These include the Counties of Perth, Oxford, Elgin, Middlesex, Essex and Huron.

First Nations

There are five First Nations located in the Lower Thames Valley Source Protection Area watershed, including:

- Caldwell First Nation
- Chippewas of the Thames First Nation
- Delaware Nation
- Munsee-Delaware First Nation
- Oneida Nation of the Thames

Provincial Agencies

Conservation Authorities have ongoing interaction with a number of Provincial Ministries and Agencies. Some examples include:

Ministry of Environment: The conservation authorities are partners in both the Provincial Water Quality Monitoring Network for surface water and the Provincial Groundwater Monitoring Network.

Ministry of Natural Resources: The conservation authorities helped to map wetlands in the region and provide land use planning comments to local municipalities regarding the protection of wetlands from development activities.

Ministry of Municipal Affairs and Housing: The conservation authorities are delegated authority on natural hazards and provide comments regarding planning issues for plans of subdivision, official plans and Ontario Municipal Board hearings. Conservation authority staff and MMAH staff meet to review files and policy initiatives.

Ministry of Agriculture, Food and Rural Affairs: The conservation authorities have worked together with OMAFRA staff on projects such as the Oxford Natural Heritage Study (2006).

Neighbouring Conservation Authorities: The conservation authorities and adjacent CAs use joint Public Service Announcements to advertise species at risk in watersheds and grants available for land owners. The Upper Thames River Conservation Authority has worked in co-operation with the St. Clair Region Conservation Authority to sample fish communities within the SCRCA watershed. Staff members sit on combined local technical committees such as the Southwestern Ontario Flood Forecasting Alliance.

Federal Government

The Conservation Authorities have ongoing involvement with various federal government agencies. Some examples include:

Fisheries and Oceans Canada (DFO): The Conservation Authorities carried out the field work to characterize municipal drains under the Fisheries Act Class Authorization System and currently provide the initial review of applications for work on drains.

Environment Canada: The Conservation Authorities were two of the agencies involved in the development of The Lake St. Clair Canadian Watershed Draft Technical Report (January 2005).

Interested Stakeholders, Engaged Public and Non-Governmental Organizations

- Health units
- Agricultural groups
- Environmental non-government organizations

- Ratepayer/neighbourhood groups
- Sports and recreation groups
- Educational institutions
    - Elementary schools
    - Post secondary institutions
    - Libraries
    - Other organizations with public education programs
- Industrial and commercial organizations and major industries
- Media

Health Units have several active programs that involve water quality issues such as monitoring pubic swimming beaches and testing private well water. In general, local Health Units are organized on a municipal basis. Seven Health Units have jurisdictions that overlap parts of the Thames Watershed & Region area, including:

- Huron County Health Unit
- Perth District Health Unit
- Oxford Public Health and Emergency Services
- Middlesex-London Health Unit
- Elgin St. Thomas Health Unit
- Chatham-Kent Public Health
- Windsor Essex County Health Unit

There are a number of agricultural organizations including commodity groups and conservation groups. In general, each farm belongs to one of the following organizations: Ontario Federation of Agriculture, Christian Farmers Federation of Ontario, or the National Farmers Union. The agricultural sector was engaged with the assistance of Ontario Ministry of Agriculture and Food and Rural Affairs county representatives, e-newsletters and advertisements in provincial and local farm media (39 newspapers) and letters to representatives of farm associations.

Major industry or commercial activities within the Thames Watershed & Region range from manufacturing to retail. Membership lists from local Chambers of Commerce were used to direct mail to industries and businesses that could be impacted by or have an interest in the Clean Water Act. A total of 17 industries and 112 commercial businesses in the region were contacted. In addition, advertisements for forums targeted to business were placed on 39 newspapers throughout the region. Oil and gas operations are particularly prominent in Chatham-Kent. Contact was made with the Ontario Petroleum Institute to engage this group. A list of aggregate operations in the region was obtained from the Ontario Aggregate Resources Corporation which included six contacts in the region.

Recreation: Golf courses, marinas, campgrounds and cottage associations were targeted as recreation activities that may be impacted by the Clean Water Act. Sixty golf courses, eight marinas, six private campgrounds and one cottage association were contacted in the Thames Watershed & Region. In addition advertisements for forums targeted to business were placed in 39 newspapers throughout the region.

Academics: The region includes the University of Western Ontario, Kings College, Huron College, Brescia College, Fanshawe College, Ridgetown College, and St. Clair College. Contacts were made to appropriate faculty at each of these institutions.

2.2 Physical Description

This section provides background information on the physical setting of the Upper Thames River Source Protection Area and the Lower Thames Valley Source Protection Area. Throughout the report, the combined areas are referred to as the Thames Watershed & Region.

The physical characteristics of a region include a wide range of unique properties. The bedrock, overburden, surficial geology, soil conditions, topography and regional climate have a profound effect on the groundwater hydrology, surface water drainage, terrestrial ecology, and aquatic ecology.

The availability of water and the physical characteristics of the region had a significant impact on human settlement and development. In turn, human activities have affected water quality and flow in the watershed.

2.2.1 Bedrock Geology

The bedrock geology has been interpreted by the Ontario Ministry of Northern Development and Mines and the Ontario Ministry of Natural Resources using information from water well records and borehole logs from oil and gas wells.

The entire Province of Ontario is underlain by ancient Precambrian rocks[9]. The Precambrian rocks were laid down during the Proterozoic period (2.5 billion to 545 million years old) as land masses (or terrains) separated by small oceans pushed together. This period of continental collision formed the Grenville Province portion of the Canadian Shield[10]. In southern Ontario, the Canadian Shield gneisses, granites and volcanic rocks are buried deep beneath Paleozoic rocks, and Quaternary (glacial and interglacial) sediments.

The bedrock topography approximates the surface topography within the Thames-Sydenham & Region Source Protection Region. The lowest bedrock surface elevations correlate with the shorelines of Lake Huron, Lake St. Clair and Lake Erie. The highest elevations are in the northeastern section of the region in Perth County. The bedrock topography is shown in **Map 3: Bedrock Topography** and the surface topography in **Map 9: Ground Surface Elevation**.

The Proterozoic basement rocks underwent varying amounts of crustal displacement from the time of their deposition (1.3 to 1.1 billion years ago) to the deposition of the overlying Paleozoic rocks approximately 545 to 300 million years ago[11]. This intense crustal displacement led to differential regional uplift and depression of the Precambrian basement. This resulted in the formation of three main structural elements: the Michigan Basin, the Appalachian Basin, and the Findlay-Algonquin Arch as shown in **Figure 2.2.1-1: Structural Elements**[12]. These three structural elements in turn had a significant impact the nature and form of the sedimentary rocks deposited beneath the study area.

Most of the region lies on the crest of the broad Algonquin Arch. This Precambrian structural feature is a basement ridge forming the spine of the southwestern Ontario peninsula. The Algonquin Arch stretches from Chatham to Collingwood and is the northern part of the Findlay-Algonquin Arch. The Findlay Arch

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[9] Ontario Geoscience Resources Network. Ontario Through Time. www.ontariogeoscience.net

[10] Easton, M. 1992. The Grenville Province and the Proterozoic history of central and southern Ontario. In: Thurston, P.C., H.R. Williams, R.H. Sutcliffe, G.M. Stott (Eds.), Geology of Ontario, Special Volume 4, Part 2. Ontario Geological Survey, Toronto, p. 714-904..

[11] Johnson, M.D., D.K. Armstrong, B.V. Sanford, P.G. Telford and M.A. Rutka. 1992. Paleozoic and Mesozoic Geology of Ontario. In Geology of Ontario, Ont. Geol. Surv., Special Vol. 4, Pt. 2, p. 907-1010.

[12] Michigan State University Department of Geography. Geo. 333 Geography of Michigan and the Great Lakes Region (www.geo.msu.edu/geo333/MIbasin.html)

extends from Essex County to Cincinnati, Ohio. The bedrock topography is slightly depressed in the Chatham area. This broad low-lying area between the crests of the Findlay and Algonquin Arches is commonly referred to as the 'Chatham Sag'[13].

The Findlay-Algonquin Arch was active until the late Devonian Period in the middle of the Paleozoic Era. It greatly influenced sedimentation patterns by acting as an open shallow water barrier, or transition zone that separated the Michigan Basin and the Appalachian Basin. These basins served as catchment areas for sediments and over time, the sediments became rock. The deposits in the basins initially on-lapped and ultimately over-lapped the arches. As a result, several of the geologic formations within southern Ontario thin towards the Algonquin Arch[11].

The Michigan Basin is a large regional geologic structure that is generally a circular, deep (approximately 4200 m), carbonate-dominated sedimentary basin centred in the State of Michigan. It consists of a large bedrock depression with a series of concentric rings of outcropping rock units that get progressively older, moving outward from the basin centre.

The Thames-Sydenham & Region Source Protection Region is located on the eastern edge of the Michigan Basin. In the western and central portion of the region, the bedrock units, exhibit a regional dip (slope) of 0.2% to the southwest similar to what is observed across the eastern side of the Michigan Basin.

To the south, the northern edge of the Appalachian Basin reaches under Lake Erie and parts of southern Ontario. It is a large elongated basin located in the eastern United States west of the Appalachian Mountains. It extends from Lake Ontario southwest into Kentucky. This siliciclastic-dominated foreland basin reaches depths of approximately 7000 m in the eastern United States.

In the southeastern portion of the region, the bedrock units near Lake Erie exhibit a regional dip of 0.5% to the south as is observed across the Appalachian Basin[11].

[13] Ontario Geological Survey, 1992. Geology of Ontario Special Volume 4, the Paleozoic and Mesozoic Geology of Ontario, Part 2.

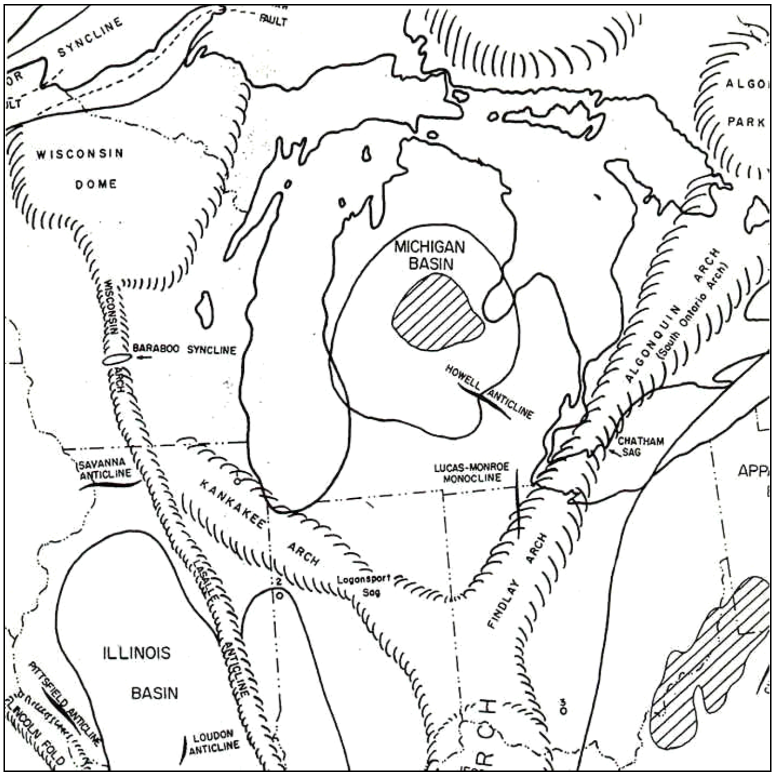

Figure 2.2.1-1: **Structural Elements**

Paleozoic Bedrock of Southern Ontario

The rise and fall of the Canadian Shield during the Paleozoic Era led to the deposition of shallow (carbonates, sandstones) and deep water (shales, siltstones) groups of rocks within the interior of North America. Carbonate rocks include the Salina, Dundee, Lucas, Bass Island, Bois Blanc, Amherstburg, Guelph and Ipperwash Formations. Shale rocks include the Kettle Point Formation, Marcellus Formation, Port Lambton Group and some members of the Hamilton Group.

The vast majority of Paleozoic rocks underlying the area were deposited within the Michigan basin. The bedrock units consist of sedimentary rocks, composed of limestone, dolostone, sandstone and shale that overlie the Precambrian basement. The thickness of the Paleozoic strata increases in a south-westerly direction and reaches up to 1500 m of interbedded carbonates, shales, and sandstones near Sarnia[14].

As a result of the sloping nature of the bedrock units, several types of rock outcrop in the region. **Map 4: Bedrock Geology** provides an overview of the different types of bedrock formations that subcrop across the region. These include the Kettle Point Formation, Hamilton Group, Dundee Formation, Detroit River Group, Bois Blanc Formation, Bass Island Formation, and Salina Formation. A summary of the bedrock formations for southwestern Ontario is provided in Table 2.2.1-1: Bedrock Geology. Most of the information in a table that was originally presented in the Six Conservation Authorities FEFLOW Groundwater Model: Conceptual Model Report. 2004.[15]

[14] Boyce, J.I, and W.A. Morris. 2002. Basement-controlled faulting of Paleozoic strata in southern Ontario, Canada: new evidence from geophysical lineament mapping. In Tectonophysics, 353, (1-4), 151-171.

[15] Waterloo Hydrogeologic. 2004. Six Conservation Authorities FEFLOW Groundwater Model: Conceptual Model Report. Unpublished report prepared for the Upper Thames River Conservation Authority.

Table 2.2.1-1: Bedrock Geology

Formation		Geology	Thickness
Precambrian		Canadian Shield gneisses, granites and volcanic rocks	
Ordovician		Sandy shale, limestones, carbonate mudstones, calcareous shales and non-calcareous shales	Varying
Salina		Interbedded shale, mudstone, dolostone, and evaporates (including gypsum and salt)	Avg - 120-200 m >500 m at Lake Huron
Bass Islands		Oolitic dolostone with minor thin beds of shaley dolostone	30 m; thickens to southwest
Bois Blanc		Cherty brownish grey, fossiliferous limestone	45 m
Detroit River Group	Sylvanian	Orthoquartzitic sandstone	60 to 90 m
	Lucas	Microcrystalline limestone	
	Amherstburg	Crinoidal limestone and dolostone	
Dundee Formation		Fossiliferous limestone	35 to 45 m
Marcellus Formation		Black, organic-rich shale	Up to 15 m
Hamilton Group	Bell	Blue/ grey shale beds with minor limestone lenses	Up to 90 m
	Rockport Quarry	Fine-grained limestone with occasional thin shaley beds	
	Arkona	Blue-grey shale with minor discontinuous limestone beds	
	Hungry Hollow	Interbedded grey shale and fossiliferous limestone	
	Widder	Interbedded shale and fossil rich limestone	
	Ipperwash	Coarse-grained, grey-brown bioclastic limestone	
Kettle Point		Black, organic-rich, shale with minor beds of silty shale	30 m at Chatham (>300 under L. Erie)
Port Lambton		Grey/black shales and sandstone	Up to 60 m

The following sections discuss the depositional history (oldest to youngest) of the Paleozoic bedrock underlying southwestern Ontario as well as the geological characteristics of each formation.

Ordovician

The Precambrian rocks of the Grenville Province are overlain by a succession of Ordovician aged rocks including sandy shale, limestones, carbonate mudstones, calcareous shales and non-calcareous shales. The Queenston Formation is the uppermost unit. It does not outcrop in the region.

Salina Formation

The Salina Formation consists of approximately 120 to 200 m of alternating beds of shale, mudstone, dolostone, and evaporates (including gypsum and salt). It reaches a total thickness of over 500 m near the southern extent of Lake Huron.

The Salina Formation is subdivided into eight members designated by the letters A1, A2, B, C, D, E, F, and G[16]. Units A1, A2, B and D are mainly evaporite deposits of salt and anhydrite. These are well developed in the subsurface in many areas of southwestern Ontario. Units C, E, F and G are varying combinations of shale, dolomitic shale and shaley dolomite.

Bass Islands Formation

The younger Upper Silurian aged Bass Islands Formation forms a narrow band of oolitic brown dolostone (with minor thin beds of shaley dolostone). The unit is approximately 30 m thick and thickens to the northwest[17].

Bois Blanc Formation

The Devonian aged Bois Blanc Formation is arranged above the Bass Island Formation. It consists of cherty brownish grey limestone containing fossils and is estimated to be 45 m thick. The Devonian aged Bois Blanc Formation and the Silurian aged Bass Islands are separated by a disconformity (a break in the sequence of sedimentary rocks).

Detroit River Group

This 60 to 90 m thick unit of limestone and dolomite is arranged in strata over the Bois Blanc Formation. This Middle Devonian aged unit includes the Lucas Formation, a microcrystalline limestone; the Sylvanian Formation, an orthoquartzitic sandstone restricted to the subsurface in the Windsor area; and the Amherstburg Formation, a crinoidal limestone and dolostone.

Dundee Formation

The Dundee Formation, a grey to brown limestone containing fossils, lies above the Detroit River Group. On average, it is 35 to 45 m thick. The Lucas Formation in the Detroit River Group and the Dundee Formation are believed to be karstic (irregular limestone with sinks, underground streams and caverns).

Marcellus Formation

Shales of the Marcellus Formation are localized in a small southern portion of the region on the north shores of Lake Erie where they overlie the Dundee Formation. The Marcellus Formation has been described as black, organic-rich shale. This unit marks a sharp change in the bedrock from older carbonate-dominated bedrock below to shale-dominated strata above (Kelly, 1995).

Hamilton Group

The Hamilton Group of interbedded mudstones, shales and thin carbonate horizons overlie the Dundee Formation. It is made up of the following formations from oldest to youngest: Bell, Rockport Quarry, Arkona, Hungry Hollow, Widder and Ipperwash (Kelly, 1995).

The Bell Formation consists of blue and grey shale beds with minor limestone lenses. The Rockport Quarry Formation is described as a grey and brown fine-grained limestone with occasional thin shaley beds with an estimated total thickness of approximately 6 m (Kelly, 1995). The Arkona Formation is a blue-grey shale unit with minor thin discontinuous limestone beds with thicknesses of up to 37 m recorded. The thin (2 m) Hungry Hollow Formation consists of interbedded grey shale and fossil containing limestone.

The Widder Formation is described as interbedded shale and fossil rich limestone with thicknesses of up to 14 m. The Ipperwash Formation is the uppermost formation in the Hamilton Group. It consists of coarse-grained, grey-brown bioclastic limestone.

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[16] Hewitt, D.F. 1972. Paleozoic Geology of Southern Ontario. Ontario Division of Mines, Geological Report 105. 18p.

[17] Karrow, P.F. 1993. Quaternary Geology of the Stratford-Conestogo Area, southern Ontario. Ontario Geological Survey Report 283, 104 p.

The shales of the Hamilton Group are reported to have a total thickness of 90 m[18]. The Hamilton Group outcrops in parts of Middlesex, Elgin, Lambton, Kent and Essex Counties (Hewitt, 1972).

The Hamilton Group forms the Ipperwash Escarpment that extends from Lake Huron southeast towards Strathroy. This bedrock escarpment is named after the Ipperwash Formation, which forms the caprock of the feature.[19] The western side of the escarpment rises approximately 30 to 60 m above the bedrock to the east. This lower area of bedrock has been interpreted to be part of a buried bedrock valley drainage network extending from Lake Huron to Lake Erie.

Kettle Point Formation

The Kettle Point Formation is a black, organic-rich (up to 15% by weight organic carbon), siliciclastic, and non-calcareous shale with minor beds of silty shale[20]. A major unconformity separates the Kettle Point Formation from the underlying Hamilton Group. This formation is part of a widespread black shale sequence that extends through the eastern United States and parts of central Canada. The Kettle Point Formation is unique as it contains large (up to 1.2 m) spherical or subspherical calcite concretions locally referred to as 'kettles'. This formation outcrops mainly in Lambton and Kent Counties in southern Ontario, and ranges from 30 m thick southwest of Chatham, to over 300 m beneath Lake Erie[21].

Port Lambton Group

The Port Lambton Group is a group of clastic rocks consisting mainly of grey and black shales and sandstones with a thickness of up to 60 m. Within southern Ontario, the Port Lambton Group strata are restricted to the subsurface in a small area south of Sarnia along the St. Clair River.

Erosion Bedrock Features and Valleys

A major nonconformity separates Paleozoic rocks from overlying Quaternary (Glacial and Interglacial) deposits across southern Ontario. This nonconformity represents a 200 million year period of non-deposition (Paleozoic to Quaternary period) where the Paleozoic bedrock surface was exposed and eroded (Johnson et al., 1992). Exposure to the elements (wind, rain, etc.), repeated glacial advances, and other forms of weathering (freeze-thaw action, biological, etc.) likely caused intense fracturing of the upper portions of the bedrock surface prior to deposition of glacial sediments. This weathering and fracturing is expected to have greatly increased the transmissivity of the uppermost bedrock formations.

Millions of years ago when the bedrock was exposed, stream erosion also played a major role in sculpting the bedrock topography of southern Ontario. Similar to our modern day river valleys, these ancient channels formed persistent topographic lows into which surface drainage was focused over long periods of time[22]. A few small scale bedrock valleys are believed to exist beneath the planning area.

As shown on **Map 3: Bedrock Topography**, a broad, low-lying bedrock depression occurs between Lake Huron and Lake Erie. This feature was mapped to extend beneath the towns of Strathroy, Parkhill and

[18] Bobba, A. 1993. Field Validation of 'SUTRA' Groundwater Flow Model to Lambton County, Ontario, Canada: Water Resources Management, 7, 289-310.

[19] Cooper, A.J. 1979. Quaternary Geology of the Grand Bend- Parkhill Area, southern Ontario. Ontario Geological Survey Report 188, 70 p.

[20] Coniglio, M., and J.S. Cameron. 1990. Early diagenesis in a potential oil shale: evidence from calcite concretions in the Upper Devonian Kettle Point Formation, southwestern Ontario. In Bulletin of Canadian Petroleum Geology, v. 38, p. 64-77.

[21] OGS. 1991. Aggregate Resource Inventory of Raleigh and Harwich Townships, Kent County, Southern Ontario. Ontario Geological Survey, Ministry of Northern Development and Mines. Aggregate Resources Inventory Paper 126.

[22] Eyles, N., E. Arnaud, A.E. Scheidegger and C.H. Eyles. 1997. Bedrock jointing and geomorphology in southern Ontario, Canada; an example of tectonic predesign. Geomorphology, 19, 17-34.

Mount Brydges[23]. The western extent of this valley is marked by the Ipperwash Escarpment, which rises 30 to 60 m above the bedrock valley[19]. This depression was interpreted to represent ancestral drainage between Lake Huron and Lake Erie[24]. Glaciation likely broadened a stream drainage feature, leading to a broad (approximately 10 km wide) bedrock depression.

Similarly, a local scale bedrock valley has been interpreted to exist west of Chatham-Kent in the Tilbury area. The valley is carved approximately 15 m into bedrock and is interpreted to represent ancestral drainage between Lake St. Clair and Lake Erie[17] (Kelly, 1995).

2.2.2 Surficial Geology

In southwestern Ontario, the overburden covering the bedrock consists mainly of deposits that were associated with geologically recent glacial activity. Retreating glaciers deposited massive amounts of glacial debris. The lakes, rivers and spillways created by successive glacial advances and retreats shaped the landscape.

Sand plains were created as early rivers emptied into the lakes. Clay and silt plains were formed in deeper quiet water basins of glacial lakes where fine-grained materials were deposited. Receding glaciers created moraines that are generally regional topographic highs. In some areas, sandy shoreline features were also deposited as a result of different glacial lakes levels.

There are some recent post glacial deposits of organic materials or alluvial sediments. Organic deposits of peat, muck and marl are deposited in localized low-lying marshy or swampy wetland areas. Modern alluvial sediments, consisting of sand and gravel, occur along the flood plains of major watercourses and smaller tributaries.

The depth to bedrock throughout the study area was determined by subtracting the bedrock topography grid from the surface topography grid based on information from the Southwest Region Edge matching Study.[25] As shown in **Map 5: Overburden Thickness**, the depth to bedrock varies widely throughout the Thames-Sydenham & Region. Bedrock depths are greatest within the areas with the bedrock valleys described in **Section 1.2.1** and under the axis of moraines deposited by receding glaciers.

The overburden ranges from 0 to 95 metres. Most of the region has a significant amount of overburden with a thickness between 25 and 75 metres as indicated by the contour lines on **Map 5: Overburden Thickness**. The thinnest areas are around St. Marys in southwest Perth County, and north of Ingersoll in Oxford County. In general, these areas of thin overburden are where there are bedrock topographic highs (**Map 3: Bedrock Topography**) and relatively little sediment (e.g. a till plain). The heaviest overburden layers are located along the Lake Erie shoreline in Elgin County and along the bedrock valley (discussed in Section 1.2.1) linking Lake Huron and Lake Erie.

The physiography of southern Ontario was altered considerably by the glacial and interglacial episodes that took place throughout the Quaternary Period (2 million years to present). Southern Ontario's glacial history is very complex[26] and the sedimentary record of southern Ontario provides evidence for three distinct climatic stages during the Quaternary. The Wisconsinan glacial stage deposits (110-10,000 years before present) are the dominant surficial material in the region. The records of the earlier Illinoian glacial

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[23] Dillon Consulting and Golder Associates. 2004. Middlesex-Elgin Groundwater Study Final Report. File 02-0394. Unpublished report.
[24] Karrow, 1973. Bedrock Topography in Southwestern Ontario: A Progress Report. In the Geological Association of Canada, Proceedings, 25, 67-77.
[25] Waterloo Hydrogeologic. 2005. Southwestern Region Edge-Matching Study.
[26] Barnett, P.J. 1992. Quaternary Geology of Ontario. In Geology of Ontario, Ontario Geological Survey, Special Volume 4, Part 2, pp. 1011-1088.

stage (130-180,000 y.b.p), and the Sangamonian interglacial stage (110-130,000 y.b.p.) are limited to very few exposures near Toronto, and as such they will not be discussed in this report.

A continental scale glacier, termed the Laurentide Ice Sheet, advanced and retreated over Ontario[27] during the Wisconsinan glacial period as outlined in **Table 2.2.2-1: Wisconsinan Quaternary Deposits in the Great Lakes Region**. The ice front advanced in cold periods (glacial stades), and retreated when the climate temporarily warmed (glacial interstades) leaving behind a complex subsurface sediment record. Most of the current landscape was formed during the late Wisconsinan maximum of the Laurentide Ice Sheet that occurred 12,000 to 25,000 years before present.

As the ice sheet advanced over southern Ontario, it scoured the bedrock surface and reworked the vast majority of pre-existing glacial and interglacial sediments. This action essentially erased the deposition of pre-Wisconsinan overburden (115,000 y.b.p.). Sediments deposited prior to the last advance are rare and found only in topographic lows on the bedrock surface, such as buried bedrock valleys and lake basins[28].

The flow of the ice through southern Ontario was largely controlled by the broad topographic depressions of the Great Lakes basins (Barnett, 1992[26]). Ice lobes developed in these basins and extended out of the main body of the ice sheet. At times, these lobes acted independently of one another in response to local conditions at the base of the glacier, rather than, or in addition to, climatic change.

Table 2.2.2-1: Wisconsinan Quaternary Deposits in the Great Lakes Region

Approximate Age (y.b.p)*	Glacial Stage	Sub Stage	Glacial Stade/ Interstade	Associated Deposits
Present-5,000	Recent or Holocene Deglaciation			Modern alluvium, organic deposits,
5,000-10,000				Glacial Lake Algonquin shoreline deposits
10,000-12,000	Wisconsinan	Late Wisconsinan	Twocreekean Interstade	Shoreline Formation, Glaciolacustrine Deposits
12,000-13,500			Port Huron Stade	St. Joseph's Till, Lake Warren and Lake Whittlesey shoreline deposits
13,500-14,000			Mackinaw Interstade	Lake Arkona Shoreline deposits, Paris/ Galt Moraines
14,000-15,500			Port Bruce Stade	Elma, Mornington, Tavistock, Stratford, Port Stanley, Wartburg, and Rannoch Tills, Glaciolacustrine Deposits
15,500-16,500			Erie Interstade	Wildwood Silts, Glaciolacustrine Deposits
16,500-20,000			Nissouri Stade	Catfish Creek Till
20,000-60,000		Middle Wisconsinan		Unnamed/ undifferentiated silty tills, (Huron-Georgian Bay lobe)
60,000-115,000		Early Wisconsinan		Canning Till (Erie-Ontario lobe) estimated between 80 000 & 53 000

* y.b.p. represents number of years before present (based primarily on Barnett, 1992. Quaternary Geology of Ontario. In Geology of Ontario, Ontario Geological Survey. Special Volume 4, Part 2, pp. 1011-1088)

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[27] Dreimanis, A., and R.P. Goldthwait. 1973. Wisconsin Glaciation in the Huron, Erie and Ontario Lobes. In Geological Society of America, Memoir 136.

[28] Eyles, N., B.M. Clark, B.G. Kaye, K.W.F. Howard and C.H. Eyles. 1985. The Application of Basin Analysis Techniques to Glaciated Terrains: An Example from the Lake Ontario Basin, Canada. In Geoscience Canada, 12, 22-32.

The individual lobes bear the name of the lake basin(s) in which they are located. As shown in **Figure 2.2.2-1: Influence Zones**[29], the Huron lobe had the most impact on the northwest portion of the Thames-Sydenham & Region area while the Erie lobe's influence was mainly in the southeast part of the region.

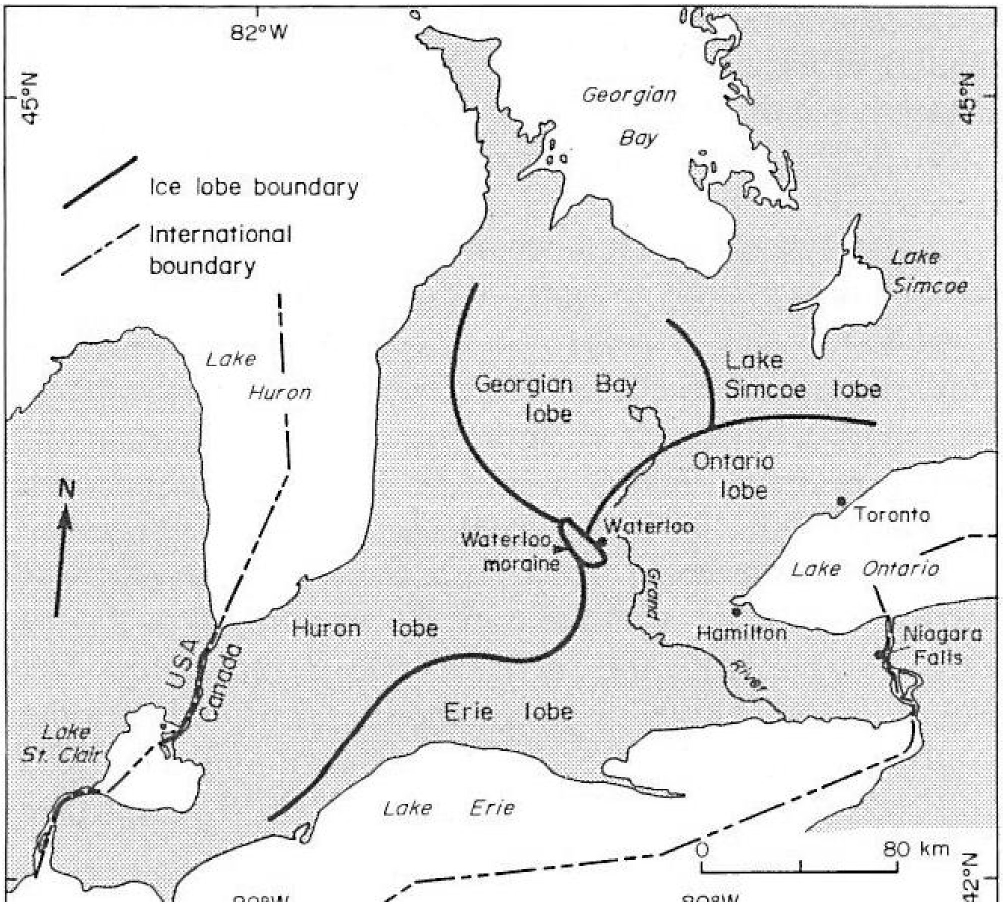

Figure 2.2.2-1: **Influence Zones**

As the glacier advanced and retreated, a series of glacial lakes was established with different water levels and shorelines. The flow of melt water in the valley area between the two ice lobes also had a significant effect on parts of the Thames-Sydenham & Region. Sand plains were created as early rivers emptied into the different glacial lakes while fine-grained clay and silt were deposited in relatively flat, quiet water basins. **Figure 2.2.2-2: Glacial Lake Maumee IV**[30] shows an example of the extended ice lobes and melt water valley.

[29] OGS. 1992. Geology of Ontario. Figure 21.32, page 1038.
[30] OGS. 1992. Geology of Ontario. Figure 21.39, page 1047.

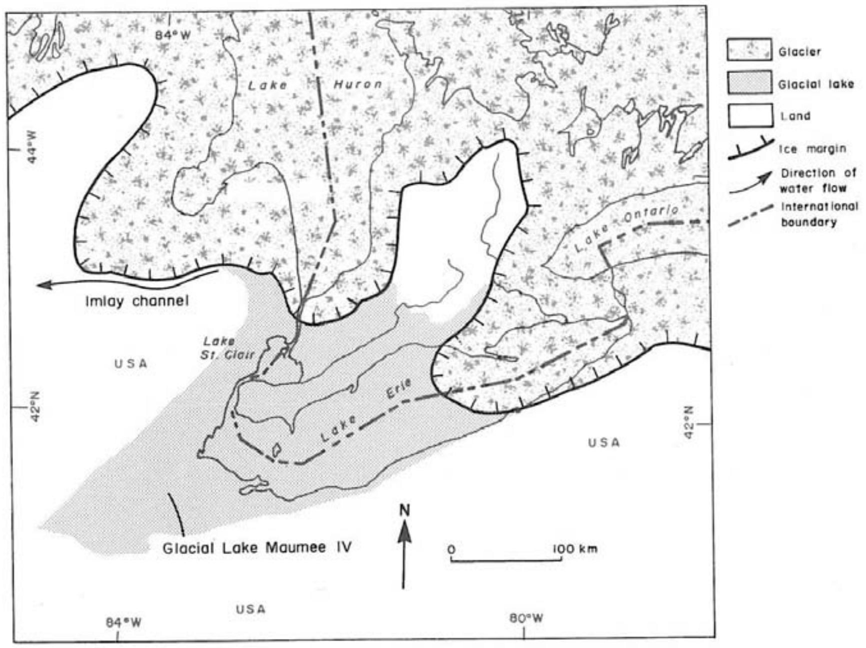

Figure 21.39. Glacial Lake Maumee IV.

1047

Figure 2.2.2-2: Glacial Lake Maumee IV

Till sheets are the most continuous and extensive sediments deposited within the study area. Till is the name for sediment that has been transported and deposited by or from glacier ice, with little or no sorting by water. In general terms, till can be divided into two main types: subglacial (deposited by melt-out processes at the base of the glacier) and supraglacial (deposited by flow from the upper surface).

The Late Wisconsinan sediments (notably the widespread till sheets) found within the study area are discussed in detail below. The Wisconsinan is commonly subdivided into the Early, Middle and Late sub-stages as shown in **Table 2.2.2-1: Wisconsinan Quaternary Deposits in the Great Lakes Region**.

Surficial geology for the region was obtained from the Ontario Geological Survey and is presented in **Map 6: Surficial Geology**. The following sections describe the different Quaternary deposits located within the Thames-Sydenham & Region area.

Early to Middle Wisconsinan

There is little sediment preserved within the area that can be attributed to the Early and Middle Wisconsinan substages. Some unnamed and undifferentiated tills are found locally in small outcrops along creek and river channels and at the base of borehole logs scattered throughout the study area. Pre-Wisconsinan sediments have also been documented from lake bluffs in Elgin County and are sometimes observed in modern day river channels and paleochannels that had orientations perpendicular to ice flow which reduced the scouring action of the overriding glacier.

The Canning Till is the only till deposited during the Early or Middle Wisconsinan found in the Thames-Sydenham & Region area that has been assigned a formal name and description. The Canning Till was deposited subglacially beneath the Erie-Ontario ice lobe during the Early Wisconsinan glacial stage (estimated as 80,000 to 53,000 years ago)[31]. This till has been described as a fine-grained till found in the

Woodstock area and areas to the east. The till is generally dark grayish brown, stiff, with clay to silt rich matrix, and contains approximately 5% clasts (Cowan, 1975[31]).

Exposures of this till and samples from borehole logs suggest that this material is a remnant ground moraine that ranges in thickness from 0.5 to 6 m. There are no estimates of total thickness due to its limited exposure. The Canning Till has very similar characteristics to the overlying Catfish Creek Till deposited during the Late Wisconsinan, making it difficult to distinguish between the two in borehole logs.

Late Wisconsinan Glacial Stage

The Late Wisconsinan lasted from 23,000 years ago to 10,000 years ago[27] and is divided into several different stades and interstades. It was during this period that the Laurentide Ice Sheet reached its most southerly extent, advancing through Ontario and extending into the United States. Also, the Laurentide thinned and formed a series of sublobes, each moving independently of one another at different rates, and in different directions. Each of these sublobes deposited a series of distinct subglacial tills and associated landforms.

The discussion of Quaternary deposits found within the study area progresses chronologically from oldest to youngest as illustrated in **Table 2.2.2-1: Wisconsinan Quaternary Deposits**.

The Nissouri Stade

The Nissouri Stade (25,000 to 18,000 years ago) represents the initial stage of ice advance of the Laurentide Ice Sheet[26]. It was during this time period that the Laurentide Ice Sheet last moved as one thick cohesive ice sheet, depositing the most extensive subglacial till sheet in southern Ontario; the Catfish Creek Till.

The Catfish Till overlies bedrock throughout the eastern part of the study area and outcrops in small areas near the town of Woodstock. It has been mapped in several parts of the planning area including London (Fenton and Dreimanis, 1976[32]) and St. Marys (Karrow, 1977[33]).

The Catfish Creek Till is composed of stacked layers of subglacial lodgement till as well as stratified glaciofluvial and glaciolacustrine sediments and supraglacial till layers and lenses. It has been described as very compact, poorly sorted, and highly calcareous with a sandy silt to silt matrix. It is often described as hardpan in water well drillers' records because of its stoniness and stiffness. The thickness of the Catfish Creek Till is generally less than 6 m; however, it reaches up to 12 m thick in some areas.

Erie Interstade

The Erie Interstade was estimated to take place between 16,500 and 15,500 years ago. It was during this period that the ice margin of the Erie-Ontario lobe of the Laurentide Ice Sheet retreated eastward to the Niagara Escarpment, while the Huron lobe margin retreated northward to the Goderich and Port Elgin areas[34] . A series of large ice contact lakes are believed to have formed in front of these receding ice margins with the deposit of fine-grained silts and clays. Subsequent ice advances may have reworked the

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[31] Cowan, W.R. 1975. Quaternary Geology of the Woodstock Area, southern Ontario. In Ontario Division of Mines, Geological Report 119, 91 p.

[32] Fenton, M.M., and A. Dreimanis. 1976. Methods of stratigraphic correlation of tills in central and western Canada. In Glacial Till: an interdisciplinary study. Edited by R.F. Legget. Royal Society of Canada, Special Publication 12, pp. 67-82.

[33] Karrow, P.F. 1977. Quaternary Geology of the St. Marys Area, southern Ontario; Ontario Division of Mines, Geological Report 148, 59 p.

[34] OGS. 1983b. Aggregate Resource Inventory of Delaware Township, Middlesex County, Southern Ontario. Ontario Geological Survey, Ministry of Natural Resources. Aggregate Resources Inventory Paper 76.

glaciolacustrine muds, removing a substantial portion of the Erie Interstadial sediment record while leaving the fine-grained tills.

Located mainly in the Upper Thames area, some thick (several metres) deposits are interpreted to have formed in deep localized lakes during the Erie Interstade. These deposits are inferred to overlie the Catfish Creek Till and underlie the tills from the Port Bruce Stade.

South of Stratford near the town of St. Marys, there are thick deposits of stratified silt termed the "Wildwood Silts" (Sigleo and Karrow, 1977[35]). These silts were overlain by sand and minor gravel. They are inferred to overlie the Catfish Creek Till and underlie the later Tavistock Till. The silts were interpreted to have formed in a deep but localized lake, and overlying sands are interpreted to represent lacustrine or deltaic sands.

In the Woodstock area, there is considerable evidence to suggest that there were several localized water bodies that led to the deposition of fine-grained glaciolacustrine sediments during the Erie Interstade. Near Plum Point, silts and clays are found sandwiched between the Catfish Creek Till and the overlying Port Stanley Till. The elevation of these sediments suggests that glacial lakes inundated much of the Woodstock area during the Erie Interstade (Cowan, 1975[31]).

Port Bruce Stade

The Port Bruce Stade (approximately 14,800 years ago) records the second advance of the Laurentide Ice Sheet into the United States during the Late Wisconsinan. The Great Lakes basins controlled the direction of flow of the individual sublobes, with glacial flow occurring radically outward from the centre of each lake basin (Barnett, 1992[26]).

Various silt and clay rich subglacial tills were deposited during this Stade, each bearing the name of their type location and/or distribution such as the Port Stanley Till, the Stratford Till and the Tavistock Till. The grain size of the matrix of the subglacial tills, as well as their clast composition, is largely dependent on the substrate over which the ice passed.

The majority of the tills deposited during the Port Bruce Stade are fine-grained, suggesting the ice overrode and incorporated extensive fine-grained glaciolacustrine sediments deposited throughout the area during the Erie Interstade.

In the early stages of the Port Bruce Stade, the southward advancing ice sheet blocked the drainage of the Lake Huron and Lake Erie basins, leading to the formation of a glacial lake (Lake Leverett) over much of the southern portion of the study area. The Essex Chatham-Kent area was inundated with water leading to the deposition of clay-rich massive (structureless) to faintly laminated glaciolacustrine sediments.

As the climate continued to cool, the Huron-Georgian Bay ice lobe overrode the study area southward into Ohio depositing the Tavistock Till in the eastern portion of the region.

Some time later during the same stade event, ice flow in the Ontario-Erie ice lobe increased and ice flow in the Huron lobe began to diminish. This led to the advance of the Erie-Ontario ice lobe westward depositing the clayey-silt rich Port Stanley Till in the southeastern portion of the region.

The Erie-Ontario ice sheet was interpreted to override the Huron lobe till south of Blenheim and Wheatley in the southern portion of the study area.

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[35] Sigleo, W.R., and P.F. Karrow. 1977. Pollen-bearing interstadial sediments from near St. Marys, Ontario. In Canadian Journal of Earth Sciences, 14, 1888-1896.

Port Stanley Till

The advance of the Erie-Ontario ice lobe deposited the Port Stanley Till. The extent of the till is poorly understood; however, it is believed to extend to areas west of Woodstock, likely terminating at the Ingersoll Moraine near Embro (Cowan, 197531; OGS, 1982a36). Along the north shore of Lake Erie, the till complex consists of up to five layers of subglacial till separated by glaciolacustrine sediments. Further inland, it consists of only one layer of Port Stanley Till with associated glaciofluvial sediments. The properties of the till vary spatially across the study area. The northern reaches of the till are strongly calcareous, with a silty to sandy silt till with a clast content ranging from 10 to 30%. The southern reaches of the till complex are described as having a clayey silt to silty clay till with a clast content less than 2%. The Port Stanley Till forms rolling till plains and hummocky moraines. It is usually 1 to 6 m thick (Cowan, 197531) and has a maximum observed thickness of 30 m.

During the ice-marginal recession of the Erie-Ontario lobe into the Lake Erie and Ontario basins, a series of end moraines were formed (or extended), including the Ingersoll, Westminster, St. Thomas, Courtland, Norwich, Tillsonburg, Orangeville, and Blenheim moraines (Karrow, 198837; Barnett, 1992). These moraines mark standstills or minor re-advances of the ice margin.

The Huron-Georgian Bay ice lobe deposited the vast majority of the surficial till sheets found within the study area. Each of these tills was deposited subglacially during the Port Bruce Stade and each represents a re-advance of the ice through the area. The Tavistock, Mornington, Stratford, Wartburg, Elma, and Rannoch Tills are associated with the advance of the Huron-Georgian Bay ice lobe.

Tavistock Till

The Tavistock Till is a highly varied till sheet that lies on the surface along much of the eastern portion of the planning area. In the London and Woodstock areas, the Tavistock Till sheet is a highly calcareous, silt to sandy silt to sand till with a clast content ranging between 5 and 10%. In the London area, the till is coarser-grained as the ice overrode and incorporated the stony Catfish Creek Till, and coarse-grained glaciofluvial sediments. The till in this area is also noted to be interbedded with glaciolacustrine sediments laid down during successive melting of the ice lobe (OGS, 1983a[38]).

Mornington Till

The Mornington Till is similar to the Tavistock Till but has fewer clasts. The Mornington Till is a thin (<5 m), clast poor, silty clay till incorporated into the till from pre-existing glaciolacustrine silts, clays and tills. The Mornington Till is the surface till north of Stratford to the Milverton Moraine. It is believed to form the core of the hummocky Macton Moraine (Karrow, 1993[17]). This till is interpreted to have been deposited subglacially as the ice sheet flowed from northwest to southeast through the study area. The Mornington Till is overlain by the Stratford Till in the southwest, and by the Elma Till in the northeast (Karrow, 1993[17]).

Stratford Till

The Stratford Till is named after the city of Stratford, where this till lies on the surface overlying the Tavistock Till. The Stratford Till is described as a stony, strongly calcareous, sandy silt to silt till with 5 to 10% clast content. The Stratford Till occurs as a thin sheet ranging in thickness from 1-3 m, and is commonly overlain by glaciolacustrine silts and clays. The Stratford Till is similar in texture to the Catfish Creek Till; however, the matrix of the Stratford Till is finer-grained, and there are fewer clasts than the Catfish Creek Till. The till extends to the Thames River in the west, and east to the Easthope

[36] OGS. 1982a. Aggregate Resource Inventory of North Dorchester Township, Middlesex County, Southern Ontario. Ontario Geological Survey, Ministry of Natural Resources. Aggregate Resources Inventory Paper 74.

[37] Karrow, P.F. 1988. Catfish Creek Till: An important glacial deposit in southwestern Ontario. In 41st Canadian Geotechnical Conference, Canadian Geotechnical Society, pp. 186-192.

[38] OGS. 1983a. Aggregate Resource Inventory of London Township, Middlesex County, Southern Ontario. Ontario Geological Survey, Ministry of Natural Resources. Aggregate Resources Inventory Paper 55.

Moraine (near the town of Shakespeare). The Stratford Till is overlain by the Wartburg Till (Milverton Moraine) northwest of Stratford, and by the Rannoch Till (Mitchell Moraine) southwest of Stratford (Karrow, 1993).

Oxford Till Plain

The soil type and characteristics of this drumlinized plain are similar to that of the Stratford Till Plain described above. This is a large physiographic region (160,000 ha) that can be observed in the northeast portion of the Study Area adjacent to the Stratford Till Plain.

Wartburg Till

The Wartburg Till is a silty clay till with few clasts (<1%) (Karrow, 1993). It ranges in thickness from 2 to 10 m. Its exposure is isolated to only a few areas in Perth County (west of Stratford). It forms the bulk of the Milverton Moraine between Fullarton to Brunner, but is inferred to lie largely buried beneath the younger Elma Till. Similar to the Mornington and Stratford Tills, the Wartburg Till is interpreted to have formed when the Huron-Georgian Bay ice margin re-advanced briefly over the local area.

Elma Till (Georgian Bay Lobe)

The Elma Till is a deposit of the Georgian Bay ice lobe. It has been mapped northeast through Stratford, Conestogo, and Palmerston (Cowan, 1973[39]). This till is silt to sandy silt to clayey silt till with a clast content that ranges from 5 to 25%. The till was deposited in the latter stages of the Port Bruce Stade (and possibly into the Mackinaw Interstade), and it ranges in thickness between 2 and 15 m. The Elma Till occurs as a ground moraine in the northwestern portion of the Thames River basin. It lies on the surface in the northern portions of Perth County.

Rannoch Till (Huron Lobe)

The Rannoch Till was deposited subglacially beneath the Huron ice lobe. The name is taken from a small village along the Mitchell moraine, west of St. Marys within Perth County. It is described as a strongly calcareous, silt to silty clay till with a low clast content (<2%) near Mitchell (Karrow, 1977[33]), but it is much more gritty or stony in areas further west (Cooper, 1979[19]).

The Rannoch Till occurs as a surface till sheet across much of the area west of the Mitchell Moraine to the Wyoming Moraine and is also associated with several end moraines including the Dublin, Lucan, and Seaforth Moraines.

This till has not been identified beneath the St. Joseph's till at any point west of the Wyoming Moraine, leading one to infer that the glacier reworked the Rannoch Till in forming the St. Joseph's Till.

Cumming and Al-Aasm (1999)[40] identified the Rannoch Till as a buried till on Walpole Island at the mouth of the St. Clair River; however, it is possible that authors interpreted a lower till (Catfish Creek Till?) at this site to be the Rannoch Till. The thickness of the Rannoch Till is between 2 and 6 m but it has been mapped up to 70 m.

As the ice lobes began to retreat out of southern Ontario, meltwater began to pond at the western end of Lake Erie, and the southern end of Lake Huron forming a large lake termed Lake Maumee. It was during this time that the Caradoc Sand Plain and Komoka Delta were formed as a meltwater stream deposited silts, sands and gravels[26] where it emptied into Lake Maumee.

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[39] Cowan, W.R. 1973. Quaternary Geology of Palmerston and Wingham Areas, southern Ontario. In Ontario Division of Mines, Summary of Field Work, 1973, 201p.

[40] Cumming and Al-Aasm. 1999. Sediment Characterization and Porewater Isotope Chemistry of Quaternary Deposits from the St. Clair Delta, Ontario, Canada. In Quaternary Research, 51, 174-186.

Shoreline deposits of glacial Lake Maumee have also been mapped between London and Delhi, and numerous other smaller scale short-lived glaciolacustrine ponds existed throughout much of the study area (OGS, 1983; Barnett, 1992[26]).

Mackinaw Interstade

The Mackinaw Interstade took place from approximately 13,500 to 14,000 years ago. The onset of this interstade was characterized by the rapid retreat of ice out of southern Ontario. The Ontario-Erie lobe retreated into the Ontario basin east of Toronto and the Huron lobe retreated into northern Michigan (Dreimanis and Goldthwait, 1973).

During this ice-free time, thin glaciofluvial outwash deposits were laid down across much of the study area as sediment-laden meltwater streams discharged from the front of the melting glacier. This led to the deposition of pebbly sands and gravels (OGS, 1983, 1989[41], 1991[42]).

As ice continued to retreat from the study area, a large lake formed over the southern margins of both Lake Huron and Lake Erie (termed Lake Maumee then Lake Arkona; Barnett, 1992). Deep water sediments consisting of silts and clays were deposited at the base of this deep lake in the Essex County area (OGS, 1989). In the shallower portions of the lake and on the lake margins, fine-grained sand was deposited, especially near Leamington (OGS, 1989).

Throughout Oxford and Middlesex Counties, the surficial till was incised by sediment-laden meltwater channels that deposited thick sequences of well sorted sand and gravel outwash (OGS, 1983a). The North Thames, Thames, and Medway Rivers are all former meltwater channels deposited in this manner (OGS, 1983a, 1983c43). The City of London lies on a sandy delta formed as a meltwater channel emptied into a glacial lake (OGS, 1983a).

As the Erie-Ontario ice lobe retreated northeastward, the drainage outlet for the Lake Ontario basin returned to the east (Rome, NY), and the outlet for Lake Huron became ice free; this created progressively lower lake levels in the Lake Erie and Lake Huron basins (Barnett, 1992; Dreimanis and Goldthwait, 1973). The higher lake levels (e.g. Glacial Lake Whittlesey) created sand plains such as the Caradoc Sand Plain in the region. These changing lake levels also created elevated sand and gravel ridges often distant from the present Great Lakes shorelines.

Port Huron Stade

The Port Huron Stade took place from approximately 13,500 to 13,000 years ago, when three distinct lobes of the Laurentide Ice Sheet advanced for the last time over southern Ontario.

In our study area, the St. Joseph’s Till was deposited beneath the Huron-Georgian Bay ice lobe. The St. Joseph’s Till is strongly calcareous silt to silty clay till with low clast content (1-2%; Barnett, 1992). This till incorporated pre-existing fine-grained glaciolacustrine silts and clays deposited during the Mackinaw Interstade and the Port Bruce Stade to give this till its fine texture. The extent of the St. Joseph’s till plain is marked by the Wyoming Moraine which parallels the modern day Lake Huron shoreline, and it is commonly overlain by outwash sands and gravels and various glaciolacustrine sediments (Barnett, 1992).

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[41] OGS. 1989. Aggregate Resource Inventory of Mersea, Gosfield North and Gosfield South Townships, Essex County, Southern Ontario. Mines and Minerals Division, Ministry of Northern Development and Mines. Aggregate Resources Inventory Paper 125.
[42] OGS. 1991. Aggregate Resource Inventory of Raleigh and Harwich Townships, Kent County, Southern Ontario. Ontario Geological Survey, Ministry of Northern Development and Mines. Aggregate Resources Inventory Paper 126.
[43]OGS. 1983c. Aggregate Resource Inventory of East Zorra-Tavistock Townships, Oxford County, Southern Ontario. Ontario Geological Survey, Ministry of Natural Resources. Aggregate Resources Inventory Paper 63.

To the east outside the region, the Halton and Wentworth Tills were deposited beneath the Ontario-Erie lobe, the Kettleby Till beneath the Simcoe lobe.

Glacial Lake Whittlesey is another glacial lake that was formed over the southern reaches of Lake Huron, and the western reaches of Lake Erie (Barnett, 1992). Associated with this glacial lake are several sandy shorelines and associated beach deposits seen on the surface in the western portions of the study area.

An extensive braided river system flowed down the Thames River valley and emptied into glacial Lake Whittlesey at areas west of London depositing extensive sand plains (Chapman and Putnam, 1984). The Bothwell Sand Plain was once the delta formed where the Thames River emptied into Lake Whittlesey (OGS, 1991).

As ice retreated from the Port Huron maximum, elevated lake levels in the Huron and Erie basins began to fall. In the wake of this ice retreat, glacial Lake Warren developed in place of Lake Whittlesey. Several sandy shoreline features associated with this Lake Warren were deposited throughout the western portion of the study area (OGS, 1989).

Thick sequences of fine-grained glaciolacustrine sediments were deposited into the proglacial lakes mentioned above. These sediments exhibit a general coarsening upward trend whereby fine-grained silts and clays are overlain by silts and sands. For example, some of the largest sand plains (Caradoc and Bothwell) and clay plains (St. Clair and Ekfrid), are underlain by glaciolacustrine sediments deposited when lake levels fell in the Huron and Erie basins (Barnett, 1992).

Twocreekean Interstade and the Greatlakean Stade

The Twocreekean Interstade represents a period of continued ice retreat out of southern Ontario, which began approximately 12,500 years ago (Barnett, 1992). By this time, the ice front had fully retreated from the study area. Ice marginal lakes began to drain as the retreating ice uncovered drainage outlets. Separate lakes formed in the Lake Ontario (Lake Iroquois) and Lake Erie (Early Lake Erie) basins, and Lake Huron and Lake Michigan merged to form one large lake: Lake Algonquin.

Holocene Deglaciation

The Holocene began approximately 10,000 years ago. At this time, Ontario was still undergoing massive deglaciation throughout much of the north. Lake Superior was still covered with ice. An isostatic depression of the North Bay area allowed the upper Great Lakes to drain through the Ottawa River, resulting in lower water levels in the Great Lakes than those seen today. Approximately 5,000 years ago, isostatic uplift closed an outlet near North Bay. From this point in time to the present day, the lake basins have rebounded and the lake levels returned to those found in the Great Lakes today.

The isostatic depression in the north also caused subaerial exposure of the St. Clair Clay Plain (Cumming and Al-Aasm, 1999). After the uplift, water flows in the St. Clair River provided a high suspended sediments load to Lake St. Clair and delta deposits began to form again near Lake St. Clair Island (Cumming and Al-Aasm, 1999) as a result of the rapid deceleration of the river's flow.

Postglacial and erosional processes during the Holocene continued to shape the landscape within the study area. Aeolian dunes formed on the surface of the Bothwell sand plain as north-westerly winds reworked the fine sand (OGS, 1991). Also, Point Pelee was formed by the interaction of longshore currents carrying sand from shorelines in the west and east throughout this time period (OGS, 1989).

Summary of Quaternary Geology

The Quaternary geology within the Thames-Sydenham & Region area is primarily the result of the Late Wisconsin glaciation (~25,000 years ago). In summary, the present day geologic setting consists of eroded Paleozoic sedimentary bedrock units, overlain by glacial deposits and more recent alluvial deposits, shown on **Map 6: Surficial Geology**.

The surficial geology of the Thames-Sydenham & Region study area has been mapped in phases throughout the last 30 years by various geologists (Cowan, 1975, 1979[44]; Cooper, 1979; Karrow, 1977, 1988, 1993; Barnett, 1982[45]; Kelly, 1995).

More recently these maps have been seamlessly assembled into a cohesive map covering the entire study area (Bajc et al., 2001[46]). This map and its associated GIS metadata will be used to help delineate the spatial extent of the above geological features.

The surface geology can be grouped into the following general features:
- Low permeability, low relief lacustrine clay plains
- Low permeability, moderate relief till plains
- Higher permeability, low relief outwash sand and gravel deposits
- Higher permeability, moderate relief, course-grained moraines
- Higher permeability, low relief recent alluvial deposits

2.2.3 Physiography

Physiography is the study of natural landscape features. The physiographic characteristics of the St. Clair Region are dominated by the effects of continental glaciation. As discussed in the previous section on surficial geology, a series of glacial advances and retreats resulted in the moraines, sand plains, till plains and clay plains that characterize this part of southwestern Ontario.

Physiographic Regions

The sections below describe the significant physiographic regions identified within the Study Area, as presented in *The Physiography of Southern Ontario*[47]. **Map 7: Physiography** shows several of these features.

Sand Plains

Sand plains are generally the result of water-laid alluvial/beach deposits.

Caradoc Sand Plain

The Caradoc Sand Plain is located in the Strathroy/Mount Brydges area. It is a large (78,500 ha) sand and gravel deltaic deposit that was formed when the early Thames River discharged sediment into Glacial Lake Warren. The Caradoc Sand Plain is composed predominantly of sand but contains some gravel. There are prominent dunes and sand ridges (terrace escarpments) that were formed by the wave action and wind as Glacial Lake Warren receded. This deposit thins towards the west where the glacial lake water became deeper, and blends into the Ekfrid Clay Plain. To the east, the Komoka Delta has more gravel and heavier materials.

Bothwell Sand Plain

This sand plain is very similar to the Caradoc Sand Plain. It was also created by the early Thames River depositing sediment in the Bothwell area as Glacial Lake Warren receded to the west. The Bothwell Sand

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[44] Cowan, W.R. 1979. Quaternary Geology of the Palmerston Area, southern Ontario; Ontario Geological Survey Report 187, 64 p.
[45] Barnett, P.J. 1982. Quaternary Geology of the Tillsonburg Area, southern Ontario; Ontario Geological Survey Report 220, 87 p.
[46] Bajc, A.F., S. Leney, S. Evers, S. van Haaften and J. Ernsting. 2001. A seamless Quaternary geology map of southern Ontario. In Summary of Field Work and Other Activities 2001, Ontario Geological Survey, Open File Report 6070, p. 33-1 to 33-5.
[47] Chapman, L.J. and D.F. Putnam. 1984. The Physiography of Southern Ontario, 3rd edition.

Plain also shows dunes and terrace escarpments, though they are not as abundant as they are on the Caradoc Sand Plain.

Clay Plains

Clay plains occur in association with sand plains and represent the sediment that was deposited in deeper water farther offshore than the alluvial/beach deposits (sand plains). The fine-grained clay and silt were deposited in a relatively flat, quiet water basin, resulting in the development of a somewhat featureless topography.

Ekfrid Clay Plain

The Ekfrid Clay Plain exists between and surrounds the Caradoc and Bothwell Sand Plains. As described above, the deposition of the clays and silt make for a featureless, flat lying area.

Lambton Clay Plain

Located to the west of the Thames Watershed & Region, the Lambton Clay Plain is the dominant physiographic region in Lambton County. The Lambton Clay Plain is bordered by the Lake Huron and St. Clair River shorelines and extends eastward to the Ekfrid Clay Plain, southeast to the Bothwell Sand Plain and southwest to the Chatham Flats.

Chatham Flats/Clay Plain

The Chatham Flats is the dominant clay plain in Chatham-Kent and is characterized by deep lacustrine clay deposits with extreme flatness. The plain parallels the St. Clair River and Lake St. Clair shorelines and stretches from southern Lambton County south to a line running east west from Ridgetown to Tilbury. A long narrow strip of the "Flats" also runs along the Thames River from Chatham east to boundary with Elgin County.

Till Plains

Till is a heterogeneous mixture of clay, silt, sand, and pebbles. Till soils are very dense, stiff materials and are often covered by a thin veneer of topsoil. Till plains have glacial till as the surficial soil type. They often display surface features such as prominent moraines, terrace escarpments, and beach/bar/spit deposits. There are different types of till plains including streamlined and bevelled till plains, till moraines, and drumlinized / un-drumlinized till plains.

Bevelled till plains are relatively flat, reworked till plains that were previously deposited and were over-ridden by a subsequent glacial advance. The till is a poorly sorted mixture of clay, sand and gravel referred to as Diamicton. In some areas, till plains were further smoothed by local shallow deposits of lacustrine clay that infill depressions in the till plain.

The different characteristics described above are illustrated by comparing **Map 7: Physiography** which shows an area as a Bevelled Till Plain; **Map 6: Surficial Geology** which shows most of the same area as Diamicton/Till; and **Map 8: Soils Information** which shows the area as being predominately silt and clay.

Till moraines occur as mounds of till deposited at the end of a glacier and are expressed as prominent topographic features.

Streamlined landforms such as drumlins and flutings are formed by variations in stress on the sediment bed by a glacier and indicate glacier flow direction. Drumlinized or un-drumlinized till plains simply refers to the presence or absence of drumlins on the surface of a till plain.

Stratford Till Plain

This un-drumlinized plain consists of calcareous silty clay and contains very little coarse-grained material. The Stratford Till Plain is a large till plain of ground moraine features interrupted by terminal moraines such as the Lucan, Mitchell, and Arva moraines. There are some gravel terraces along the Thames River.

Oxford Till Plain

The soil type and characteristics of this drumlinized plain are similar to that of the Stratford Till Plain described above. This is a large physiographic region (160,000 ha) that can be observed in the northeast portion of the study area adjacent to the Stratford Till Plain.

Essex Till Plain

This area is composed of bevelled till with a shallow mantle of clay. The plain covers most of Essex County and the southwestern part of Chatham-Kent. In the planning area, the clay and clay loam extends from the Lake Erie shoreline north to an east-west line running from Tilbury to Ridgetown.

Moraine Dominated Regions

Moraine dominated areas have regional topographic highs and are characterized by hummocky terrain and till soils. Moraines commonly occur in sub-parallel groups as they are deposited by the receding glacier.

Mount Elgin Ridges

This physiographic region lies between the Thames River Valley, and the Norfolk Sand Plain, and covers a large area (147,000 ha). This region is made up of several prominent moraines accounting for its name. The Ingersoll, Westminster, St. Thomas, Sparta, and Tillsonburg moraines are all located within this physiographic region. These moraines give the region a rolling topography that controls the surface water drainage patterns. The soil type is similar to that of the Stratford Clay Plain, but contains more sand.

Huron Lobe Moraines

The orientation of these recessional moraines and end moraines mimic the shape of the shore of Lake Huron forming a concentric pattern of topographically high ridges.

The Wyoming moraine is the largest moraine in the study area at over 20 km wide and very long. It begins approximately 6 kilometres southwest of Wyoming and extends far to the north of the study area. The soil is pale brown, calcareous, fine-textured till.

The Seaforth moraine is very similar in shape to the Wyoming moraine, but it is much more narrow (between 5 - 10 km wide), with more of its length being within the study area. This moraine is located north of the village of Poplar Hill.

The Lucan moraine is concentric with both the Wyoming and Seaforth moraines, but does not run continuously through the Study Area. The Lucan moraine begins west of London and bends northwards to the east of Lucan and out the northern limit of the study area.

The Mitchell moraine runs in a northeast direction and converges with the Lucan moraine just south of Lucan.

The Arva moraine is discontinuous, and trends north-northeast for approximately 30 km north of London.

Erie Lobe Moraines

The recessional and end moraines formed by the Erie Lobe are oriented in an east-west direction in the London area and trend more southwest/northeast as they approach the shore of Lake Erie. The Erie Lobe created the Ingersoll, Westminster, St. Thomas, Sparta, and Tillsonburg moraines.

The Ingersoll moraine varies in width from 1- 10 km and trends east from the area southwest of London.

The Westminster moraine is 5 km to the south and runs parallel to the Ingersoll moraine.

The St. Thomas moraine is a discontinuous moraine located south of the Westminster moraine. It begins near the West Lorne/ Rodney area, and runs northeast through the city of St. Thomas.

The Sparta and Tillsonburg moraines are similar to the St. Thomas moraine in that they are discontinuous but begin east of St. Thomas.

The Dorchester moraine is an irregular shaped end moraine located in the Dorchester area. This moraine, formed at the most northward advance of the Erie Lobe, represents the oldest moraine in the Study Area (Cowan, 1975. It is composed of a sandy drift till that is part of the Catfish Creek Till. Glacial processes around Dorchester deposited till in a mound-like moraine, rather than the linear shape that is common to recessional or end moraines.

There are also several small to medium sized end moraines in the southwestern portion of the region including the Charing Cross and Blenheim moraines. These moraines generally consist of poorly sorted glacial till and are overlain by subsequent lacustrine clay deposits that smooth the topography.

Glacial Beaches and Shore Cliffs

A number of beaches and shore cliffs remnant from glacial lakes occur in Lambton, Elgin and Chatham-Kent. Beach deposits of Glacial Lakes Warren, Whittlesey, Algonquin and Lundy occur throughout the region.

The landscape includes the broad expanse of level lands beginning in the Strathroy-Caradoc area and extending to south, east and north to Lakes Erie, St. Clair, and Huron. Long ridges of sandy gravel interrupt what would otherwise be great expanses of flat land. Also, many sand dunes occur along the inland margins of the old beach ridges, far from any current body of water.

Terraces (from each elevated lake level) leading down to the Great Lakes transect the level lands. Each terrace is separated from its neighbour by a high or low step cliff. These terraced areas have areas of heavy clay (Chatham-Kent/Essex) interspersed with stretches of water-washed sand and gravel. The flat areas were once lake beds and the ridges of gravel were beaches. The flat stratified sand and gravel plains and clay plains with a veneer of sand or gravel were fillings of old bays or ancient lake basins and the deltas of rivers flowing into them (Komoka and the Caradoc Sand Plain). Elevated glacial lakes reworked pre-existing till plains and sand and gravel sediments were deposited along the now relic lake margins.

Some of these are shown on **Map 8: Soils Information** and **Map 6: Surficial Geology** as narrow bands of sand and/or gravel. For example, Glacial Lake Warren beaches follow the Lake Erie shoreline in the Blenheim and Ridgetown area. Similarly, a band of sand and gravel running from north of Wyoming through Forest generally parallels the Lake Huron shoreline

Lake Whittlesey was approximately 225 metres elevation, Lake Warren approximately 208-210 metres elevation, and Lake Lundy varied between 185 and 195 metres. In comparison, the current levels of Lakes Huron and Erie are between 176.5 and 174.5 metres. Over time, streams and rivers have eroded and down cut their stream beds to the current lake levels creating misfit channels on the present landscape.

Modern Shorelines

There are two types of natural Great Lakes shorelines in the region: 1) low lying areas dominated by sand, and 2) clay and till dominated bluffs between 10 and 20 metres high. Both the bluffs and low lying areas are cut by river channels. In several areas, development has resulted in hardened erosion control structures lining the shoreline.

Lake Erie Shoreline

In the eastern part of the region, long stretches of the shoreline consist of high bluffs cut into unconsolidated glacial sediments. Glacial Lake Warren beaches follow the coastline in the Blenheim and Ridgetown area. Short, smaller creeks, characterized by deep, steep-sided gullies, flow south to enter Lake Erie.

In the west (Rondeau Bay watershed), the land falls relatively evenly to the Bay and the streams have a much shallower profile.

Summary of Physiographic Regions

The major physiographic regions in the area are extensive sand, clay and till plains. These have varying characteristics depending on their origin and may be significantly affected by remnant glacial moraines, beaches and shorecliffs.

Together with the surficial geology of the region, the physiographic characteristics led to the development of several different types of soil in the Thames-Sydenham and Region area.

2.2.4 Soil Characteristics

The development of different soil types is an intriguing story. Beginning with a relatively uniform parent material, a combination of climate, drainage, and vegetation resulted in different soils developing over a period of time[48].

The characteristics of the soil at any given place depend on:

- The physical and mineralogical composition of the parent material
- The climate under which the soil developed
- The plants and animals that live in and on the soil
- The relief and drainage
- The length of time the forces of development have been acting on the parent material

Of the above factors, the parent material and the local relief and drainage were the major factors affecting the development of the different soils in the Thames-Sydenham & Region area.

In general, the ages of the various soils in southwestern Ontario are relatively the same and differences in the effects of weathering are difficult to establish. Similarly, the climate has been relatively uniform and did not result in soil differences that are readily noticeable.

Prior to clearing for cultivation, most of the area was covered by deciduous forest. There were some areas of grassland, marsh or coniferous forest. However, most variations in vegetation were directly related to differences in drainage or the texture of the parent material.

Soil Groups

Soils are classified into Great Soil Groups. Soils that have developed where the factors of climate and vegetation have reached their full expression are known as *zonal* soils. In areas where inadequate drainage has hindered normal soil development, *intrazonal* soils develop. *Azonal* soils develop in areas where relief or excess drainage prevented the development of a normal soil profile.

The soils of southern Ontario generally fall into the zonal great soil group *Grey-Brown Podzolic Soils* or *Grey-Brown Forest Soils*[49]. These soils are formed from the decay of leaves and wood in locations where moisture and nutrients were favourable for the growth of hardwood trees.

[48] Ontario Ministry of Agriculture and Food and Agriculture Canada. 1957. Soil Survey of Lambton County.

Some Intrazonal great soil groups are found in the area including the poorly drained Dark Grey Gleisolic and Organic. The poorly drained soils tend to have a higher pH than the Grey-Brown Podzolic Soils. Organic soils have a layer of muck or peat overlying the poorly drained soil.

Azonal soils (Alluvial and Regosol) are also found in localized parts of the area. Alluvial soils occur in stream bottoms or other areas where soil horizons have not developed because of recent deposition of soil materials. Regosols occur on drifting dune sand or shaley gravel.

Soil Profile

A single parent (raw) material can result in several different classifications of soil. For example, one area may have compact subsoil that restricts water movement and root penetration while another may have open porous subsoil that permits rapid water movement and easy root penetration. Therefore, the entire soil profile is considered in classifying soils.

Most soils are made up of layers called horizons formed by the acid reaction of surplus water percolating downwards through the soils. A vertical cross-section is cut through all layers from the topsoil to the unaltered parent material to form a soil profile. The soil profile reflects influences such as type of bedrock, climate, slope, vegetation and drainage. In general, the main soil layers or horizons are designed as A, B, G and C. These may be divided into sub-layers.

The “A” horizon (topsoil or surface layer) is the uppermost layer. A_0 is the thin surface layer of partially decomposed litter. A_1 contains accumulated organic matter that has been leached of mineral constituents. A_2 is immediately below A_1 and contains little or no organic material. It is the most strongly leached layer in the profile.

The “B” horizon or subsoil contains some of the materials, chiefly iron, alumina and clay, removed from the A horizon by the leaching process. The B horizons are usually browner than the A_2 and finer in texture.

In poorly drained soils, a B horizon does not develop and a G horizon appears. The G horizon is usually a grey mottled reddish brown coloured layer. The mottled colour is a result of alternating oxidation and reduction caused by a fluctuating water table.

The deepest layer is the “C” horizon, also known as the parent material.[50] The upper slightly weathered part of the C horizon may be designated as the C_1 horizon.

Soil Type and Soil Series

Soil type consists of a group of soils with similar genetic horizons that developed from similar parent material. A given soil type may include a limited range of properties and the boundaries between different soil types vary in sharpness. Also, there is often a zone between two soil types that includes features of both.

Two or more soil types that developed from similar parent material and similar drainage conditions but have differing texture in the surface horizon are grouped together as a Soil Series.

[49] Department of Planning and Development. 1952. Upper Thames Valley Conservation Report.
[50] OMAF and Agriculture Canada. 1957. Soil Survey of Lambton County.

Soil Catena

Well drained, imperfectly drained and poorly drained soils often occur in close association. The term "catena" is used to designate two or more soil series that have developed from the same parent material with differing drainage.

Thames-Sydenham & Region Soils

Extensive and detailed soil surveys have been made on a county basis for most of Ontario, including all of the Thames-Sydenham & Region area. **Table 2.2.4-1** provides a summary of the soil surveys for this area.

Table 2.2.4-1: Soil Surveys in Thames-Sydenham & Region

County	Soil Report Number	Year Completed
Huron	13	1952
Perth	15	1952
Oxford	28	1961
Middlesex	56	1992
Lambton	22	1957
Elgin	2	1929
Kent	64	1996
Essex	11	1947

The Ontario soil surveys follow a convention of naming various soil series after the locality in which it was first identified. Given the wide variation in drainage or relief that can be combined with an assortment of parent materials, a complex variety of soil types and soil series can be in a relatively small area.

The variety of soils based on parent material and drainage is illustrated by **Table 2.2.4-2: Classification of Soil Series in Lambton County** which has been taken from the Soil Survey of the Ontario Soil Survey for Lambton County.

Table 2.2.4-2: Classification of Soil Series in Lambton County

Parent Material	Great Soil Group					
	Grey Brown Podzolic		Dark Grey Gleisolic	Bog	Alluvial	Regosol
	Well Drained	Imperfectly Drained	Poorly Drained	Very Poorly Drained	Poorly Drained	Well Drained
Glacial Till Loamy calcareous Water modified clay till Shaley clay till	 Guelph Huron -	 - Perth Caistor	 - Brookston -			
Outwash Materials Sand Gravels Sand over clay till	 Fox Burford -	 Brady Brisbane Berrien	 Granby Gilford -			 Plainfield Shashawandah -
Lacustrine material Fine sandy loam & silt Silt and clay Silt and clay (grass) Silt and clay till		 - - - Lambton	 Colwood Toledo Clyde -			
Recent Alluvium					Blackwell	
Organic deposits Well decomposed Poorly decomposed				 Muck Marsh & Peat		

The differences associated with drainage and parent material are shown in **Table 2.2.4-3: Characteristics of Soil Series in Lambton County** which has been extracted from the Ontario Soil Survey for Lambton County.

Table 2.2.4-3: Characteristics of the Soil Series in Lambton County

Parent Material	Texture of Surface Soil	Drainage				
		Excessive	Good	Imperfect	Poor	Very Poor
Outwash Sand Outwash sand over clay	Sand, sandy loam Sand, sandy loam	Plainfield Eastport	Fox	Brady Berrien	Granby	
Outwash medium gravel Shaley gravel Loamy till	Loam Loam Loam		Burford Shashawandah Guelph			
Clay till	Clay loam, clay		Huron	Perth Caistor	Brookston	
Lacustrine fine sand	Fine sandy loam				Colwood	
Silt and clay	Clay, clay loam Loam, silt loam			Toledo Lambton	Clyde	
Recent alluvium Organic	Clay				Blackwell	 Muck, peat

Table 2.2.4-4: Soil Series and Types in the Thames-Sydenham & Region summarizes some of the catena of soils in area and lists the associated soil types found within each catena.

The different soil surveys were completed on a county-by-county basis, in different years and with different degrees of detail. Therefore, it was difficult to use the surveys to compare the different soil series across the watershed. In 2004, the Ontario Ministry of Agriculture and Food undertook a Soils Ontario Project to consolidate the soil data in a seamless digital database. This consolidated information has allowed the production of soils information maps for the Thames-Sydenham & Region watersheds.

For the purposes of source protection, hydrological classification in terms of porosity or infiltration potential is of more interest than specific soil types. Thus, the various soil series in the watershed area have been grouped into several hydrologic soil classifications. The groupings are shown in **Table 2.2.4-5: Generalized Soil Textures** and include:

- Fine Sand
- Loam
- Sand Loams
- Silt and Clay
- Silt and Clay Loams

Table 2.2.4-6: Percentages of Soils in the Thames Watershed & Region provides comparison of the soil types in the total watershed and the individual CA areas. The information of this table is based on the soils classification used to produce **Map 8: Soils Information**. Silt and clay soils are the largest percentage (39%) of soil. The combination of loam soils, silt and clay loams (25%), sand loams (16%) and loams (9%), represent half of the soil in the watershed. There is a distinct different in the LTVCA and UTRCA watershed areas with a much higher percentages of silt and clay type soils in the LTVCA area. The high percentage of "Not Mapped" reflects the larger urban communities in this region.

Table 2.2.4-4: Soil Series and Types in the Thames-Sydenham & Region

Catena	Associated Types
Huron	• Huron • Perth • Brookston • Brantford • Bennington • Bryanston • Muriel
Guelph	• Guelph • London • Parkhill • Maplewood • Honeywood • Embro • Crombie • Bennington • Tavistock
Dumfries	• Dumfries • Lyons
Fox	• Fox • Brady • Granby • Barrien • Bookton • Wauseon • Wattford
Burford	• Burford • Brisbane • Gilford • Donnybrook • Caledon • Teeswater
Waterloo	• Waterloo
Harriston	• Listowell
Plainfield	• Plainfield
Walsher	• Walsher
Brant	• Brant

Table 2.2.4-5: Generalized Soil Textures

Generalized Soil Classification	Hydrologic Soil Classification	Soil Survey Soil Association
Fine sand	Fine Sand	Plainfield
Loam	Loam	Parkhill Loam London Loam London Silt Loam Perth Silt Loam Parkhill Silt Loam Guelph Loam Guelph Silt Loam Burford Loam Guilford Loam
Sand Loams	Fine sand loam Gravelly loam Gravelly silt loam Loamy fine sand Loamy sand Loamy very fine sand Sand loam Very fine sandy loam	Bookton Walsher Fox Waterloo Sandy Loam Brady sandy loam Granby Sandy Loam Brisbane Sandy Loam Burford Loam Berrian Sandy Loam Burford Sandy Loam Brady Loamy sand Burford Caledon Wattford
Silt and Clay	Clay Clay loam Silt clay loam Silty clay Silty loam	Brookston Clay Loam Huron Clay Loam Perth Clay Loam Brookston Clay Loam Huron Clay Loam Perth Clay Loam Huron Silt Loam Brookston Silt Loam Donnybrook Sandy Loam Harriston Silt Loam Huron Silt Loam Listowell Silt Loam Perth Silt Loam Bennington Silt Loam Embro Silt Loam Honeywood Silt Loam Maplewood Silt loam Crombie Silt Loam Tavistock Silt Loam Bryanston Brantford Bennington Honeywood Brant Huron Teeswater Muriel

Table 2.2.4-6: Percentages of Soils in the Thames Watershed & Region

General Soil Grouping	Percentage (%)		
	Thames Region	LTVCA	UTRCA
Silt and Clay	39	51	26
Sand Loams	16	24	7
Silt & Clay loams	25	12	39
Loams	9	4	15
Bottom Land & Beach	3	4	3
Organic	1		2
Not Mapped & Other	7	5	8
Total	100	100	100

2.2.5 Topography

The topography of the land was formed by the retreat of the Wisconsin Glacier, about 14,000 years ago. The Thames Watershed & Region is divided into three areas: the Thames River which discharges into Lake St. Clair, a small triangle of land that drains directly to Lake St. Clair, and the shoreline area that drains to Lake Erie. **Map 9: Ground Surface Elevation** provides an overview of the Thames Watershed & Region topography.

Thames River

The Thames River is thought to be the first river to have formed in Ontario. At its earliest stage, the great Thames spillway drained a large area that included the neighbouring watersheds of the present day Saugeen, Maitland and Grand Rivers[51].

The Thames rises at three distinct points near Mitchell (North Thames), Hickson (Middle Thames) and Tavistock (South Thames). The Middle Branch is only approximately 26 kilometres long. It joins the South Branch, which is 86 km long, east of the City of London. The South Branch continues west to meet the North Branch, which is 77 km long, at the Forks in London. From there, the river flows 187 km southwest before it empties into Lake St. Clair at Lighthouse Cove. A profile[52] of the Thames River is given in **Figure 2.2.5-1: Thames River Profile**.

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[51] Thames River Background Study Research Team. 1998. The Thames River Watershed, A Background Study for Nomination under the Canadian Heritage Rivers System.

[52] Lower Thames Valley Conservation Authority website July, 2006. www.lowerthames-conservation.on.ca/

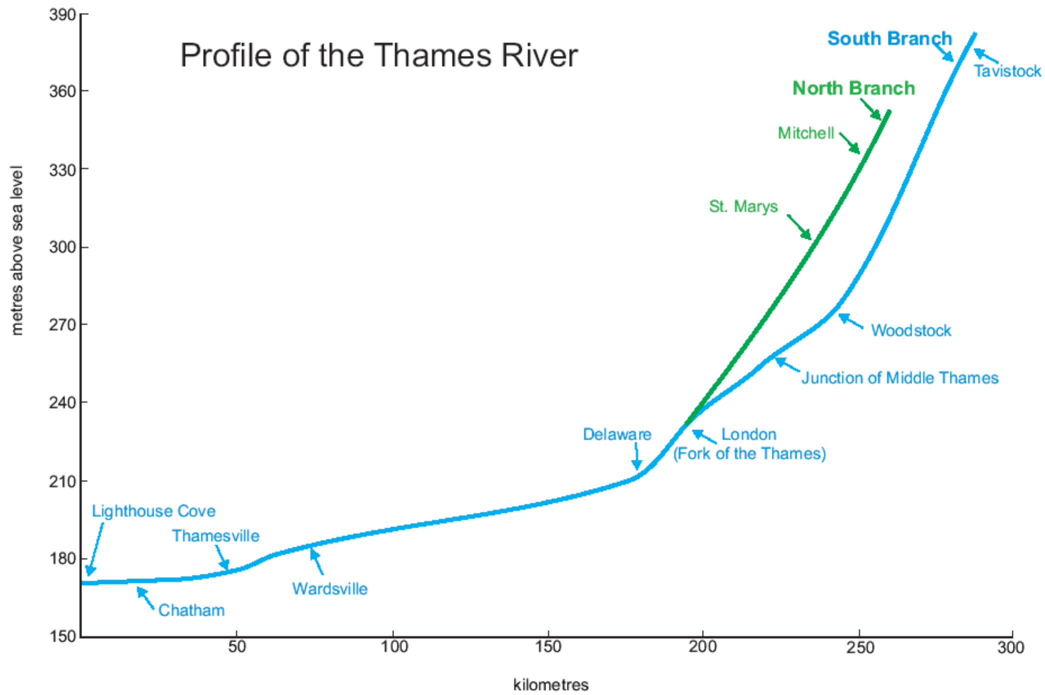

Figure 2.2.5-1: Thames River Profile

The upper branches of the river flow through ancient glacial spillways. Today they are termed *misfit* or *underfit* streams which mean the modern watercourses are too small to have cut the valleys they currently occupy. The river beds are rocky and the valley slopes are steep, with bluffs or terraces on at least one side. In contrast, the lower part of the Thames has carved its own channel into flat plains of clay and sand. Here, the river bed is soft and the water flow is gentle.

The headwaters of the South Branch have an elevation of 380 metres above sea level near Tavistock. The North Thames and Middle Thames river headwaters are approximately 355 metres above sea level. The overall elevation of the upper Thames falls at a moderate rate (1.9 m/km). The Avon River, a tributary of the North Thames, has the highest headwater elevation in the watershed at approximately 400 m above sea level.

The division between upper and lower Thames is considered to occur at Delaware with an elevation of 210 metres above sea level. The elevation at the mouth of the river is approximately 170 metres above sea level. In the lower Thames, the average rate of fall is approximately 0.2 m/km.

Downstream of Chatham, the river is so shallowly entrenched below the old lake plain that dykes have been constructed to control flooding of the adjacent lands. The ditches that drain the farmland in the Chatham area are often pumped to their outlets since there is limited flow by gravity over the flat terrain.

Lake St. Clair Shoreline

Much of the area is dyked and dewatered by pumping to support agricultural activities. These lands have little relief and are drained via numerous small creeks or drains constructed under the Drainage Act. Most of the farmland is systematically tiled. In order to have outlet for these small creeks and drains, all of the drains that empty into Lake St. Clair are pumped.

The Lake Erie Shoreline

The Lower Thames Valley Conservation Authority has 120 kilometres of Lake Erie shoreline. Most of the shoreline is characterized by high bluffs and incised valleys. Fully developed beach and marsh are the other significant shoreline features.

A height of land divides the Thames and Lake Erie watersheds. The distance from the height of land to the lake is up to 12 kilometres in the eastern part of the region and as small as 100 metres at points in the western portion. In the east, this narrow watershed is drained into the lake by numerous short watercourses with deep valleys cut into sand and clay plains. In the west, the Rondeau Bay watershed is somewhat different. This land falls relatively evenly to the Bay and the streams have a much shallower profile.

2.2.6 Land Forms and Human Character of the Watershed

Several topographical features, especially those related to water, played an important part in the development and human character of the Thames Watershed & Region. The Thames River and its many tributaries were important to fishing, hunting and crop cultivation for early inhabitants. European settlement depended on water transportation and prior to the initiation of railway lines in the mid-1800s, the Thames River was the most efficient transportation route for cargo[53]. As a result, the Thames facilitated the development of trade and commerce especially below London. The shoreline of Lake Erie also provided locations for the growth of communities, particularly those that had good port facilities.

The community of Chatham benefited from having the Thames River connection to Lake St. Clair and the Great Lakes shipping traffic. The Detroit River, Lake St. Clair and the St. Clair River provided a connecting channel between Lake Erie and Lake Huron. The Thames River also provided a navigable water route into interior areas of the watershed. Above Chatham, the Thames River was navigable to London for canoes, small craft and barges to transport staples to local businesses. The depth of the river allowed log running which was a major economic development in the history of the watershed. The depth of the river was also conducive to the growth of a major shipbuilding industry in Chatham.

The historic and present farming community reflects the good soil types across much of the Thames Watershed & Region. Initially, the relatively flat topography, lack of drainage and flooding in some parts of the watershed was a limitation on agricultural usage especially in the LTVCA watershed. However, over 125 years of drainage works have made most lands available for farming. As shown in **Map 30: Generalized Land Cover**, the watershed is over 80% agricultural. **Map 33: Land Capability for Agriculture** illustrates that most of the land has no significant or only moderate limitations on use for crops.

Saw mills and grist mills using water power were erected as areas were settled. The location of these mills led to the development of small pioneering settlements along the Thames River and its tributaries. Water power helped communities such as London, Stratford, Woodstock and Ingersoll grow before the advent of steam and electrical power.

Along the shores of various sections of the upper Thames River, the early European settlers found limestone especially in the St. Marys and Beachville areas. From the mid-1840s, dozens of small quarries were developed and provided an important export for the local economy. Today, St. Marys is the home of a major cement company that uses locally quarried limestone.

[53] Thames River Background Study Research Team. 1998. The Thames River Watershed, A Background Study for Nomination under the Canadian Heritage Rivers System.

The presence of oil in the bedrock has also had a significant impact on the human character and development of the area. The first oil well in North America was completed at Oil Springs in Devonian strata in the Dundee formation[54] just north of the LTVCA watershed. **Map 31: Oil and Gas Wells** shows that more of the wells are located in the LTVCA watershed than have been located in the UTRCA watershed. To date, oil production has been largely restricted to the Dundee and Lucas Formations. The Hamilton Formation generally forms an upper seal for the Lucas and Dundee oil and gas formations. Minor amounts of oil and gas have been found in the overlying Hamilton Group carbonate beds.

2.3 Hydrology & Climatic Character

This section provides an overview of the climatic conditions and hydrology of the Thames Watershed & Region.

2.3.1 Climate and Meteorological Trends

In general, the climatic factors that influence the rainfall-runoff process are of the most interest from a source protection perspective. These factors include:

- rainfall volume and intensity
- snow accumulation
- air temperature
- wind speed and direction
- solar radiation

2.3.1.1 Climate Monitoring Stations

Different networks have been established to monitor meteorological and climatic trends in the region. The main ones are the Environment Canada network, and the Conservation Authority networks.

The Environment Canada network of automatic and synoptic stations is best for observing long-term trends. These stations have longer periods of record, measure winter precipitation and have uniform quality control. The locations of the main long-term Environment Canada climate stations in the Thames-Sydenham & Region Source Protection Area are listed in **Table 2.3.1.1-1**, and shown on **Map 10: Environment Canada Climate Monitoring Stations**.

[54] OGS. 1992. Geology of Ontario, Sp. Vol. 4, The Paleozoic and Mesozoic Geology of Ontario, Part 2, p. 977

Table 2.3.1.1-1: Environment Canada Climate Stations in the Thames-Sydenham & Region[55]

Station	Period of Record
Chatham	1879 - present
Ridgetown	1883 - present
Wallaceburg	1905 - 1997
Petrolia	1953 - present
Sarnia	1882 - present
Dorchester	1976 - present
Foldens	1963 - present
Ingersoll	1870 - 1969
London	1871 - present
Stratford	1865 - present
Strathroy	1879 - present
Woodstock	1870 - present

Conservation Authorities also maintain their own climate networks. Generally, these were established for the purposes of flood forecasting by measuring rainfall and snow pack depth.

The Conservation Authority-managed tipping bucket rain gauges measure hourly rain and are useful for measuring spring, summer and fall rain events. These gauges do not provide as complete an information base as Environment Canada's climate network, since the stations generally do not measure winter precipitation directly. Also, they are often located on the roofs of stream station huts and may not meet all World Meteorological Organization standards for placement and calibration. However, they can support modelling of events by helping to fill in information gaps in the Environment Canada network.

Snow course networks are used for the purposes of spring flood prediction by recording the accumulated snow depth. These stations are generally monitored on a twice monthly basis. They provide a history of the water content in the snow pack for each winter season. These stations provide a fairly good data set, with some having continuous periods of record going as far back as the early 1950s.

The locations of climate data stations maintained by the Upper Thames River and Lower Thames Valley Conservation Authorities are illustrated on **Map 11: Climate Monitoring Network**. Location names and histories are summarized in **Table 2.3.1.1-2: UTRCA Rain Gauge Network**, **Table 2.3.1.1-3: UTRCA Snowcourse Network**, and **Table 2.3.1.1-4: LTVCA Rain Gauge Network**.

[55] Environment Canada. 2002. Canadian Daily Climate Data on CD-ROM - Eastern Canada, 2002 Version.

Table 2.3.1.1-2: UTRCA Rain Gauge Network

Station	Period of Record
Mitchell	1982 - present
Avon River	1982 - present
St. Marys	1982 - present
Thorndale (Plover Mills)	1982 - present
Fanshawe Dam	1982 - present
Medway River	1982 - present
Innerkip	1982 - present
Pittock Dam	1998 - present
Ingersoll	1982 - present
Thamesford	1982 - present
Waubuno Creek	1982 - present
Dingman Creek	2000 - present
Reynolds Creek	2002 - present
Trout Creek (Fairview)	2002 - present
Oxbow Creek	2002 - present
Orr Dam	2003 - present

Table 2.3.1.1-3: UTRCA Snowcourse Network

Station	Period of Record
Bornholm	1957 - present
Fullarton	1957 - present
Rostock	1957 - present
Kirkton	1978 - present
Wildwood	1978 - present
Elginfield-Birr	1964 - present
Fanshawe	1957 - present
Embro	1957 - present
Woodstock	1957 - present
Hyde Park	1999 - present
Putnam	1957 - present
Medina	1964 - present
Sebringville	1957 - present

Table 2.3.1.1-4: LTVCA Rain Gauge Network

Station	Period of Record
Dutton	1975 – present
Thamesville	1975 – present
McGregor Creek	1975 – present

2.3.1.2 Climate Monitoring Parameters & Meteorological and Climatic Trends

Variations in climate conditions have significant impacts on local watercourses and the recharge of groundwater aquifers. Water levels vary from season to season and from year to year because of the combined effects of precipitation, runoff and evaporation.

Climate normals are used to summarize or describe the average climatic conditions of a particular location. The World Meteorological Organization considers 30 years to be long enough to eliminate year-to-year variations. At the end of each decade, Environment Canada updates as many climatic characteristics as possible.

The most recent Canadian climate normals are based on stations that have at least 15 years of data from 1971 to 2000. **Table 2.3.1.2-1: Normal Precipitation** shows monthly and annual precipitation normals based on the 30 year period between 1971 and 2000. **Table 2.3.1.2-2: Normal Air Temperatures** provides similar information for air temperature normals.

Data from some of the Environment Canada Climate Stations in the Source Protection Region has been tabulated and plotted to illustrate climatic differences across the region.

Table 2.3.1.2-1: Normal Precipitation (mm) Thames Watershed & Region, 1971-2000

	London			Stratford			Woodstock			Sarnia			Petrolia			Chatham			Strathroy			Ridgetown		
	Rain	Snow	Total	Rain	Snow	Total	Rain	Snow	Total	Rain	Snow	Total	Rain	Snow	Total	Rain	Snow	Total	Rain	Snow	Total	Rain	Snow	Total
Jan	31.1	52.6	74.2	28.7	75	104	32.4	31.9	64.3	22.1	31.6	50.1	27.5	40.7	68.3	30	31.1	61.1	27.2	48.1	75.3	25.6	28.6	54.2
Feb	29.1	38.1	60	25.4	43.6	69	32.1	21.6	53.7	24	26.3	47.7	29.5	23.8	53.3	35.3	19.1	54.4	26.9	34.2	61.1	36.1	25.4	61.4
Mar	53.8	28.6	78.4	46.8	28.3	75.1	52.9	19	71.9	44.1	19.3	62.6	49.5	16.6	66.1	49.5	10.8	60.2	51.2	23.8	74.9	66.6	15.2	81.9
Apr	73.8	9.2	82.2	76	9	85.1	75.2	5.2	80.3	70.1	5.4	75.4	81.5	3.8	85.4	76.8	1.4	78.2	75.2	8.8	84	73	4.5	77.5
May	82.6	0.3	82.9	82.2	0.3	82.5	80.4	0.1	80.5	69.9	0	69.9	79.2	0	79.2	74.5	0	74.5	73.9	0.1	74	76.8	0	76.9
Jun	86.8	0	86.8	77.4	0	77.4	84.3	0	84.3	85.6	0	85.6	89.2	0	89.2	83.4	0	83.4	74.5	0	74.5	82.1	0	82.1
Jul	82.2	0	82.2	90.1	0	90.1	95.5	0	95.5	74.1	0	74.1	76	0	76	86.1	0	86.1	71.7	0	71.7	92.8	0	92.8
Aug	85.3	0	85.3	83.3	0	83.3	91.5	0	91.5	77.1	0	77.1	82.2	0	82.2	86.3	0	86.3	82.1	0	82.1	105	0	105
Sep	97.7	0	97.7	104	0	104	93.9	0	93.9	94	0	94	97.5	0	97.5	92.6	0	92.6	89.8	0	89.8	92.9	0	92.9
Oct	74.9	2.7	77.6	79.2	1.6	80.8	72.8	1.2	73.9	64.2	1.8	66	72.6	0.6	73.3	68.6	0.1	68.6	67.4	3.4	70.8	55.4	0.1	55.4
Nov	73.7	19.7	91.1	79.3	22.5	102	75.8	9.9	85.6	67	10.2	76.4	76.7	7.9	84.6	72.9	1.7	74.6	77.6	16.9	94.5	84.2	9	93.3
Dec	47	51.1	88.6	47.7	63.4	111	49.9	28.7	78.6	40.5	30.3	68	50.5	29	79.6	51.7	15.1	66.7	45.9	46.5	92.4	61.1	34.5	95.6
Annual	818	202	987	820	244	1064	837	117	954	733	125	847	812	123	935	808	79.2	887	764	182	945	851	117	969

Table 2.3.1.2-2: Normal Air Temperature (^{o}C) Thames Watershed & Region, 1971-2000

	London			Stratford			Woodstock			Sarnia			Petrolia			Chatham			Strathroy			Ridgetown		
	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min
Jan	-6.25	-2.41	-10.1	-6.72	-3.21	-10.2	-6.27	-2.31	-10.2	-5.36	-1.73	-8.94	-5.32	-1.58	-9.01	-3.68	-0.32	-7.02	-5.78	-2.16	-9.37	-6.04	-2.52	-9.54
Feb	-5.5	-1.4	-9.7	-6	-2.2	-9.7	-5.4	-1.1	-9.6	-4.4	-0.6	-8.3	-4.4	-0.3	-8.5	-2.4	1.1	-6	-5.2	-1.2	-9.2	-4.6	-1	-8.2
Mar	-0.3	4.2	-4.7	-1	3.1	-5	-0.3	4.2	-4.8	0.7	4.8	-3.5	1	5.7	-3.6	2	6.1	-2.1	0.5	4.7	-3.7	0.7	4.5	-3.1
Apr	6.3	11.6	1	5.8	10.6	1	6.4	11.6	1.1	6.5	11.4	1.5	7.2	12.6	1.8	8.3	13.2	3.4	7	12	1.9	7.1	11.9	2.2
May	13	19	7	12.6	18.3	6.8	13.2	19.2	7.1	12.7	18.3	6.9	13.8	19.8	7.7	14.8	20.2	9.4	13.6	19.4	7.7	13.6	18.9	8.3
Jun	18	23.8	12.1	17.4	23.1	11.8	18.2	24.1	12.2	18	23.6	12.4	18.8	24.9	12.8	20.2	25.5	14.9	18.6	24.3	12.8	18.8	23.9	13.5
Jul	20.5	26.3	14.6	19.7	25.4	14	20.4	26.4	14.5	20.9	26.3	15.5	21.5	27.4	15.5	22.5	27.5	17.4	21.2	27	15.3	21.5	26.8	16.2
Aug	19.5	25.2	13.7	18.9	24.3	13.3	19.6	25.3	13.7	20	25.3	14.8	20.6	26.3	14.8	21.4	26.3	16.6	20.2	25.8	14.5	20.6	25.5	15.6
Sep	15.3	20.9	9.6	14.9	20	9.7	15.4	20.9	9.8	16.1	21.3	10.7	16.6	22.2	11	17.6	22.4	12.7	16	21.4	10.5	16.8	21.6	12
Oct	9	14	4	8.8	13.1	4.4	9.1	14.1	4.1	9.9	14.7	5.1	10.3	15.2	5.3	11.2	15.6	6.9	9.8	14.5	5.2	10.6	14.8	6.3
Nov	3.1	6.9	-0.7	2.5	5.6	-0.6	3.1	6.8	-0.7	3.9	7.6	0.2	3.9	7.6	0.2	4.8	8.1	1.5	3.8	7.3	0.3	4.5	8	1
Dec	-3	0.6	-6.5	-3.5	-0.4	-6.5	-3	0.5	-6.5	-2.3	1.1	-5.6	-2.2	1.2	-5.5	-1.2	1.8	-4.3	-2.5	0.7	-5.7	-1.9	1.4	-5.2
Annual	7.5	12.4	2.5	7	11.5	2.4	7.5	12.5	2.6	8.1	12.7	3.4	8.5	13.4	3.5	9.6	13.9	5.3	8.1	12.8	3.3	8.5	12.8	4.1

Figure 2.3.1.2-1: Annual Precipitation Normals and **Figure 2.3.1.2-2: Annual Average Temperature** provide comparisons of average annual precipitation and average temperatures, respectively, for the period from 1971 to 2000.

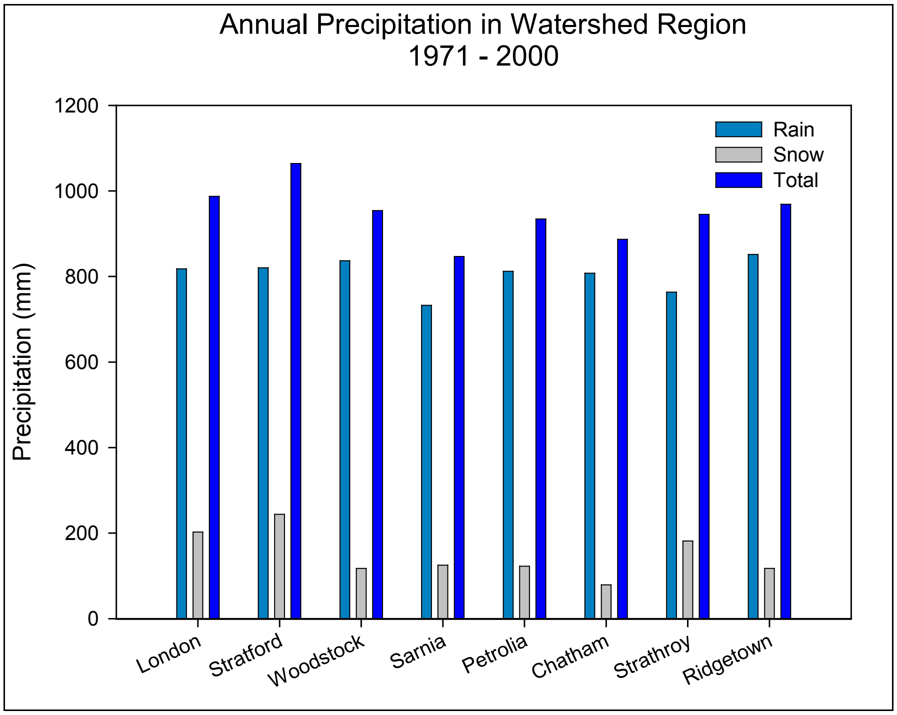

Figure 2.3.1.2-1: Annual Precipitation Normals

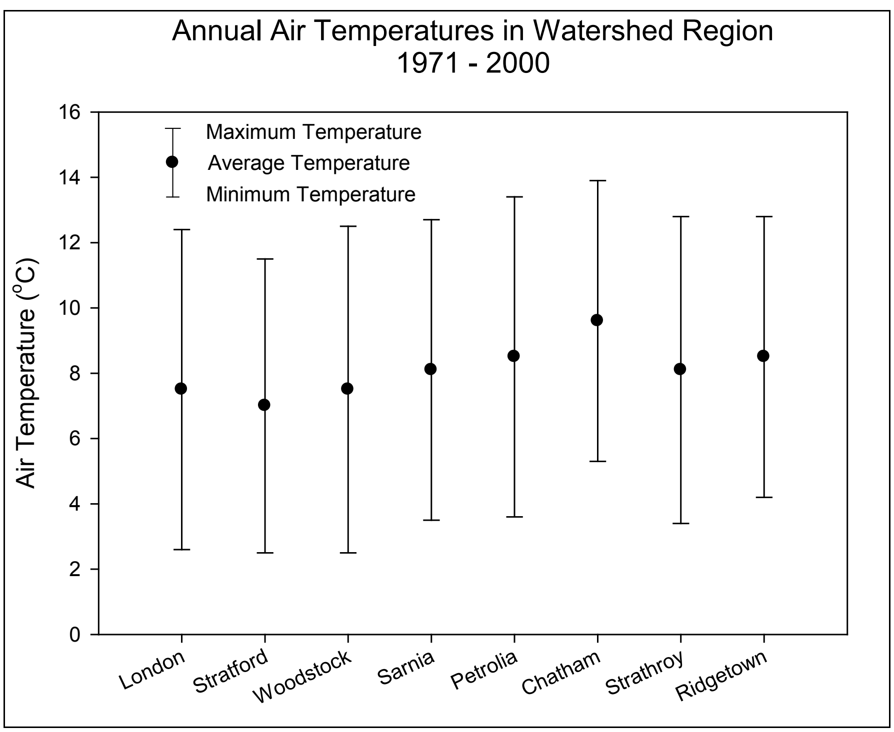

Figure 2.3.1.2-2: Annual Average Temperature

Environment Canada data from 1950 to 2005 has been used to provide some background information on the total annual precipitation at four climate stations (Stratford, Woodstock, London and Chatham) in the

Thames Watershed & Region. The meteorological files have been reviewed to clean up records and fill in missing data values using the procedures outlined in the paper *Filling Gaps In Meteorological Data Sets Used For Long –Term Watershed Modelling* presented at the Ontario Water Conference in 2000[56].

Table 2.3.1.2-3 Thames Region Annual Precipitation illustrates the variation over the years from 1950 to 2005. Within the region, annual precipitation can vary by almost 2.5 times from year to year and station to station. The minimum annual precipitation was as low as 530 mm (Chatham – 1963) while the maximum precipitation was as high as 1,347 mm (Stratford – 1985). The wide range in precipitation from year to year and station to station means that there can be a significant difference in the water available to recharge groundwater aquifers or maintain stream flow.

Table 2.3.1.2-3: Thames Region Annual Precipitation 1950-2005 in mm

Location	Average	Max (year)	Min (year)
Chatham	845	1234 (1985)	530 (1963)
London	978	1315 (1990)	569 (1963)
Woodstock	902	1264 (1996)	542 (1953)
Stratford	1029	1347 (1985)	688 (1963)

Environment Canada data from 1950 to 2005 has also been used to plot graphs of the total annual precipitation for the Stratford, Woodstock, London, and Chatham climate stations. These plots are shown in **Figure 2.3.1.2-3: Thames Watershed & Region Annual Precipitation 1950-2005**.

The linear trend lines are shown for each station. All stations have increasing linear trend lines.

As a way to smooth out the year to year fluctuations while trying to capture trends, 10 year running averages[57] have been calculated and plotted on the graphs. In general, the 10 year running averages appear to show an increasing level of precipitation in the 1970s and early 1980s, with decreases more recently.

The data sets for the individual stations have been plotted in separate figures to provide a clearer picture for the different locations. These figures also have the long-term (56 year) average shown. For all stations, the 10 year running average was less than the long-term average in 1965; higher than the long-term average in 1985; and has decreased to be close to the long-term average in 2005.

[56] Schroeter & Associates. March 6, 2007. Meteorological Data Missing - Value Fill-in Study for Ontario (Draft 1).

[57] NOAA's National Weather Service Weather Forecast Office. Climate Trends in Southeast South Dakota from 1895 through 2005. www.crh.noaa.gov

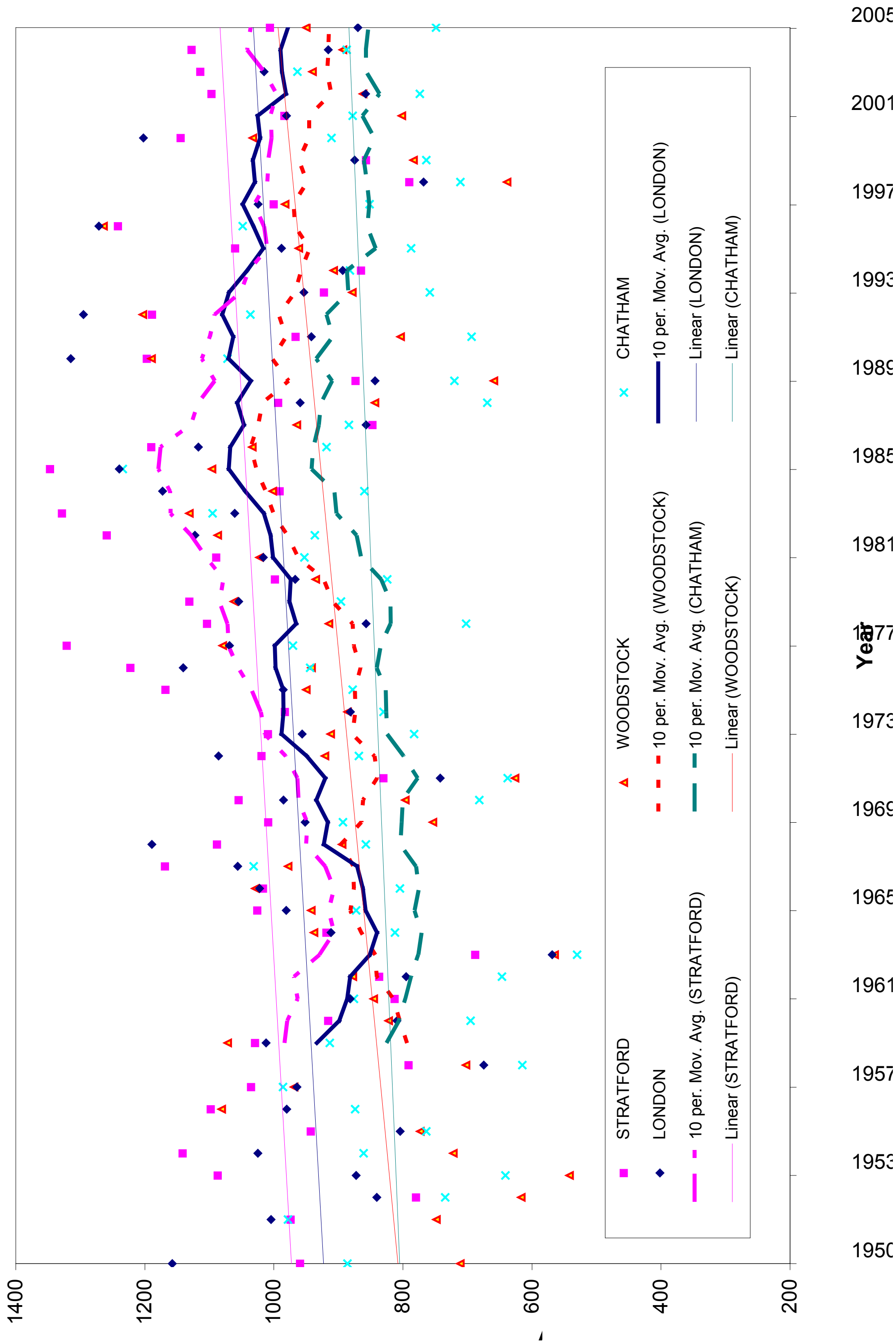

Figure 2.3.1.2-3: **Thames Watershed & Region Annual Precipitation 1950-2005**

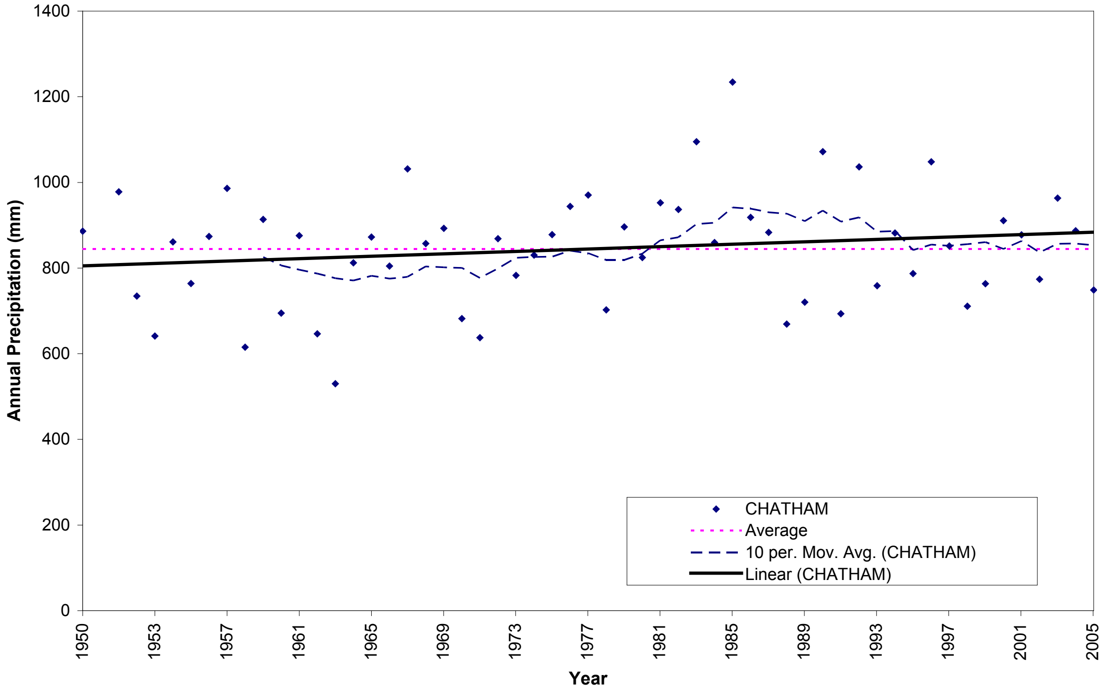

Figure 2.3.1.2-4: **Chatham Annual Precipitation 1950-2005**

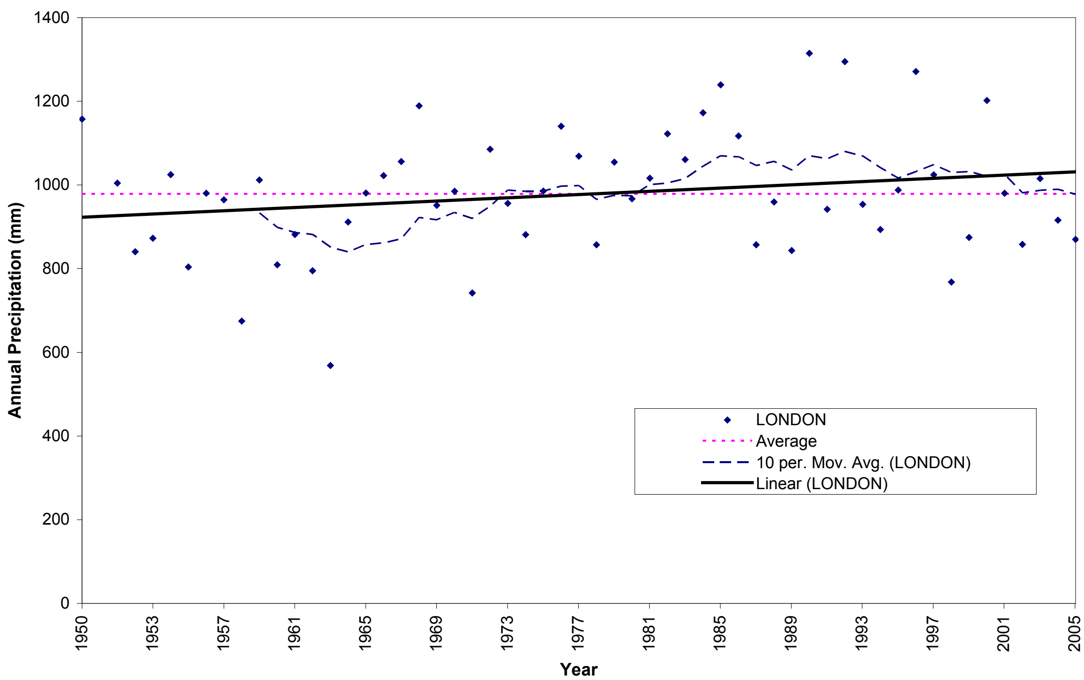

Figure 2.3.1.2-5: **London Annual Precipitation 1950-2005**

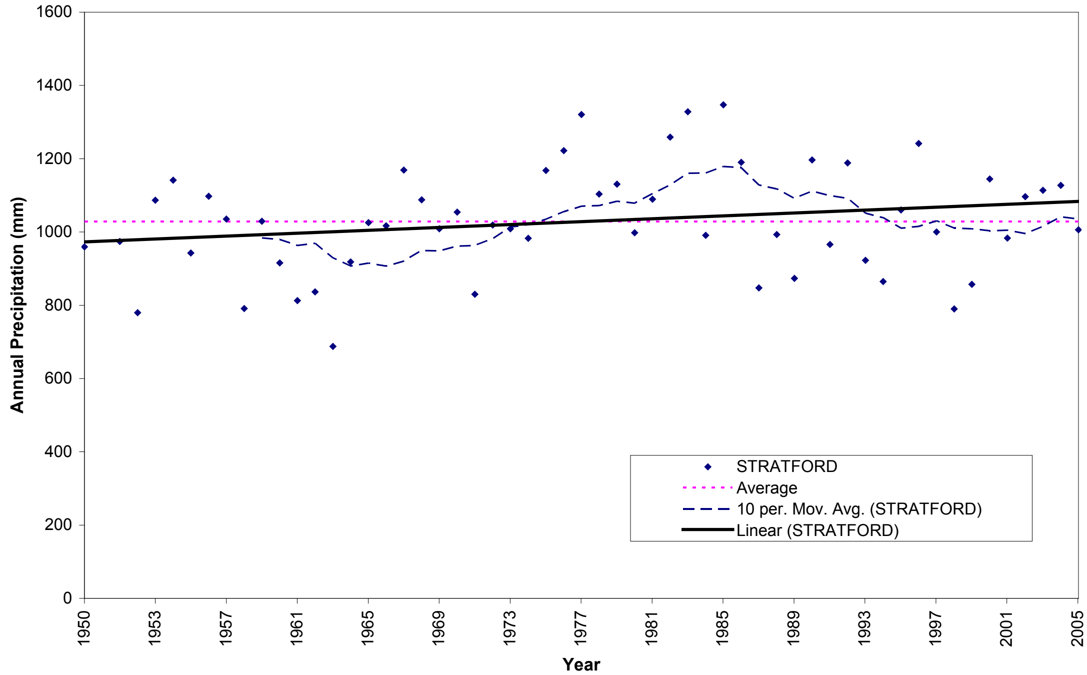

Figure 2.3.1.2-6: Stratford Annual Precipitation 1950-2005

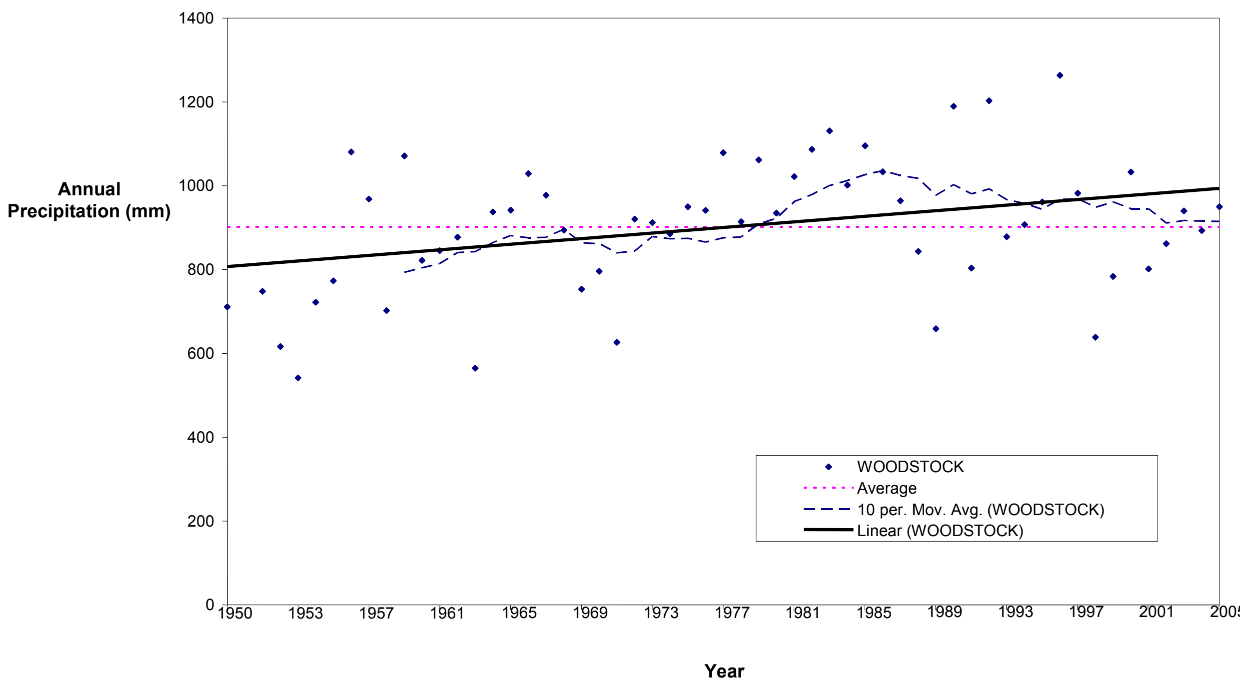

Figure 2.3.1.2-7: Woodstock Annual Precipitation 1950-2005

The average annual temperatures for these stations have also been plotted and are shown in **Figure 2.3.1.2-8: Thames Region Average Temperature 1950-2005**. The minimum annual average temperature was 5.1 degrees centigrade (Stratford – 1950) and the maximum was 11.8 (Chatham – 1998). The linear lines of best fit are shown. All stations have increasing trend lines.

The 10 year running averages are shown to smooth out year to year fluctuations and to try capture possible trends. The most southerly station, Chatham, has a higher 10 year average line than the other stations. While the London and Woodstock stations' averages are lower than Chatham, they have 10 year running average temperature values that have a pattern similar to Chatham. Stratford has the lowest 10 year running average temperatures. Since the 1970s, the Stratford 10 year running average has a pattern similar to the other stations but during the 1960s, it shows a different pattern with lower temperatures. This difference is also shown by the steeper linear trend line for Stratford.

The temperature data sets for the individual stations have been plotted in separate figures to provide a clearer picture for the different locations. These figures also include the long-term (56 year) averages. The 10 year running averages for the Chatham, London and Woodstock stations all are above the long-term average in the early 1960s; below the long-term average in the 1970s and 1980s; and above the long-term average in the 1990s and early 2000s. For Stratford, the 10 year running average is below the long-term average until the 1990s and early 2000s.

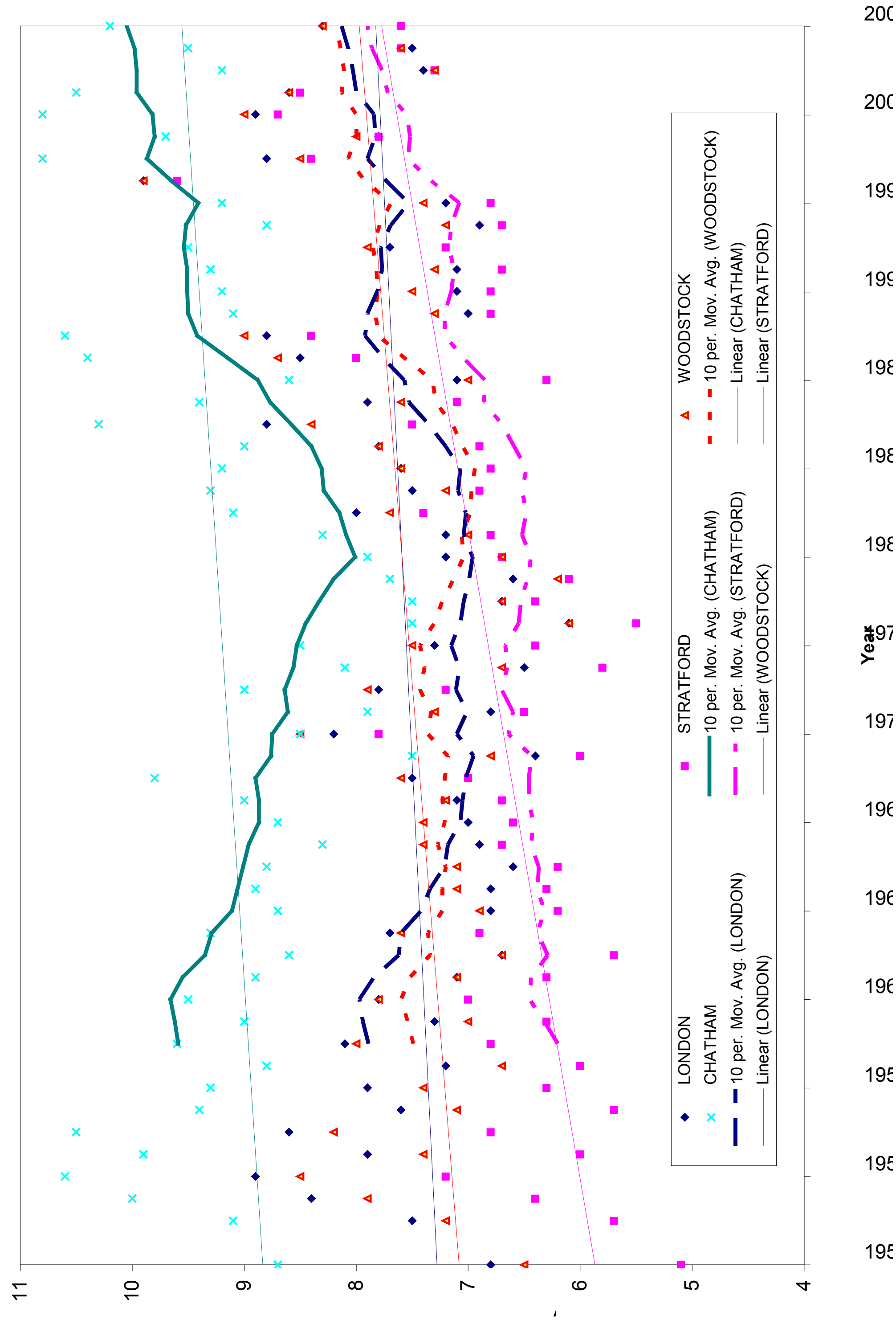

Figure 2.3.1.2-8: **Thames Watershed & Region Average Annual Temperature 1950-2005**

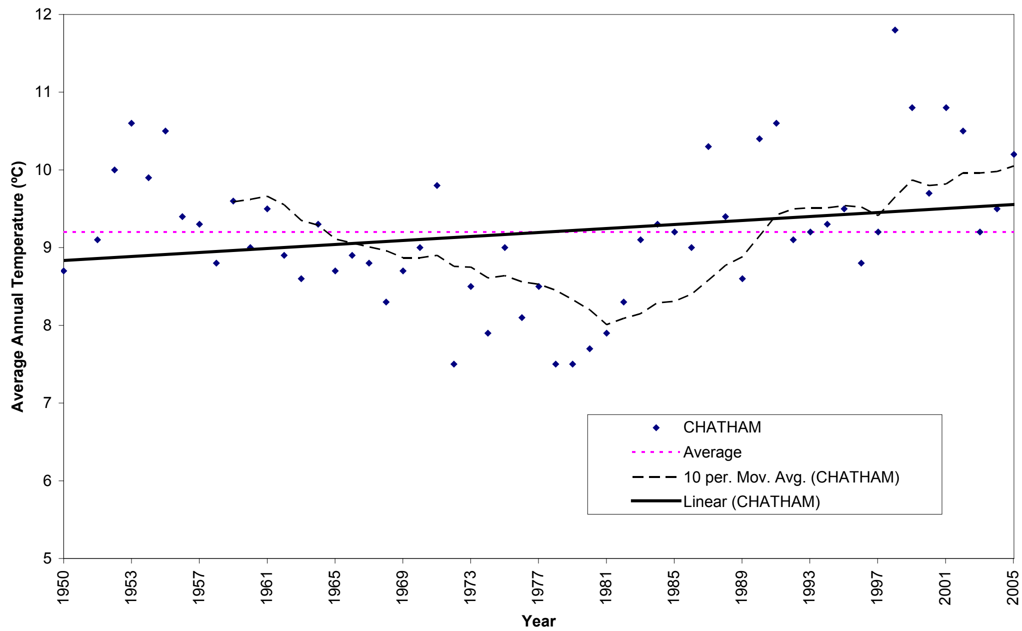

Figure 2.3.1.2-9: **Chatham Annual Average Temperature 1950-2005**

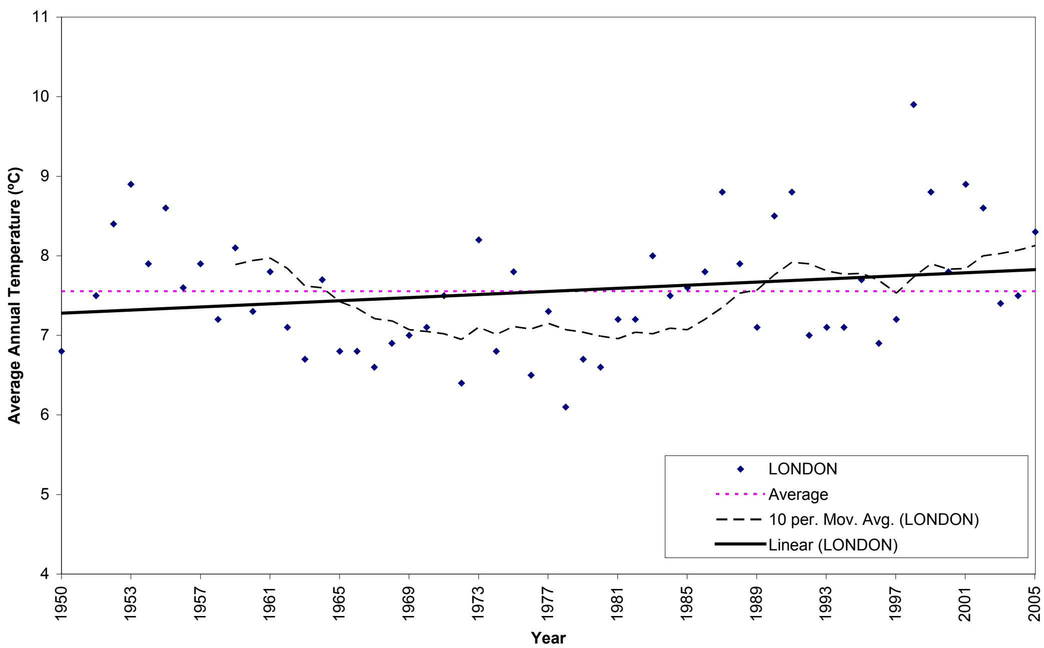

Figure 2.3.1.2-10: **London Annual Average Temperature 1950-2005**

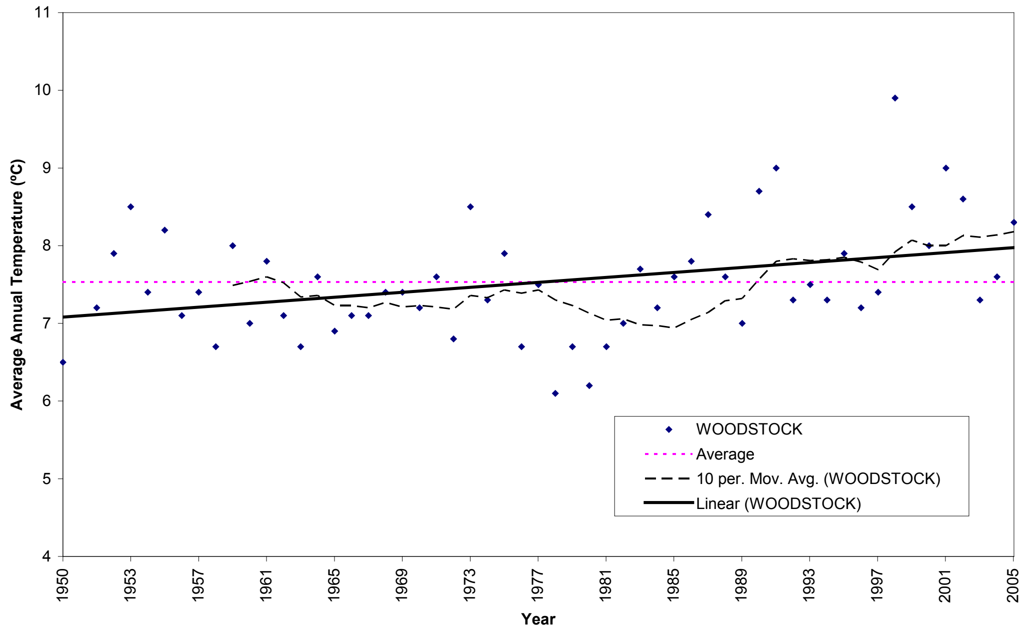

Figure 2.3.1.2-11: **Woodstock Annual Average Temperature 1950-2005**

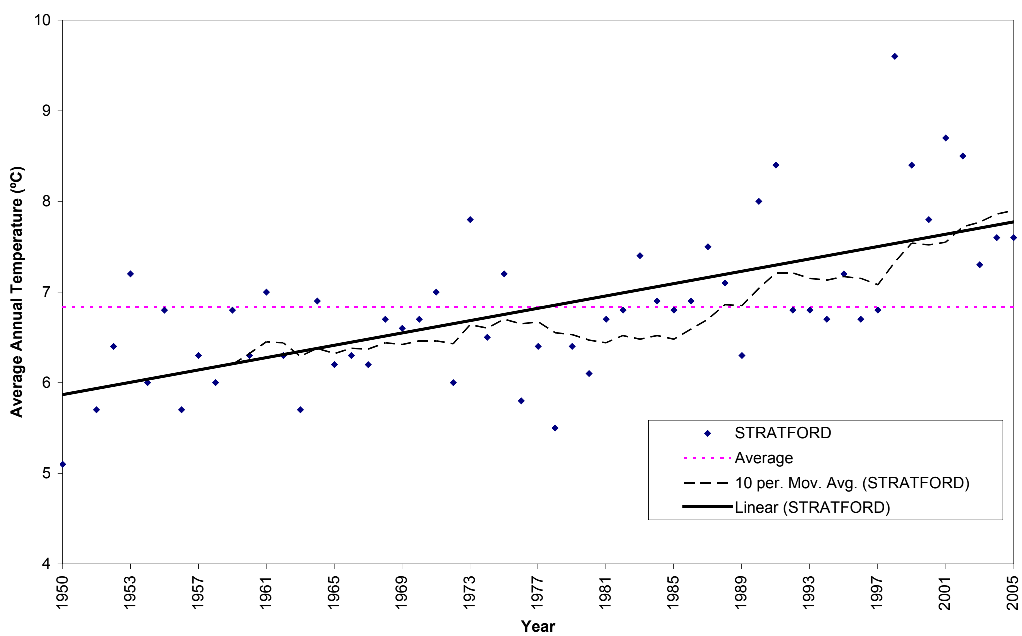

Figure 2.3.1.2-12: **Stratford Annual Average Temperature 1950-2005**

The Thames-Sydenham & Region Source Protection Region is a part of the Great Lakes Basin. The Great Lakes receive their water supplies from the precipitation that falls on the lakes themselves and the portion of the precipitation in their drainage basins that eventually flows into the lakes. A plot of the average annual water level recorded in Lake St. Clair for the period 1918 to 2005 is provided in **Figure 2.3.1.2-**

13: Lake St. Clair Water Levels. It illustrates the effect that varying climatic and meteorological conditions can have on water supplies.

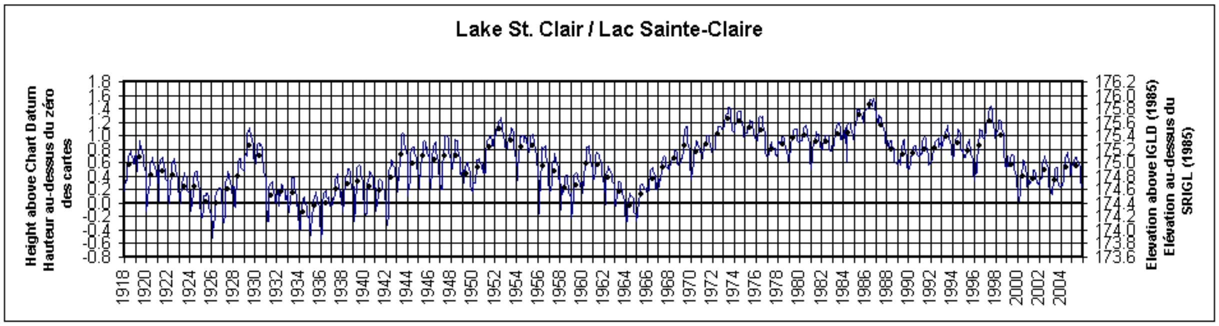

Figure 2.3.1.2-13: Lake St. Clair Water Levels

Over a period of years, there are long-term fluctuations that result from persistent low or high net water supplies[58]. More than a century of records in the Great Lakes basin indicate no regular, predictable cycle. Extremely low lake levels were recorded in 1926, the mid-1930s and mid-1960s, while high levels occurred in 1952, 1973 and 1985-86.[59] From the mid 1970s to the late 1990s, there was a 20 year period of high water levels. In the early 2000s, they returned to the lower levels experienced in the late 1930s and early 1940s.

2.3.1.3 Ontario Low Water Response

Southwestern Ontario has experienced periods of low summer (and fall) rainfall in recent years. Combined with high temperatures, this has resulted in all of the Thames-Sydenham & Region Source Protection Planning Area experiencing low water conditions of varying severity during the years from 1998 to 2005.

In 2000, the Provincial Government started the Ontario Low Water Response Program to deal with low water issues. Definitions of low water and drought were established. The plan currently uses precipitation and stream flow (surface water flow) measurements as the primary indicators for defining low water levels and drought. Indicators for base flow, groundwater and aquifer levels are to be developed.

The plan established three low water condition levels: Level I (Conservation), Level II (Conservation, Restriction) and Level III (Conservation, Restriction, Regulation). **Table 2.3.1.3-1: Summary of Levels and Thresholds** provides a simplified outline of how the indicators are used to determine when low water level conditions exist.

[58] Fisheries and Oceans Canada, Canadian Hydrographic Service Central and Arctic Region. June 2006. Fluctuations in Lake Levels.

[59] Environment Canada. July 2006. Freshwater Website: Fluctuating Water Levels (Great Lakes).

Table 2.3.1.3-1: Summary of Levels and Thresholds

Condition	Indicator	
	Precipitation	Stream Flow
Level I	Less than 80% of average	Spring: monthly flow less than 100% of lowest average summer month flow Other times: monthly flow less than 70% of lowest average summer month flow
Level II	Less than 60% of average Weeks with less than 7.6 mm (one week for high demand and two weeks for moderate demand areas)	Spring: monthly flow less than 70% of lowest average summer month flow Other times: monthly flow less than 50% of lowest average summer month flow
Level III	Less than 40% of average	Spring: monthly flow less than 50% of lowest average summer month flow Other times: monthly flow less than 30% of lowest average summer month flow

Under the Ontario Low Water Response plan, a local Water Response Team has been created to handle the responsibilities for the response process for each watershed. For the province, a standing Low Water Committee has been established. This committee must be notified and becomes active when any watershed enters a Level II condition.

Since the Low Water Response Program was established, the Upper Thames River Conservation Authority has had Level I conditions occur in four of the five years between 2001 and 2005. The Lower Thames Valley Conservation Authority has had Level I conditions in all five years. The occurrences are summarized in **Table 2.3.1.3-2: Low Water Level I Advisory History**. Low water conditions generally begin with low precipitation (and high temperatures) in the summer. The combination of low fall rains and winter snow has extended some UTRCA Level I Advisories into the spring of the next year.

Table 2.3.1.3-2: Low Water Level I Advisory History Thames Watershed & Region

Year	Lower Thames Valley CA		Upper Thames River CA	
	Start	End	Start	End
2001	July	August	October	Spring 2002
2002	July	August	July	Spring 2003
2003	July	August	September	November
2004	September	October	n/a	n/a
2005	July	October	July	March 2006

2.3.1.4 Climate Change

The Canada Country Study: Climate Impacts and Adaptation[60] was the first national assessment of the social, biological and economic impacts of climate change for Canada. There has been warming of about 1° C over the past century with increased annual precipitation over the past 50 years in Canada. These figures are consistent with global trends. Climate change projections suggest that over the next century, further warming of 1 to 3.5° C will occur. Based on this scenario, the Canada Country Study found that

[60] Environment Canada. The Canada Country Study: Climate Impacts and Adaptation. www.on.ec.gc.ca/canada-country-study

the implications of climate change for water resources are a key to defining overall impacts for all sectors and regions of the country[61].

The Ontario Region Executive Summary[62] for the Canada Country Study provides a synopsis of the impacts expected for southern Ontario. The results of the Global Circulation Model (GCM) simulations considered for the study suggested an average annual warming of some 2 to 5° C by the latter part of the 21st century for Ontario. However, it was also noted that even the most sophisticated GCMs do not incorporate the effects of important local climate controls, such as the Great Lakes. For this and other reasons, there was considerable uncertainty about the application of GCM results on a regional scale.

In southern Ontario, the climate is highly modified by the influence of the Great Lakes. The addition of moisture from the Great Lakes in autumn and winter increases precipitation amounts. The Great Lakes also protect the region from the worst of winter's cold and, in summer, they act to moderate the potentially oppressive heat of tropical air that regularly approaches the region.

In 2007, the Ontario Ministry of Natural Resources and the Canadian Forest Service prepared a new website[63] (Go Green Ontario – Climate Change Projections for Ontario) to allow people to see projections of possible future climates in Ontario over the 21st century. Since climate change projections depend on many factors, the two scenarios used for the website are considered intermediate scenarios that were approved by the Intergovernmental Panel on Climate Change.

The scenario with lower emissions of greenhouse gases indicates that in southern Ontario at the end of the century, temperatures would be 2 to 4° C warmer in summer and 3 to 5° C warmer in winter. By 2071-3000, most of southern Ontario would receive up to 10% less precipitation in summer and up to 20% less precipitation in winter compared to 1971-2000.

The scenario with the higher emissions of greenhouse gases indicates that most of southern Ontario would be 4 to 5° C hotter in summer and 20% less rain will fall from April to September. Winters in some southern Ontario locations will be up to 6° C warmer with 10 to 20% less precipitation from October to March by 2071-3000.

While the level of change varies depending on the model assumptions, the projection of warming by the latter part of the 21st century is expected to cause Ontario to experience:

- fewer weeks of snow,
- longer growing season,
- less moisture in the soil,
- increase in frequency and severity of droughts,
- changes to aquatic ecosystems and alterations to wetlands,
- decline of the Great Lakes levels to record lows, and
- increase in extreme weather (hot days, severe thunderstorms, freezing rain).

The overall impacts are difficult to predict, but there are several potential changes that are of concern for water quality and quantity for drinking water sources.

- Less rainfall and rainfall at different times could increase the demand for irrigation water, especially on drought-prone soils or shallow-rooted crops such as potatoes.
- Less rainfall and snow could have an impact on groundwater aquifers and base flow in streams.

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[61] Environment Canada. November/December 1997. The Science and the Environment Bulletin.
[62] Environment Canada. The Canada Country Study - Ontario Region Executive Summary. www.on.ec.gc.ca/canada-country-study
[63] Go Green Ontario. Climate Change Projections for Ontario, www.gogreenontario.ca

- In the Great Lakes, higher water temperatures could lead to reduced water quality by creating more favourable environmental conditions for microbes and algae. Lower water levels may affect the ability of intakes to draw water.

2.3.2 Groundwater Hydrogeology

Groundwater hydrogeology is the science that deals with the occurrence and movement of the water below the ground surface. To a large extent, groundwater studies deal with the unseen and, therefore, depend on modelling of the perceived underground water pathways. Groundwater modelling requires an integrated approach that incorporates geology, chemistry, physics, meteorology and engineering.

The first step in conceptualizing the groundwater flow regime is to study well driller's logs. These can provide observations of the material that characterize overburden layers.

The primary differentiation is based on whether the material has the properties of an aquifer (readily transmits water) or has the properties of an aquitard (prohibits the movement of water).

In most cases, groundwater flow obeys Darcy's Law, which states that the velocity of groundwater is proportional to both the hydraulic conductivity (water conducting capacity of the material) of the formation and the hydraulic gradient (slope of the groundwater surface).

The approach taken reviewed the regional setting, from basic recharge and general introduction, and then moved to more specific groundwater flow interpretation and the identification of aquifers and aquitards. Most of this section was taken directly from the (unpublished) report[15] by Waterloo Hydrogeologic, Inc.

Regional Hydrogeologic Setting

Groundwater occurrence and flow within the region is primarily controlled by:

- precipitation and evapotranspiration;
- topography and enhanced (tile) drainage;
- water table (piezometric) levels and soil moisture conditions;
- surficial geologic units, which define porosity and hydraulic conductivity; and
- the spatial distribution and connectivity of geologic units.

Precipitation is the primary source of groundwater recharge. Groundwater recharge is determined by three factors: the amount of precipitation that is not lost by evapotranspiration and runoff; the vertical hydraulic conductivity of the surficial deposits (the ability for the water to move downwards); and the gradient of the water table (potentiometric surface) which determines how the water can move away from the recharge area.

In some areas, rivers, lakes and streams may recharge aquifers. However, we are most concerned with groundwater recharge associated with precipitation over large land areas. This recharge is controlled by a number of factors, including permeability and porosity of surficial units, topography and land use.

Within the region, there are a number of aquifers and aquitards that vary greatly in spatial extent and thickness. Two distinct aquifer types, bedrock and overburden, were identified during cross-section interpretations. Bedrock aquifers can usually be subdivided into "contact" and "deeper" bedrock aquifers. Overburden aquifers may be divided into shallow, intermediate and deep overburden aquifers. In addition, aquifers are classified as either confined (bounded by two low permeability units) or unconfined (the upper surface is defined by the water table).

2.3.2.1 Bedrock Aquifers

Bedrock groundwater is less affected by surface watershed boundaries than overburden aquifers are. Groundwater moves faster in areas where there is more of a slope in the bedrock water table, such as

Shakespeare or St. Marys. It moves more slowly where the water table is relatively flat in Chatham-Kent and Lambton. In bedrock groundwater terms, “fast” means it takes tens or hundreds of years to move a small distance under natural conditions, and “slow” means it takes thousands of years.

Bedrock aquifers are regionally extensive and are productive aquifers for both municipal and domestic water supply. Groundwater in higher recharge areas where the water moves faster is aesthetically good (i.e. low mineral content) while groundwater in low recharge areas carries more minerals such as sulphur and iron because it has had more time to leach or react with minerals from the rock.

As discussed earlier, the majority of the Paleozoic bedrock units dip regionally to the southwest toward the centre of the Michigan Basin. However, the bedrock units in the southeastern portion of the region (north shore of Lake Erie) dip regionally south toward the centre of the Appalachian Basin.

The bedrock aquifers can usually be subdivided into “contact” and “deeper” bedrock aquifers. The upper three to five metres of the bedrock surface is more weathered and fractured and, therefore, form a more transmissive “contact” aquifer than the underlying “deeper” competent bedrock units.

Map 12: Bedrock Water Table presents a generalized groundwater level (potentiometric surface) map for the bedrock units in the region. **Map 13: Water Table Elevation** also provides information on groundwater elevations. The bedrock water table elevation across the combined watersheds of the Thames-Sydenham & Region ranges from 355 to 170 metres above sea level (masl). This information is based on the Southwestern Edge-Matching Study[25] which compiled data from the Essex/Chatham-Kent[64], Lambton[65], Middlesex/Elgin[66], Huron[67], Perth[68] and Oxford[69] municipal groundwater studies.

Regionally, the “contact” aquifer groundwater in the fractured bedrock flows from the topographically high areas to the lower elevations where it discharges to rivers, streams and the Great Lakes basins. Therefore, the “contact” aquifer behaves like an overburden aquifer in many areas.

The bedrock within the regional area includes numerous limestone, dolostone shale and lesser sandstone Paleozoic rock formations. The shale units act as regional aquitards while the limestone and dolostone bedrock formations form excellent aquifers. As bedrock is buried throughout the region (outcropping in only a few locations), the bedrock aquifers including the limestone and dolostone formations typically form confined aquifers.

The Silurian aged Bass Islands and the Devonian aged Bois Blanc Formation are separated by a disconformity (a break in the sequence of sedimentary rocks). This feature may be significant from a hydrogeologic perspective as the upper surface of the Bass Islands is interpreted to be weathered, highly fractured and, therefore, able to transmit greater volumes of water than the more competent rock at depth.

The Lucas Formation is known to be a good aquifer[70]. Both the Dundee Formation and the Lucas Formation are believed to be karstic (irregular limestone with sinks, underground streams and caverns). In Huron-Perth, bedrock water levels decrease dramatically from east to west at the sub crop boundary between the Dundee Formation (west) and the underlying Lucas Formation (east).

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[64] Dillon Consulting and Golder Associates. December 2004. Essex Region/Chatham-Kent Region Groundwater Study.

[65] Dillon Consulting and Golder Associates. December, 2004. Lambton County Groundwater Management Study, Final Report.

[66] Dillon Consulting and Golder Associates. July 2004. Middlesex-Elgin Groundwater Study, Final Report.

[67] Golder Associates. 2002. Groundwater Resource Assessment, County of Huron.

[68] Waterloo Hydrogeologic. April 2003. Perth County Groundwater Study, Final Report.

[69] Golder Associates. 2001. Phase II Groundwater Protection Study, County of Oxford.

[70] Waterloo Hydrogeologic. 2005. Southwestern Region Edge-Matching Study.

Groundwater associated with the Salina Formation is generally of poor quality as the evaporite deposits (anhydrite, gypsum and salt) often result in sulphurous qualities including sulfate and/or hydrogen sulfide gas. This formation is used primarily for irrigation, and due to the sulfurous qualities is seldom used for domestic water supply. Several companies extract salt from Salina Formation with deep brine wells at Windsor, Sarnia and Goderich (Hewitt, 1972).

Due to their depth below the ground surface, the older basement rocks are not expected to have a significant influence on groundwater flow directly.

2.3.2.2 Overburden Aquifers

Overburden aquifers in the region include the coarse-grained sands and gravels of the various sand plains, kame moraines and coarse-grained interstadial sediments that lie between till sheets. Coarse-grained overburden deposits (e.g. outwash deposits and kame moraines) are the most transmissive units. Groundwater flows rapidly through these units making them excellent regional and local aquifers.

Fine-grained overburden units such as till plains or clay plains represent local and regional aquitards that impede groundwater flow and recharge to deep aquifers. While aquitards are not suitable for groundwater supply, they can serve to protect adjacent aquifers from contamination as they restrict migration of contaminants.

Overburden aquifers may be divided into shallow, intermediate and deep overburden aquifers. The overburden aquifers can be surficial unconfined (the upper surface is defined by the water table) or confined (bounded by two low permeability units).

Surficial Unconfined Aquifers

This type of aquifer is associated with the coarse-grained surficial deposits such as the extensive sand plains, or outwash sand deposits that blanket the flanks of the end moraines within the study area (i.e. Wyoming Moraine). These shallow aquifers are commonly used in private and domestic water use. As they are highly susceptible to groundwater contamination, they are not often used as municipal groundwater resources.

Within the study area, the majority of the overburden aquifers are unconfined, including the sand plains (Bothwell, Caradoc) and a few of the kame moraines (e.g. Staffa Kame). Smaller scale features of the terrain, such as hummocky topography and moraine ridges can influence local groundwater flow directions.

Confined Overburden Aquifers

Confined overburden aquifers include intermediate and deep aquifers. Intermediate overburden aquifers are present erratically within the region. These interpreted to be interstadial outwash sands and gravels that lie at an in-between depth. Generally, these are pockets of material surrounded by aquitard layers.

Deep overburden aquifers consist of saturated sand and gravel deposits and can be discontinuous in nature due to glacially-related erosional and depositional conditions. These deep overburden aquifers are spatially discontinuous, but can act as highly productive aquifers in some areas.

Sand and gravel deposits have been identified between the St. Joseph’s Till and the underlying black shale till. A deep basal aquifer overlies the Catfish Creek Till in many portions of the study area. The basal aquifer is interpreted to be outwash, or interstadial sands and gravels deposited following the retreat of the Nissouri Stade ice.

As well, sand and gravel deposits can occur at the base of the overburden overlying the bedrock and may be part of the “contact” bedrock aquifer in the first few metres of weathered and fractured bedrock.

2.3.2.3 Aquifer Interaction (Aquifer Hydrostratigraphy)

Hydrostratigraphic Units

Grouping geologic units allows the subsurface to be simplified into a series of 'packages' that can be examined for the analysis of groundwater flow.

Complex geologic units with similar hydrogeologic properties, textural characteristics and a similar stratigraphic position can be grouped together to form a 'hydrostratigraphic unit'. A hydrostratigraphic unit can be a formation, a part of a formation, or a group of formations that possess similar hydrologic characteristics. This allows the subsurface to be divided into aquifers and aquitards.

Table 2.3.2.3-1: Hydostratigraphic Units provides an outline of the hydrostratigraphic units in the region. The type of unit (aquifer/aquitard), a brief description, and the geologic subunits are summarized.

Table 2.3.2.3-1: Hydrostratigraphic Units in the Thames-Sydenham & Region

Hydrostratigraphic Unit	Description	Specific Geologic Subunits
HU I Aquifer AQ1	Coarse-grained glaciofluvial/ glaciolacustrine/ ice-contact sands and gravels	Includes Bothwell, Caradoc, Norfolk and Leamington Sand Plains, and Easthope and Staffa Kame Moraines
HU II Aquitard AT1	Fine-grained subglacial till sheets, glaciolacustrine diamicts and lacustrine clay plains	Tills include Rannoch, Stratford, Wartburg, St. Joseph's, and Elma Clay plains include Ekfrid and St. Clair Clay Plains
HU III Aquifer AQint	Intermediate depth interstadial outwash sands and gravels	Includes intermediate aquifers located in Elgin and Middlesex Counties
HU IV Aquitard AT1	Lower fine-grained subglacial till sheets, and lacustrine clays	Tills include Tavistock and Port Stanley
HU V Aquifer	Basal outwash sand and gravel (interstadial complex) overlying Catfish Creek and older tills	Discontinuous sands and gravels
HU VI Aquitard	Subglacial lodgement (overconsolidated) tills	Tills include Catfish Creek, Canning, Early and Mid-Wisconsinan tills
HU VII Aquifer	Weathered and highly fractured upper portion (3-5 m) of the bedrock surface	Variable bedrock depending on location
HU VIII Bedrock Aquifer	Fractured Paleozoic bedrock	Carbonates (limestone, dolostone), sandstone and shales

Mapping of the distribution of each of these hydrostratigraphic units in the study area was undertaken by interpreting subsurface information from well drilling and other sources. Waterloo Hydrogeologic, Inc. as part of the Six Conservation Authorities FEFLOW Groundwater Model: Conceptual Model Report, (Draft WHI, 2004) Schematic cross-sections were completed on a 10 km grid spacing throughout the study area. **Figure 2.3.2.3-1 Schematic Cross-section of Hydrostratigraphic Units** gives a visual presentation of the various units in a conceptual geological model for the region. Additional schematic cross-sections are available on a CD-ROM prepared as part of the report.

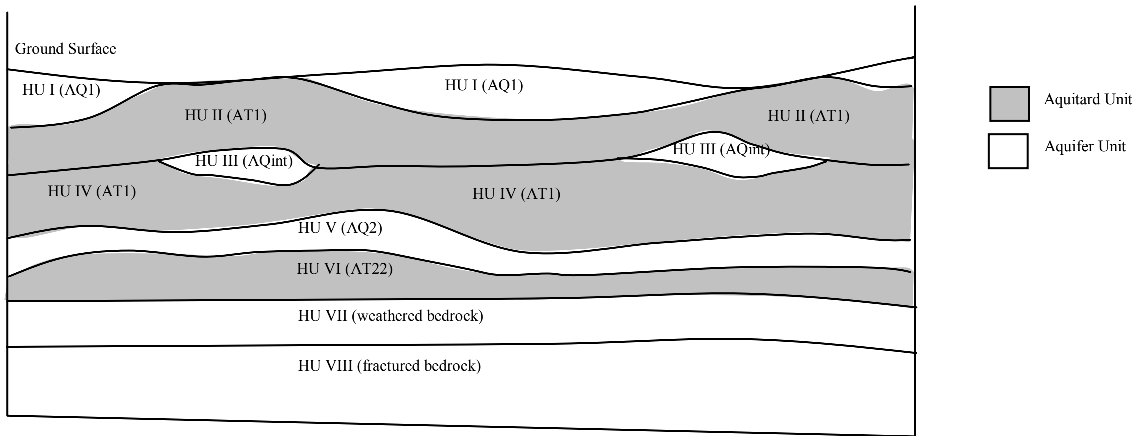

Figure 2.3.2.3-1: Schematic Cross-section of Hydrostratigraphic Units

Conceptual Hydrostratigraphic Units (HUs)

Hydrostratigraphic Unit I (HU I), Aquifer 1 (AQ1)

HU I includes coarse-grained glaciofluvial / glaciolacustrine / ice-contact sands and gravels such as portions of the Bothwell, Caradoc and Norfolk Sand Plains as well as Easthope, and Staffa Kame Moraines. The thickness of this hydrostratigraphic unit varies from 0 to 50 m throughout the study area.

Hydrostratigraphic Units II, and IV (HU II to IV), Aquitard 1 (AT1) and Intermediate Aquifer (AQint)

In many portions of the study area, HU II and HU IV are in direct contact. It was very difficult to differentiate between the geologic subunits in HU II and the geologic subunits in HU IV where the intermediate aquifer (HU III) is not present. The geological descriptions provided on drilling logs generally do not provide enough detail to differentiate between these two fine-grained units. Where this occurs, the combined units represent the thickness of aquitard material between the upper aquifer HU I, and the lower aquifer HU V.

The package of HU II (Rannoch, Stratford, Wartburg, St. Joseph’s, and Elma Till; and the Ekfrid and St. Clair Clay Plains), and IV (Tavistock and Port Stanley Tills) is extensive across the study area, ranging in thickness from 1 m to nearly 100 m. This package is interpreted to be thickest near Strathroy, London, St. Thomas, and along the Lake Erie shoreline west of St. Thomas. The bedrock valley interpreted to exist between Grand Bend, Strathroy, and St. Thomas explains the increased thickness of the overburden package in these areas.

Hydrostratigraphic Unit III (HU III), Intermediate Aquifer (AQint)

The intermediate aquifer (HU III) is present erratically within the study area where HU II and HU IV are not in direct contact. This unit is interpreted to be interstadial outwash sands and gravels that lie at an intermediate depth below the ground surface. The thickness of HU III varies between 0 and 30 m, and is thickest near Strathroy, London, Ingersoll, and Woodstock. The unit is also identified in Perth County at the Easthope Moraine, and in Chatham-Kent east of Chatham, north and south of Highway 401.

Hydrostratigraphic Unit V (HU V), Aquifer 2

HU V represents discontinuous sands and gravels that are interpreted to be outwash sand and gravel (interstadial complex) overlying the Catfish Creek Till and other older well consolidated tills. (This subsurface layer is similar to what is seen on the present surficial geology.) The thickness of HU V varies from 0 to 40 m, with the thickest areas located near St. Thomas.

Hydrostratigraphic Unit VI (HU VI), Aquitard 2

HU VI is interpreted to be the Catfish Creek Till, and other older tills such as the Canning Till that lie immediately on top of the Paleozoic bedrock. The thickness of HU VI varies from 0 to more than 50 m. HU VI is regionally extensive in the northern portion of the study area, throughout most of Perth County.

Surface Water - Groundwater Interactions

The Thames-Sydenham & Region Source Protection Region comprises three Conservation Authorities, each with a series of watersheds. There are two major river systems and many more subwatersheds within the region.

In rivers and subwatersheds, stream flow rates measured during base flow (low flow) periods can be used to identify areas of significant groundwater discharge. The base flow is assumed to be equal to the quantity of groundwater that discharges to the upstream reach of the river and its tributaries. Comparison of the flows present at each stream measurement station can be used as a means of identifying groundwater discharge areas.

Map 14: Areas of Potential Groundwater Discharge shows zones of potential discharge within the area. To differentiate areas where water is moving downward through the overburden, from areas where water is moving upwards from the bedrock to the overburden, bedrock recharge and discharge areas were mapped. These areas were mapped by comparing the static water levels in the bedrock aquifer and the ground surface topography. Discharge is expected to occur where the static water level is greater than the ground surface elevation.

This map shows the potential discharge along the major river systems and their tributaries. The location and quantity of groundwater discharges to the Great Lakes is not fully understood.

Estimation of Hydraulic Properties of the Aquifers and Aquitards

Recharge

Precipitation is the primary source of groundwater recharge. When precipitation falls on the ground, a portion of this water moves overland to rivers and creeks as overland flow (or interflow) and another portion is returned to the atmosphere by evaporation. The remainder infiltrates into the ground and may become groundwater recharge water.

Recharge is the portion of precipitation that infiltrates into the ground, and is not lost to evapotranspiration, or retained as soil moisture.

Recharge occurs throughout the Study Area in all areas except where water is applied directly to surface water features[71]. The rate of recharge is dependent on the ground surface topography, land use cover and surficial geology.

Areas with steep topography experience greater overland flow and therefore less groundwater recharge than areas where the terrain is more subdued. Areas of hummocky topography are locations where enhanced recharge may occur as water that would otherwise be lost to runoff becomes trapped in storage depressions.

Land use also plays a role on the amount of recharge entering the groundwater system. Built-up urban areas have reduced recharge as water flows over concrete, buildings and streets into managed storm

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[71] Singer, S.N., C.K. Cheng and M.G. Scafe. 1997. The Hydrogeology of Southern Ontario. Hydrogeology of Ontario Series, Ministry of the Environment and Energy.

drains rather than recharging the groundwater system. Areas having artificial drainage (tile drains) are expected to have lower groundwater recharge rates than similar areas without artificial drainage.

Recharge will be greatest on the sand plains and kame moraines where water infiltrates rapidly into the deeper groundwater system. Clay and till plains are expected to have reduced recharge as a larger proportion of precipitation will likely be lost as overland flow to rivers and streams rather than infiltrating.

Table 2.3.2.3-2: Recharge Estimates (mm/year) for Surficial Geologic Material presents the estimates of recharge determined from a number of previous studies carried out in the region. These include Municipal Groundwater Studies for Perth, Middlesex-Elgin, Lambton and Oxford. (Recharge estimates were not provided in the Essex/Chatham-Kent study.) Information from the (unpublished) Six Conservation Authorities FEFLOW Report is also included. In most studies, the ice-contact stratified drift is estimated to have a higher net recharge than the sandy silt to sandy till. (Drift is a general term that encompasses all tills and stratified drift is a till deposited in a subaquatic environment, e.g. areas west of Strathroy-Caradoc.)

Table 2.3.2.3-2: Recharge Estimates (mm/year) for Surficial Geologic Material

Material	Perth	Lambton	Middlesex-Elgin	Oxford	Six CA report, WHI
Sand and Gravel Kames or Outwash	150	n/a	300	250-350	250
Sand Plains	n/a	n/a	130-300	50-200	Not reported
Clay Plains	n/a	80	n/a	50	10-25
Clay/ Silt Till	65-100	n/a	9-55	20-50	100-150
Sand/ Silt Till	85-130	n/a	9-55	100	150
Urban Areas	40	n/a	n/a	n/a	Not reported

Groundwater Inflow / Outflow

The basic groundwater summarization[72] in this section is from Piggott, A., S. Day, B. Neff and J. Nicholas, 2005. (Base Flow Due to Groundwater Discharge (Indicator 7102): State of the Great Lakes). Additional analyses and interpretation are required to validate this tentative assessment and the water quantity portion of groundwater will be investigated in more detail in the Water Budget Report.

The Great Lakes form the boundary of the Thames-Sydenham & Region Source Protection Region and influence the inflow/outflow of groundwater. To date, the location and quantity of groundwater in the Thames river basin and the interaction with the Great Lakes basin is not fully understood. Basically, a significant portion of precipitation over the inland portion of the Great Lakes basin returns to the atmosphere by evapotranspiration[73]. Water that does not return to the atmosphere either flows across the land to surface water features (rivers, lakes and wetlands) or infiltrates the subsurface to recharge groundwater aquifers. Water that infiltrates into the subsurface and recharges groundwater also results in flow toward the Great Lakes[73].

The component of stream flow due to runoff from surface flow is transient and variable. Base flow due to groundwater discharge is less variable and is a more consistent part of stream flow. Another source of groundwater discharge is the regional flow through bedrock and overburden units to the Great Lakes

[72] Piggott, A., S. Day, B. Neff and J. Nicholas. 2005. Base Flow Due to Groundwater Discharge (Indicator 7102). State of the Great Lakes.
[73] Neff, B.P., A.R. Piggott and R. A. Sheets. Estimation of Shallow Groundwater Recharge in the Great Lakes Basin. USGS Scientific Investigations Report 2005-5284.

(Lakes Erie, Huron and Ontario). The major groundwater resource issues revolve around 1) groundwater quantity interaction with the Great Lakes; and 2) groundwater and surface water interaction and how this quantity impacts the Great Lakes.

While some recharge to groundwater occurs from surface water sources, the primary source of recharge to groundwater is that portion of precipitation which is not lost to evapotranspiration or through runoff. Groundwater recharge is highest when the soil is saturated, but diminishes when the soil is completely saturated[74] (reaches field capacity). In the Thames and Sydenham River basins, this occurs primarily between March and early May, based on the data from the Provincial Groundwater Monitoring Network (PGMN). However, winter thaws can produce recharge events. The PGMN is an extensive system and several sites are located in the Thames Watershed & Region. The locations are shown on **Map 15: Provincial Groundwater Monitoring Network**.

Groundwater recharge is estimated by a variety of methods and the Water Budget Report will provide a more detailed discussion. The rate of recharge is dependent on a number of factors such as ground surface topography, land use and surficial geology. Singer[74] averaged groundwater recharge from 33 gauging stations throughout the province and found that recharge rates varied between 83.3 to 284.9 mm/yr (baseflow separation techniques were not outlined).

More recently, shallow groundwater recharge was estimated in the Great Lakes basin, based on HYSEP baseflow separation techniques. The Thames River basin recharge rate was estimated to be between 200 and 210 mm/yr while the rate for the Sydenham basin was estimated to be 160 mm/yr[73]. Based on modelling completed for the Six Conservation Authorities FEFLOW Groundwater project (WHI, 2006 draft), recharge rate estimates ranged between 25 and 250 mm/yr.

Most shallow groundwater flow discharges to local streams and most deep flow discharges to regional sinks. The Great Lakes watershed divide serves as a groundwater divide for shallow flow, however, the deep groundwater aquifer divide can be distant from the watershed divides.

Groundwater outflow provides a base flow for the various rivers and streams in the region. **Map 14: Areas of Potential Groundwater Discharge** shows zones of potential discharge within the region which are predominantly located along river courses.

Groundwater, primarily from shallow aquifers, also discharges directly to the Great Lakes. Based on modelling completed for the Six Conservation Authorities FEFLOW Groundwater project (WHI, 2006 draft), it is estimated that about 3% of the total water discharges directly to Lake Erie, 1.1% to Lake St. Clair and 2% to Lake Huron. These estimates do not include the groundwater component of stream flow to the Great Lakes.

Another source of groundwater discharge is the regional flow through bedrock and overburden units to the Great Lakes (Lakes Erie, Huron and Ontario). To date, the location and quantity of groundwater to the Great Lakes is not fully understood.

Large groundwater takings by municipal wells and industrial water takings (i.e. quarry dewatering) also represent an outflow of groundwater within the region. For municipal wells, information on well operation may also be contained in Well Operations Reports. For agricultural irrigation wells, where pumping is for a short time period and a portion of the pumped volume re-infiltrates, rates may be estimated. More detailed discussion will be presented in the Water Budget Report.

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[74] Singer, S. N., C.K. Cheng, and M.G. Scafe. 2003. The Hydrogeology of Southern Ontario, 2nd ed. Environmental, Monitoring and Reporting Branch, OMOE.

Information on significant wells and other water taking operations is contained in the OMOE Permit to Take Water (PTTW) database. Information from this database was used to produce **Map 16: Permit to Take Water Locations by Type** and **Map 17: Permit to Take Water General Purpose of Taking**.

Hydraulic Conductivity

Hydraulic conductivity refers to the capability of subsurface materials such as sand, rock, etc. to transmit water. It is a property that can vary considerably from one geologic unit to the next. Estimates of hydraulic conductivities are typically derived from aquifer test data, literature values, and previous groundwater flow studies or models.

Table 2.3.2.3-3: Range of Hydraulic Conductivity Values presents the estimated lateral hydraulic conductivity values for each hydrostratigraphic unit along with values used in local wellhead protection area models completed as part of the OMOE funded Municipal Groundwater Studies (Perth, Lambton, Oxford and Middlesex-Elgin). The Huron and Essex/Chatham-Kent studies did not report these values. Some overburden units are not present in various counties. Also, some bedrock units are not present or are too deep to be used as a water supply source.

Typically, the vertical hydraulic conductivity is assumed to be one order of magnitude less than the horizontal hydraulic conductivity. The variation in hydraulic conductivity between different studies reflects the degree of heterogeneity of the hydrostratigraphic unit. A heterogeneous mixture is one that consists of many different types of sediment that are often difficult to sort or separate though they are clearly distinct. These differences result varying hydraulic conductivity values being reported. The largest discrepancy lies in the bedrock aquifers where the bedrock formation and intensity of fracturing varies widely across the study area.

A groundwater model is used to represent nature and provide a numerical representation of the geology and hydrogeology. Models need input parameters and boundaries. The FEFLOW model is a finite element (FE) groundwater model that was utilized to simulate the groundwater system in a complex glacial and bedrock environment. FEFLOW was used as it is capable of a realistic representation of the stratigraphy, water table and water budget. Groundwater stresses can be simulated to evaluate the response of the groundwater system to stress or to evaluate future conditions.

Within the groundwater flow model, hydraulic conductivities will vary across each hydrostratigraphic unit. For example, the Stratford and Mornington Tills are grouped with other similar subglacial tills to form HU II. Although these will be represented in the model as one layer, the area of the Stratford Till Plain (sandy silt till) will be assigned a higher hydraulic conductivity than that of the Mornington Till (clay till) to account for the differences in matrix grain size.

During the development and calibration of the FEFLOW groundwater model, initial and calibrated hydraulic conductivity values used in the model will aim to be consistent with the range of values utilized within previous models, and also with hydraulic conductivities cited in literature for studies completed within the study area.

Table 2.3.2.3-3: Range of Hydraulic Conductivity Values (m/s) of Hydrostratigraphic Units Tabulated from the Municipal Groundwater Studies

<table>
<tr><th colspan="2">Hydrostratigraphic Unit (HU)</th><th>Literature Values</th><th>Perth</th><th>Lambton</th><th>Middlesex-Elgin</th><th>Oxford</th></tr>
<tr><td colspan="2">HU I – Surficial Sands</td><td>6x10^{-3} to 1x10^{-7}</td><td>n/a</td><td>n/a</td><td>1x10^{-4} to 5x10^{-4}</td><td>1x10^{-4} to 6x10^{-4}</td></tr>
<tr><td colspan="2">HU II – Fine-grained tills and lacustrine sediments</td><td>1x10^{-6} to 1x10^{-11}</td><td>2x10^{-6} to 2x10^{-8}</td><td>1x10^{-7}</td><td>1x10^{-6} to 5x10^{-8}</td><td>3.5x10^{-6} to 1x10^{-7}</td></tr>
<tr><td colspan="2">HU III – Interstadial sands and gravels</td><td>3x10^{-2} to 1x10^{-6}</td><td>n/a</td><td>n/a</td><td>1x10^{-4} to 2x10^{-4}</td><td>5x10^{-5} to 5x10^{-4}</td></tr>
<tr><td colspan="2">HU IV – Fine-grained tills and lacustrine sediments</td><td>1x10^{-6} to 1x10^{-11}</td><td>2x10^{-6} to 2x10^{-8}</td><td>n/a</td><td>1x10^{-6} to 5x10^{-8}</td><td>3.5x10^{-6} to 1x10^{-8}</td></tr>
<tr><td colspan="2">HU V – Basal sands and gravels</td><td>3x10^{-2} to 1x10^{-6}</td><td>n/a</td><td>n/a</td><td>1x10^{-4} to 2x10^{-4}</td><td>1x10^{-4}</td></tr>
<tr><td colspan="2">HU VI – Overconsolidated tills</td><td>2x10^{-7} to 1x10^{-12}</td><td>n/a</td><td>n/a</td><td>n/a</td><td>n/a</td></tr>
<tr><td rowspan="10">HU VIII – Bedrock Formations</td><td>Salina Formation</td><td>1x10^{-4} to 1x10^{-7}</td><td>n/a</td><td>n/a</td><td>n/a</td><td>n/a</td></tr>
<tr><td>Bass Islands Fmn</td><td>1x10^{-4} to 1x10^{-7}</td><td>1x10^{-5}</td><td>n/a</td><td>n/a</td><td>n/a</td></tr>
<tr><td>Bois Blanc Fmn</td><td>1x10^{-4} to 1x10^{-7}</td><td>8x10^{-5}, 8x10^{-6}</td><td>n/a</td><td>n/a</td><td>1x10^{-4} to 5x10^{-5}</td></tr>
<tr><td>Lucas/ Sylvanian Fmn</td><td>1x10^{-4} to 1x10^{-7}</td><td>7x10^{-5}</td><td>n/a</td><td>n/a</td><td>5x10^{-5} to 7.5x10^{-5}</td></tr>
<tr><td>Amherstburg Fmn</td><td>1x10^{-4} to 1x10^{-7}</td><td>7x10^{-5}</td><td>n/a</td><td>n/a</td><td>1.3x10^{-4} to 3x10^{-5}</td></tr>
<tr><td>Dundee Fmn</td><td>1x10^{-4} to 1x10^{-7}</td><td>2x10^{-4} to 1x10^{-5} (IWS)</td><td>1.6x10^{-4}</td><td>5x10^{-6}</td><td>1.2x10^{-4}</td></tr>
<tr><td>Marcellus Fmn</td><td colspan="5" rowspan="4">There is very little information available on these formations at the present time. Where these formations sub-crop in the study area, the communities rely on surface water for drinking water supplies.</td></tr>
<tr><td>Hamilton Group</td></tr>
<tr><td>Kettle Point Fmn</td></tr>
<tr><td>Port Lambton Fmn</td></tr>
</table>

2.3.2.4 Groundwater Monitoring

Historically the Ministry of the Environment monitored water levels at about 450 observation wells throughout the province. In general, the monitoring wells were used to monitor groundwater levels for detailed hydrogeologic studies, water supply forecasting, and resolution of interference complaints.

The original network existed between 1946 and 1979. This monitoring was substantially reduced in the 1980s and was virtually eliminated in the Thames Watershed & Region Source Protection Region.

In 2001, in recognition of the need for the data, a monitoring network was re-established. The Provincial Groundwater Monitoring Network (PGMN) was re-established due to concerns that include quantity issues associated with depletion resulting from competing demand, quality concerns associated with a range in anthropogenic activities and sustainability issues. Most of the wells are new to the monitoring system and their locations may not be near the original locations.

Wells in the monitoring network vary in depth, elevation and geology between bedrock and overburden wells. There are 34 PGMN wells at 30 different locations in the region. These are listed in **Table 2.3.2.4-1: Provincial Groundwater Monitoring Network Locations**. The LTVCA has 12 wells and the UTRCA has 22 wells. There are three sites with multiple wells at different depths in the UTRCA network.

Table 2.3.2.4-1: Provincial Groundwater Monitoring Network Locations

Well ID	Conservation Authority	Location Information		
		Approx Elev (m)	Location	Period of Record
W53	Upper Thames River	323	Thamesford	July 01 to July 06
W54	Upper Thames River	336	Motherwell	July 01 to present
W55	Upper Thames River	282	Mt. Elgin	July 01 to present
W56	Upper Thames River	222	Komoka	July 01 to present
W76	Upper Thames River	340	Wildwood	Oct 01 to present
W107	Upper Thames River	250	Dorchester	July 02 to present
W180	Upper Thames River	305	Innerkip	Dec 2002 to present
W181	Lower Thames Valley	187	Shrewsbury	Oct 03 to present
W182	Lower Thames Valley	210	Thamesville	Dec 02 - decommissioned
W184	Lower Thames Valley	237	Caradoc Twp	Nov 02 to present
W185	Lower Thames Valley	205	Dunwich	Nov 02 to present
W201	Upper Thames River	304	Golspie Swamp	Dec 2002 to present
W211	Lower Thames Valley	191	Tilbury West	Nov 02 to present
W217	Upper Thames River	255	Sifton Bog	Dec 2002 to present
W218 shallow	Upper Thames River	363	Shakespeare CA	Dec 2002 to present
W218 intermediate	Upper Thames River	363	Shakespeare CA	Dec 2002 to present
W218 deep	Upper Thames River	363	Shakespeare CA	Dec 2002 to present
W219	Upper Thames River	360	Mitchell North	Dec 2002 to present
W236	Lower Thames Valley	183	Tilbury East	Dec 02 to present
W237	Lower Thames Valley	187	Romney	Dec 02 to present
W247	Lower Thames Valley	186	Chatham	Feb 03 to present
W248	Lower Thames Valley	175	Mosa	Feb 03 to present
W249	Lower Thames Valley	196	Ridgetown	Feb 03 to present
W250	Lower Thames Valley	205	Bothwell	Feb 03 to present
W368	Upper Thames River	330	Ellice Swamp	July 04 to present
W369	Upper Thames River	337	Embro CA	Oct 03 to present
W369	Upper Thames River	337	Embro CA	Oct 03 to present

Well ID	Conservation Authority	Location Information		
		Approx Elev (m)	Location	Period of Record
W370	Upper Thames River	269	Fanshawe CA Sugar Bush	Sept 03 to present
W371	Upper Thames River	302	Fish Creek CA	Sept 03 to present
W371	Upper Thames River	302	Fish Creek CA	Sept 03 to present
W385	Upper Thames River		Fanshawe CA Workshop	06 to present
W405	Upper Thames River	304	Science Hill	06 to present
W437	Upper Thames River	na	Workshop well	Mar 05 to present
W438	Lower Thames Valley	205	Thamesville	06 to present
W445	Lower Thames Valley	291	Eagle	06 to present

While the data available is limited, it does show that well water levels vary on an annual, seasonal and daily basis. Water level variations are also affected by the geology and depth of the well. Information from several different wells has been used to illustrate some of the variations.

As shown in **Figure 2.3.2.4-1: Annual and Seasonal Variation in Water Levels**, seasonal water levels are elevated in the wells during the late fall, winter and early spring. The levels decline during the summer months and, in general, reach the lowest point in late September or October. The seasonal variation in the water levels can be in the order of several metres. On an annual basis, there are insufficient years to determine a true long-term trend at this time. However, the (linear) long-term trend in water level variation in Well 76 seems to indicate an overall decrease between 2001 and 2005.

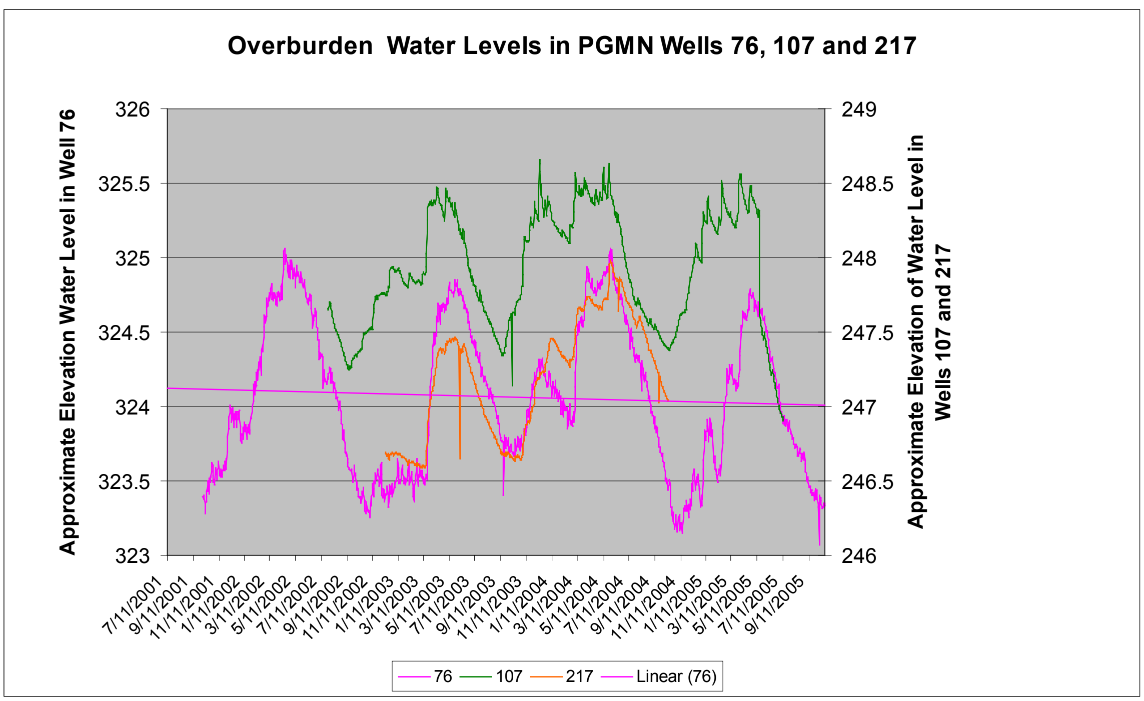

Figure 2.3.2.4-1: Annual and Seasonal Variation in Water Levels

Daily fluctuations occur in many wells as illustrated in **Figure 2.3.2.4-2: Daily Water Levels**. This illustrates the variation in water levels over the course of a day in an overburden well that is adjacent to a wetland (Sifton Bog). The hourly readings were averaged over a course of 8 and 24 days. There is an apparent decline throughout the course of a day with a rebound occurring during the night.

Water level variations are also affected by the geology and depth of the well. The water level variations of a well nest in Shakespeare are shown in **Figure 2.3.2.4-3: Water Levels for Shallow, Intermediate and Deep Wells**. The shallow well has a depth of 7.1 metres (218-3), the intermediate well has a depth of 24.4 metres (218-4) and the deepest well is completed in bedrock at 61.6 metres (218-5) depth.

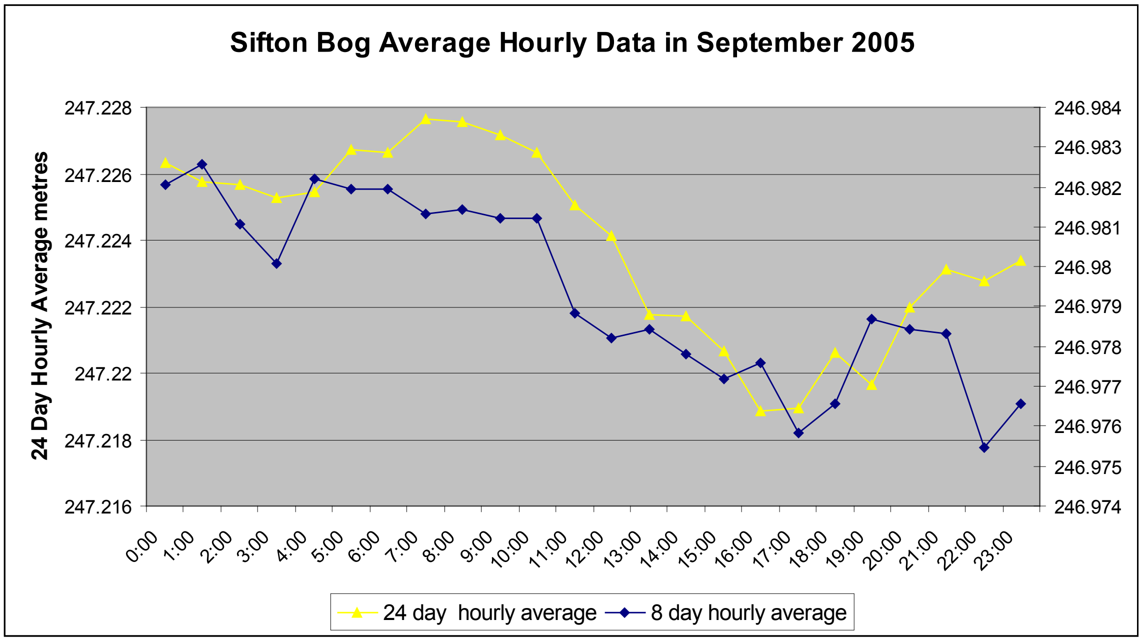

Figure 2.3.2.4-2: Daily Water Levels

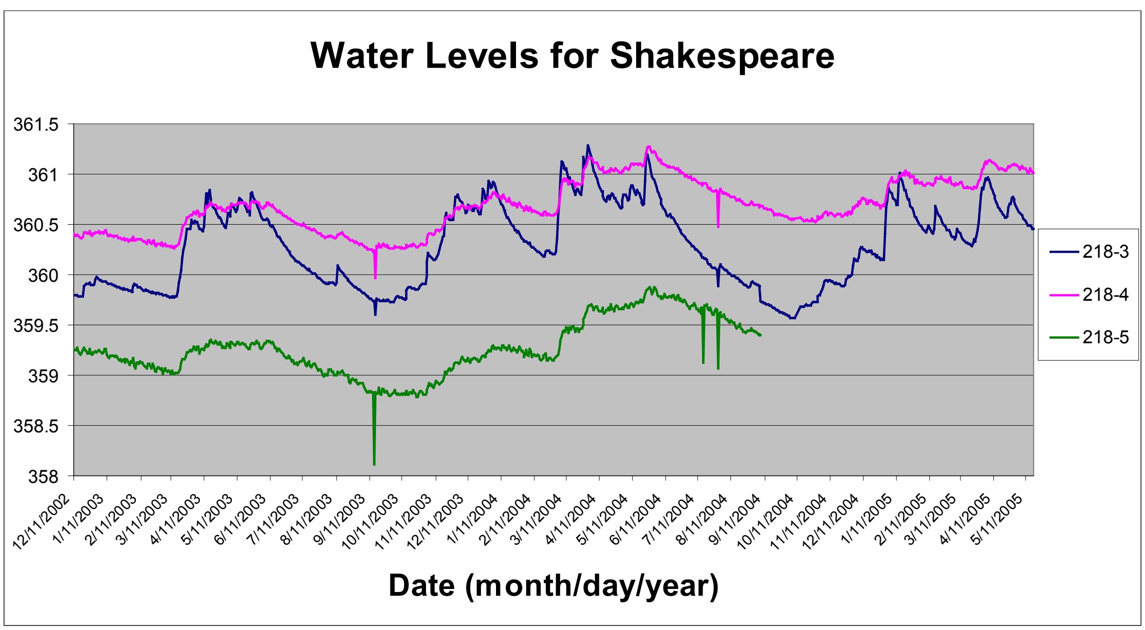

Figure 2.3.2.4-3: Water Levels for Shallow, Intermediate and Deep Wells

The three wells are within a few metres of each other at the surface. To compare the relative water level changes, the amplitudes were calculated relative to October 1, 2005 (a common low point). The shallowest well has the largest amplitude variations in water level relative to October 1, 2005 as shown in **Figure 2.3.2.4-4: Difference in Water Levels for Shallow, Intermediate and Deep Wells**. The intermediate and deep aquifers have approximately the same variation.

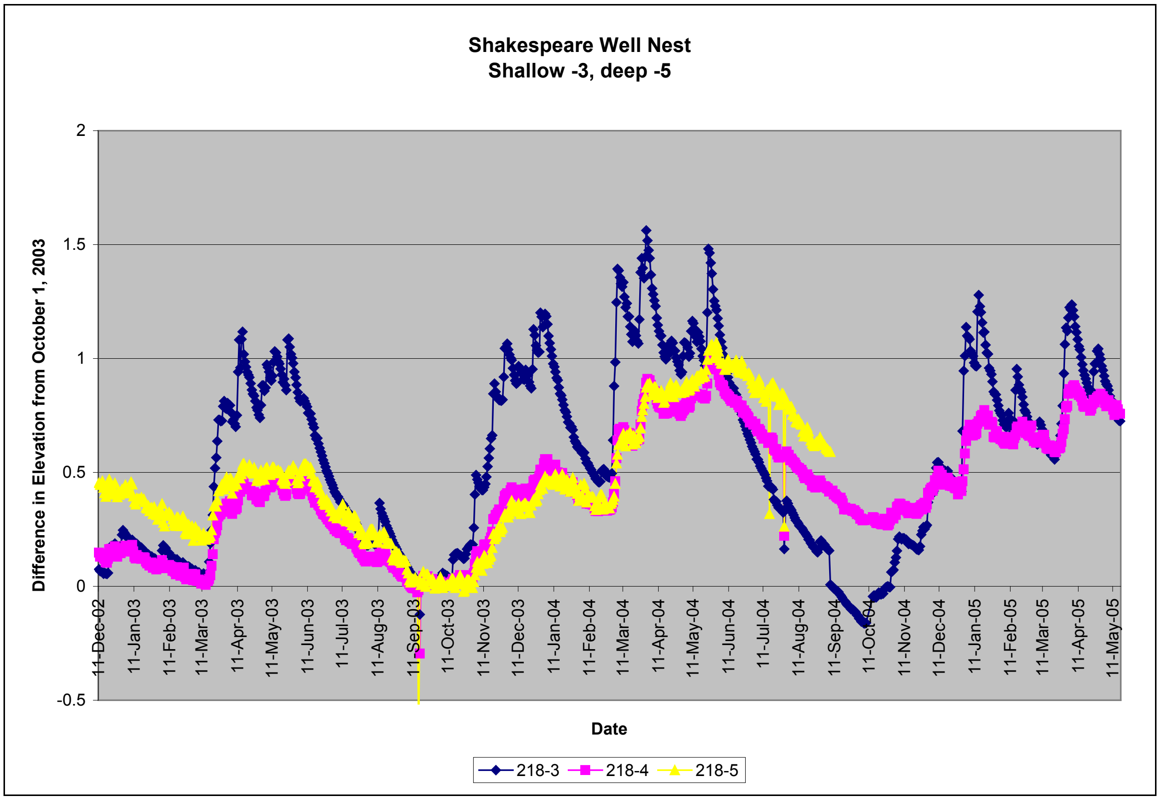

Figure 2.3.2.4-4: Difference in Water Levels for Shallow, Intermediate and Deep Wells

Water levels in wells can also be affected by stresses. Water may be removed by pumping of supply wells or de-watering such as quarrying operations. Aquifer recharge may be reduced by paving, hardened surfaces such as roof tops in developed areas, storm sewers and possibly agricultural drainage tiles.

In **Figure 2.3.2.4-5: Comparison of Seasonal Water Levels**, the water levels from monitoring well 53 show similar seasonal variations for years 2002 to 2005. On closer examination other factors such as pumping are apparent as shown in **Figure 2.3.2.4-6: Variation in Water Levels** which provides a more detailed outline of water levels in September 2005. For example, there are sudden drops in water level at 3:00 on September 6, 2005 and 16:00 on September 4, 2005. The drawdown curve is characterized by a sharp decline and a squared off appearance. The recharge curve also has a sharp rebound.

In summary, the wells in the PGMN monitoring network show annual, seasonal and daily variations. Water level variations are also affected by the geology and depth of the well. All of these factors, together with other impacts such as localized water usage or changes in the recharge, have to be considered when assessing groundwater levels.

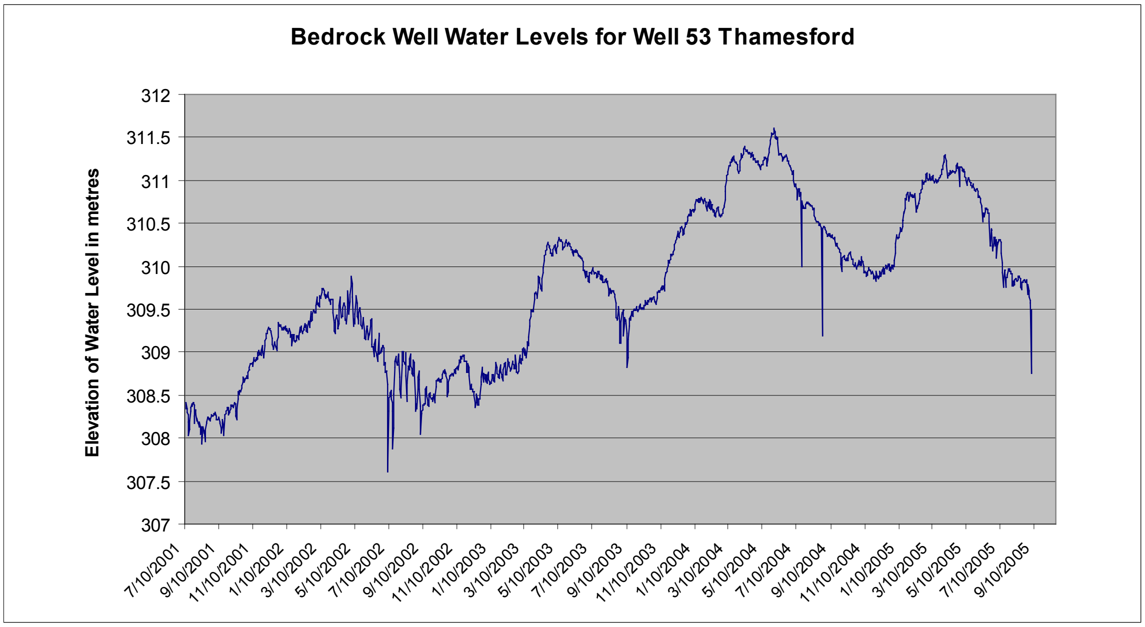

Figure 2.3.2.4-5: **Comparison of Seasonal Water Levels**

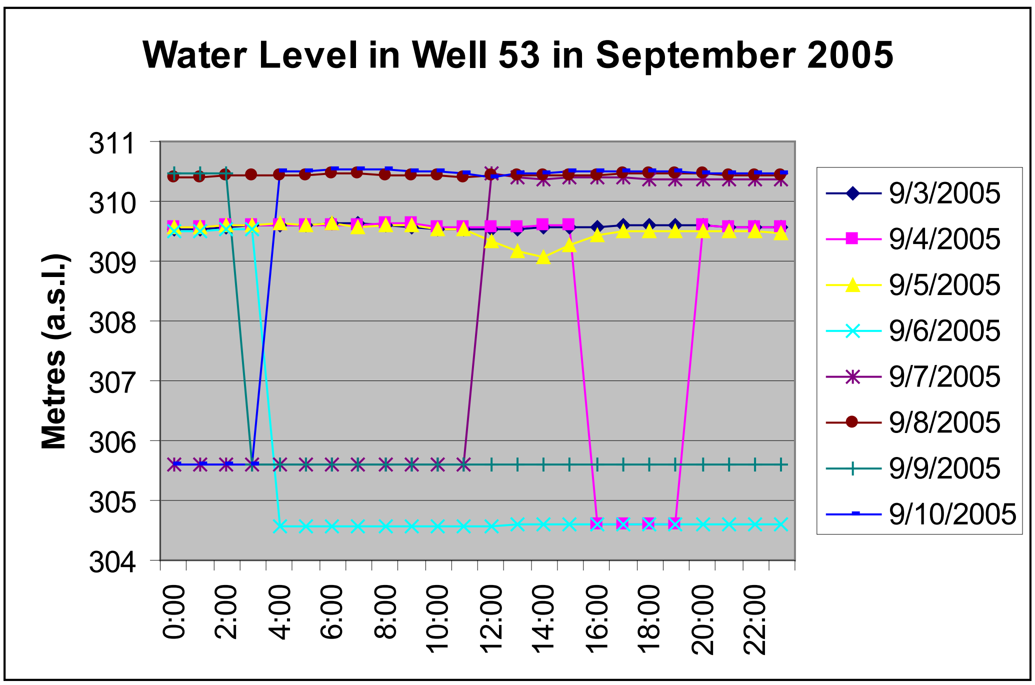

Figure 2.3.2.4-6: **Variation in Water Levels**

2.3.2.5 Aquifer Vulnerability

The two key attributes considered that affect aquifer vulnerability are the depth to water table and the conductivity of geologic material in the unsaturated zone (or above a confined aquifer). Although the method considered only the intrinsic susceptibility of the shallowest aquifer, assessments of deeper aquifers were completed in some municipalities. This method assesses intrinsic vulnerability or susceptibility with limited consideration of the specific attributes of the hydrogeologic system or the behaviour of contaminants. Intrinsically, fine unfractured media retards contaminant migration, whereas fractured media, or coarse porous media, provides faster travel times and less retardation and, hence, more vulnerability. For example, 20 metres of silt over a confined aquifer would have a low intrinsic susceptibility. However, 10 metres of clean coarse sand or fractured rock would have a high susceptibility to contamination. The method is based on calculating a susceptibility index at each well, then mapping the indices using an interpolation.

The intrinsic susceptibility of groundwater resources is evaluated using an Intrinsic Susceptibility Index (ISI). This is a calculated value that estimates the vulnerability of the groundwater resource to contamination at a given point. The ISI values are characterized as falling into one of three groupings; low (>80), medium (30-80) or high (<30), based on the original terms of reference used for the various groundwater studies (OMOE, 2001a).

ISI values are calculated on a well-by-well basis by examining the geology and the aquifer/aquitard relationships found within each well of the Water Well Information System (WWIS). This is accomplished by multiplying different geologic sequences by their respective conductivity factor (K-factor) for each WWIS record, as defined in the Technical Terms of Reference for the study (OMOE, 2001a).

The susceptibility of the water table was also calculated by examining the depth to water table in each well of the WWIS. In calculating the susceptibility of the bedrock aquifer, the overburden thickness and geology were used to calculate ISI values.

The ISI values were subsequently interpolated across the entire county to provide ISI maps on a county basis. The county ISI maps were then somewhat seamlessly mapped into a regional map of Southwestern Ontario. **Map 18: Intrinsic Susceptibility Index** provides a map of the region. When preparing the regional map, differences of one or two levels between counties were identified and are shown on the map.

This process has limitations, as it does not take land use, slope, or hummocky topography into consideration. These factors, however, in addition to Quaternary geology and soil composition were considered when developing an infiltration map of Perth County[75]. These maps were used to evaluate the susceptibility maps for the Perth County Groundwater Study[75]. In many cases, the susceptibility maps are similar to the infiltration potential map of the County.

2.3.3 Surface Water Hydrology

According to the United States Geologic Survey (USGS):

"Surface-water hydrology is the study of the origin and processes of water in streams and lakes, in nature, and as modified by man. It includes such subjects as infiltration, channel storage, floods and droughts, direct runoff, and base flow. Surface-water hydrology shares with meteorology the study of precipitation and evaporation. Also, surface-water hydrology shares with geomorphology the study of the shape, size, and number of river channels; because river channels are formed as a consequence of the rates and quantities of water they must carry."[76]

The total surface area of the Thames Watershed & Region is 6,697 sq. km. The region extends from Lake St. Clair in the west and Lake Erie in the south to the highlands of Perth and Oxford Counties northeast of London. The Thames River system drains 5,820 sq. km (approximately 87%) of this land to Lake St. Clair. Another 140 sq. km (2%) drain directly to Lake St. Clair. The remaining 737 sq. km (11%) of the land is drained by several small watercourses to Lake Erie. **Table 2.3.3-1: Drainage Areas Thames Watershed & Region** provides a summary of the watersheds and the responsible conservation authority.

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[75] Waterloo Hydrogeologic. April 2003. Perth County Groundwater Study, Final Report.

[76] United States Geological Survey. 1995. Manual of Hydrology: Part 1. General Surface-Water Techniques.

Table 2.3.3-1: Drainage Areas Thames Watershed and Region

Watersheds in Thames Watershed & Region	Area (sq km)	Percentage of Jurisdiction
Lake St. Clair - LTVCA	140	2
Lake Erie - LTVCA	737	11
Thames River - LTVCA	2,397	36
Thames River - UTRCA	3,423	51
Total	**6,697**	**100**

Lake St. Clair

In Chatham-Kent, the watershed boundary of the Thames River at some points is only a few kilometres north of the Thames River. Lands north of this boundary drain west to Lake St. Clair.

Much of the land in this area is flat to very gently rolling and is highly productive agricultural land. Lands immediately adjacent to Lake St. Clair have been dyked and reclaimed for agricultural uses. To provide adequate drainage for these agricultural lands, systematic tiling has been installed. In order to have outlet for these drains, all of the drains that empty into Lake St. Clair are pumped. Some very large pumping facilities have been constructed in the area since all the water discharged from this watershed area is pumped to the lake.

Lake Erie

The land to the south of the Thames River watershed drains into Lake Erie. As shown on **Map 2: Major Subwatershed Delineations**, this narrow watershed varies from up to 12 km wide in the east to less than 100 metres at points in the west. To the east, the shoreline is noted for its very high bluff immediately adjacent to the lake. This bluff is upwards of 30 metres high for much of its length and exposes much of the underlying soil characteristics. The land surface is made up of sand and clay plains and the topography is flat to gently rolling. As a result, many of the watercourses draining into Lake Erie are relatively short in length and are located within deep valleys.

The Rondeau Bay watershed is somewhat different as the land falls relatively evenly to the Bay and, therefore, the streams have a much shallower profile.

Thames River

The Thames River is one of the main watersheds in Southern Ontario. The river's drainage basin is approximately 200 km long with a maximum width of 56 km. The Thames River watershed represents almost 60% of the Canadian portion of Lake St. Clair's drainage basin.

Table 2.3.3-2: Thames River Drainage Areas outlines the land areas in the Upper Thames River and Lower Thames Valley Conservation Authorities.[77]

[77] Ontario Ministry of the Environment and Ontario Ministry of Natural Resources. 1975. Thames River Basin Water Management Study.

Table 2.3.3-2: Thames River Drainage Areas

Thames River Basin	Area (sq km)	Percentage of Area
Upper Thames River CA	3,423	59
Lower Thames Valley CA	2,397	41
Total Thames River	**5,820**	**100**

Hydrologic parameters of the Thames River have been measured in some form as far back as 1792. The Water Survey of Canada installed the first stream gauge measuring the water level and associated flow on the Thames River at Byron (now part of London) in 1914.[78] The Thames River is subject to significant variations in flow rates throughout the year, with annual peak values generally occurring in the period from March to April. Annual peak flows also vary to a great degree on a year to year basis.

On average, approximately 60% of precipitation that falls on the Thames Basin infiltrates into the ground, evaporates or is evapotranspirated by plants. The remaining 40% ends up as flow in the river. In the upper Thames Basin, flow in the river is comprised of approximately 40% surface water runoff and 60% baseflow, while in the lower portion, the flow is 60% surface runoff and 40% baseflow[79]. In addition to groundwater, baseflow includes contributions from tile drains, flow augmentation from reservoirs and treated sewage effluent discharge.

Evapotranspiration is simply all water that is lost to evaporation and plant uptake. Potential evapotranspiration (PET) refers to the maximum amount of losses if water is available. During a drought, actual evapotranspiration will be much less than potential as there is little water available to evapotranspire. As an example, annual total precipitation measured at London Airport averages about 960 mm per year, and the method of Thornthwaite and Mather[80] calculates that 620 mm annually is *potentially* lost by evapotranspiration. The Thornthwaite and Mather method allows an estimate of actual evapotranspiration by considering the capacity of the soil to hold water. This method estimates that about 90% of the potential amount (545 mm) on average is actually lost to evapotranspiration.[81]

Figure 2.3.3-1: Potential Evapotranspiration, Precipitation and Discharge for the Thames River above Thamesville plots monthly precipitation, potential evapotranspiration, and stream flow measured at the Thamesville stream gauge. The stream flow data has been transformed to the total millimetres of equivalent water over the area of the entire basin. (For example, 100 mm/month equivalent depth at the Thamesville Stream Gauge equates to 100 mm of water on all of the area draining upstream to this point in a time period of one month.)

This plot illustrates and compares the relative amounts of water that the Thames River discharges, the potential losses to evapotranspiration, and the average amount of precipitation that falls on the watershed.

During the spring, peak flows occur as a result of the combination of spring rains and snow melt. There is very little evapotranspiration and most available water shows up as flow at Thamesville. Generally, as we

[78] Thames River Background Study Research Team. 1998. The Thames River Watershed, A Background Study for Nomination under the Canadian Heritage Rivers System.
[79] From analysis of historic stream flow records and using BFLOW to perform a baseflow separation analysis. Note that baseflow includes contributions from tile drains, flow augmentation reservoirs, treated sewage effluent as well as groundwater discharge.
[80] Thornthwaite, C. W., and J.R. Mather. 1957. Instructions and Tables for Computing Potential Evapotranspiration and the Water Balance.
[81] Thames-Sydenham & Region Source Protection Region. 2006. Thames-Sydenham & Region Draft Conceptual Water Budget.

would have expected, this plot tells us that during the summer when the potential evapotranspiration losses exceed the precipitation, flows in the river decrease. In the fall, as evapotranspiration decreases, flow in the river begins to increase.

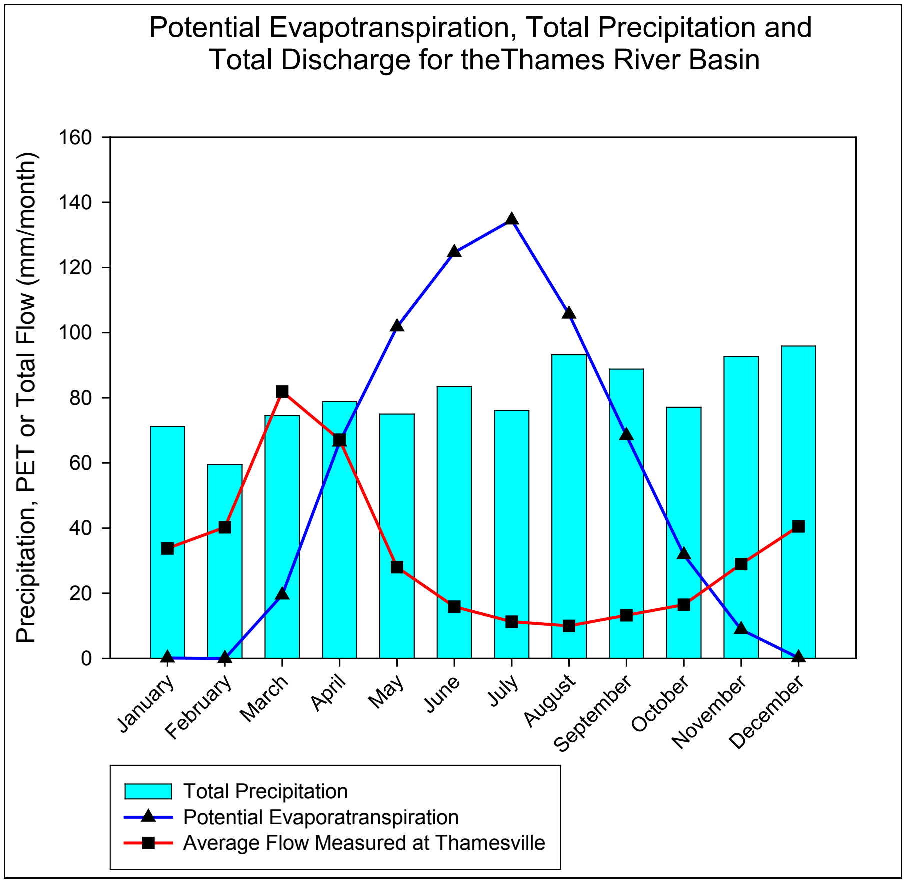

Figure 2.3.3-1: **Potential Evapotranspiration, Precipitation and Discharge for the Thames River above Thamesville**

The Thames River basin may be physiographically divided at Delaware into upper and lower portions. This divide is the approximate point where the river's morphology and hydrologic behaviour changes. It is here that the river exits its glacial spillway valley with a relatively steep gradient to become a low gradient incised valley.

Upper Thames River Conservation Authority Watershed

The upper Thames drainage pattern is a random network of tributaries reaching out like the branches of a tree. The smaller tributaries collect into three branches (North, Middle and South) that join together to form the main river. In truth, the South Branch is the main Thames River but, for this discussion, the upper part of the Thames River will be referred to as the South Branch.

The North Thames River drops at a fairly uniform rate of approximately 1.3 m/km from its source in Perth County to the City of London. The south branch starts in Oxford County, drops more rapidly for the first 32 km, at a rate of 2.1 m/km, and then flattens out just downstream of Woodstock to a gradient of about 0.9 m/km. The Middle branch drops at a rate of about 2.1 m/km for its length of approximately 37 km and joins the South Branch approximately 10 km west of Ingersoll, The South branch then travels another 30 km from the confluence with the Middle Thames River, before meeting the North Thames River at the forks in Downtown London, forming the main Thames River. There are a few tributaries that connect to the main river downstream of the 'Forks' between London and Delaware. **Table 2.3.3-3** summarizes the subwatersheds in the upper Thames Basin in terms of area, and size relative to the entire UTRCA watershed.

Table 2.3.3-3: Subwatersheds of the UTRCA Thames River Basin

Major Subwatersheds in Upper Thames River Conservation Authority	Area (km^2)	Percentage of Jurisdiction
North Branch	1718	50.0%
Medway Creek at North Thames R.	205.9	6.0%
North Thames R. above Whirl Cr.	176.2	5.1%
Fish Creek at N. Thames River	157.5	4.6%
Black Cr. At North Thames R.	144	4.2%
Trout Cr. Above Wildwood Dam	132.4	3.8%
Whirl Cr. at N. Thames R.	130.1	3.8%
Avon R. at Stratford	97.2	2.8%
Flat Creek at N. Thames R.	91.3	2.7%
North Thames R. at Fanshawe Dam (incl Wye Cr.)	91.3	2.7%
N. Thames R. below Fish Cr. (incl Gregory Cr.)	87.9	2.6%
N. Thames River above St. Marys	79.6	2.3%
North Thames River in London (incl Stoney Cr.)	73.9	2.1%
Avon River at North Thames R.	71.8	2.1%
North Thames River above Avon R.	57.5	1.7%
North Thames R. above Black Cr.	53.5	1.6%
North Thames R. above Fish Cr.	39.3	1.1%
Trout Cr. at Thames R.	28.8	0.8%
South Branch	1352	39.3%
South Thames R. at Ingersoll	175.9	5.1%
South Thames R. at Innerkip	162	4.7%
Reynolds Cr. at South Thames R.	156	4.5%
South Thames River at Waubuno Cr.	113.5	3.3%
Waubuno Cr. at South Thames R.	105.7	3.1%
Cedar Cr.	94.8	2.8%
South Thames R. at Pittock Dam	86.1	2.5%
South Thames R. at Ealing (incl Pottersburg Cr.)	65	1.9%
South Thames R. at Middle Thames R.	49.3	1.4%
South Thames R. at North Thames R. (Forks)	19.8	0.6%
Middle Branch	324.1	9.4%
North Branch Creek	97.6	2.8%
Mud Creek	69.7	2.0%
Middle Thames River at South Thames R.	35	1.0%

Major Subwatersheds in Upper Thames River Conservation Authority	Area (km^2)	Percentage of Jurisdiction
Main River below London to Delaware	370	10.7%
Dingman Cr. at Thames R.	170.4	5.0%
Oxbow Cr. at Thames R.	88.9	2.6%
Thames R. at Dingman Cr.	44.5	1.3%
Thames R. at Oxbow Cr.	34.7	1.0%
Thames R. at Byron	31.1	0.9%
Total Area	3440	100.0%

The substantial amount of impervious clay soils, high river bed gradient and steep lateral slopes on the tributaries control the runoff rates in the upper Thames River. Increasing the rate of runoff is the generally low amount of forest cover remaining on the landscape, few lakes and swamps in their natural states, and a dense network of municipal drains throughout the watershed, which include the widening and straightening of smaller streams.

The rate of runoff in the upper Thames basin is relatively high, resulting in the river overtopping its banks in some locations and in the flooding of low lying areas. Historically, floods have occurred at any time of the year, but most of the large floods measured on the upper Thames River have been in the spring[82].

Beginning in the early 1950s the UTRCA undertook a number of remedial measures to reduce flooding, including channelization and building several large dams. This work is discussed in greater detail in **Section 2.3.3.3: Floodway Area**.

Lower Thames Valley Conservation Authority Watershed

In general, the lower Thames basin has little relief except for the incised river channel from Delaware to Thamesville and the relatively mature valleys carved by the tributaries as they discharge into the river. Much of the land surface is sand and clay plains and the topography is flat to gently rolling. Due to the long and narrow shape of the lower Thames watershed, most of the tributaries that enter it are short and steep[83] with relatively mature tributary valleys carved into the sand and clay plains.

The most notable physiographic features are the Bothwell and Caradoc sand plains, the Ekfrid and Chatham clay plains, and the Essex bevelled till plain. The Bothwell and Caradoc sand plains are delta outwash deposits. The Ekfrid clay plain is lacustrine. The Essex bevelled till plain has a very thin veneer of lacustrine clays and in poorly drained portions, deposits of peat and muck have developed. The Chatham clay plain, of lacustrine origin, lies below Chatham and extends almost to the river's mouth in a long narrow strip along the river.

Two relatively minor moraines occur in the lower basin. The Blenheim moraine between Rodney and Blenheim has a maximum relief of approximately 30 m and forms a part of the boundary between the lower Thames and Lake Erie watersheds. A second, lesser moraine passing by Charing Cross is a long, gently-rolling feature of low relief.

The distance from Delaware to the discharge into Lake St. Clair is approximately 174 km. The slope of the river over the first 126 km from Delaware to Thamesville is fairly uniform with an average gradient of

[82] Department of Planning and Development. 1952. Upper Thames Valley Conservation Report.
[83] F.J. Galloway Associates. November 1998. Organizational Alternatives Review for the Lower Thames Valley Conservation Authority.

23 cm/km. These are unusually flat gradients and consequently the velocity of the river flow is low and the flood peaks are not spectacular.

From Thamesville downstream to Chatham for a distance of 19 km, the river drops about 1.2 m with an average gradient of 6 cm/km. From Chatham to Lake St. Clair, a distance of 29 km, there is less than 30 cm difference in elevation. The water levels in this later section of the river are controlled by the level of Lake St. Clair and, for all intents and purposes, remain the same as the lake level during periods of low flow. This stretch of the river varies in depth from 2.5 to 6 m in depth. Large areas from Chatham to the mouth of the river are poorly drained naturally. Extensive tile and open drain schemes with pumps have been developed and maintained over the years.[84]

The natural river banks vary from about 1.5 m high near the mouth to 6 or 8 m at Thamesville. In the upper part from Delaware to Thamesville, the area is more rugged and the valleys are deeply incised, with banks ranging up to 30 m in height.

Because of its very long, narrow shape, the lower Thames River, in response to a runoff event, fills almost evenly along its length, and then drains to its outlet (much like a house's eaves trough).

The total flow at Thamesville is the sum of the flow generated from within the lower Thames watershed and the routed flow from the upper Thames basin. While runoff is occurring in the lower Thames, the rate of runoff is building in the upper Thames basin.

Typically, the flood hydrograph at Thamesville exhibits a 'knee' as the water levels rise. This 'knee' represents the break between the dominant flow regimes. The flows below the 'knee' point are caused predominantly from runoff in the lower Thames basin while those above the 'knee' are from flows generated in the upper Thames basin.

This includes the attenuation achieved by the UTRCA flood control reservoirs at Fanshawe, Pittock and Wildwood Conservation Areas. While the flood control works in the upper Thames reduce river flows in the lower Thames, their effectiveness declines as the distance downstream from them increases.

The lower Thames has numerous tributaries that are comparatively short with small drainage areas. Some of the significant subwatersheds of the LTVCA are listed in **Table 2.3.3-4: Major Subwatersheds in Lower Thames Valley Conservation Authority**.

Although the tributaries of the lower Thames River are comparatively small, their stream gradients are much higher than the main river and they can cause severe damage to property and crops. A case in point is McGregor Creek, which starts in Ridgetown and follows a meandering course to its outlet into the Thames River at Chatham. Just above its confluence with the Thames River, it is joined by Indian Creek. This area was a source of flooding problems for decades, but was essentially resolved with the construction of flood control works by the Authority in the 1970s through 1995.

[84] Department of Energy and Resources Management. 1965. Lower Thames Valley Conservation Report.

Table 2.3.3-4: Major Subwatersheds in Lower Thames Valley Conservation Authority Drainage Areas

Major Subwatersheds in LTVCA	Area (sq km)	Percentage of Jurisdiction
Thames River Subwatersheds		
Jeannettes Creek	396	12.1
McGregor Creek	223	6.8
Big Munday Creek	165	5.0
Fleming Creek	116	3.5
Big Creek	110	3.4
Baptiste Creek	103	3.1
North Marsh Creek	82	2.5
Tilbury Creek	68	2.1
Newbiggen Creek	56	1.7
Gentleman Creek	55	1.7
Cruikshank Creek	47	1.4
Indian Creek	45	1.4
Battlehill Creek	35	1.1
Sharon Creek	30	0.9
Wolfe Creek	20	0.6
Total of above subwatersheds	**1549**	**47.4**
All of LTVCA Thames River subwatersheds	**2397**	**73.2**
Lake Erie Subwatersheds		
Rondeau Bay	203	6.2
Talbot Creek	159	4.9
Two Creeks	40	1.2
Clear Creek	40	1.2
Brock Creek	27	0.8
Morden Drain	24	0.7
Sixteen Mile Creek	20	0.6
Total of above subwatersheds	**511**	**15.7**
All of LTVCA Lake Erie subwatersheds	**737**	**22.5**
Lake St. Clair Subwatersheds		
McFarlane and Rivard Creeks	126	3.8
Total of above subwatersheds	**126**	**3.8**
All of LTVCA Lake St. Clair subwatersheds	**140**	**4.3**
Total LTVCA Watershed area	**3274**	**100.0**

Summer Flow in the Thames River Watershed

As previously discussed in Section 2.3.1.3, southwestern Ontario, including all of the Thames-Sydenham & Region Source Protection Region, has experienced summer low water periods of varying severity. Below average precipitation, combined with above average temperatures, has created conditions where many streams in the region dried up completely.

Low summer flows have been a concern in the Thames River in the past, but during the summer months the main branches of the river usually have enough flow to allow for sufficient flushing. To further alleviate low flow issues on the main branches of the river, water is added to the system by two major flow augmentation reservoirs at Wildwood and Pittock dams. During years of extreme low water, many smaller tributaries may dry up entirely. Larger tributaries in which low water has been an issue in the past are Medway River and Waubuno Creek.

Historic accounts appear to suggest that low flow issues were less of a problem during the summer, when there was less clearing of the forests and draining of wetlands[49]. These surficial features tend to retain water on the landscape and allow for a longer sustained release during the dry summer months. Looking at **Figure 2.3.3-1: Potential Evapotranspiration, Precipitation and Discharge for the Thames River above Thamesville**, the lowest flows occur during the months of July and August on the Thames River System.

In 2000, the provincial government started the Ontario Low Water Response Program to deal with drought issues. In this program, indicators were established to try to quantify drought based on average precipitation and stream flow. Low Water Response programs were initiated in the summer of 2001 in both the UTRCA and LTVCA watersheds under guidance from the Province of Ontario[85]. This program involves forming a local Water Response Team comprised of water regulators and water users, to help plan for and to attempt to alleviate the effects of drought, to the extent that this is possible.

2.3.3.1 Watercourse Classification

Fish habitat in Ontario’s agricultural drains makes a significant contribution towards sustainable fisheries. Drain maintenance activities can alter essential fish habitat components by changing riparian vegetation, substrate composition and width to depth ratios. The resiliency of drains can be categorized according to flow, temperature, fish species present, and stability. The most sensitive drains are those with permanent flow, cool or cold water, and top level predator or cold water fish species; or those drains that have not been recently cleaned and may have reached an equilibrium state. This section is intended to provide background on the development of the municipal drain classification program and summarize some of the information that was collected during the drain evaluations.

Direct and indirect uses have resulted in alterations to natural watercourses. Rural and urban development, road construction, recreational uses and agricultural practices have all required some form of watercourse alteration especially the creation of straight watercourses channels. The straight line pattern of watercourses found on the accompanying maps for this document indicates the numerous watercourses have had their channels changed in the past. Today, watercourse alterations require permits from various agencies and, in most instances, these changes will minimally impact the aquatic environment.

Agricultural land use practices have significantly modified the natural surface water drainage patterns in the Thames River watershed. Agricultural ditches have been an integral part of Southwestern Ontario’s watercourses since the 1800s. **Map 19: Agricultural Tile Drains** provides an overview of drainage in the

[85] Ontario Ministry of Natural Resources, Ontario Ministry of the Environment, Ontario Ministry of Agriculture and Food, Ontario Ministry of Municipal Affairs and Housing, Ontario Ministry of Enterprise, Opportunity and Innovation, Association of Municipalities of Ontario, Conservation Ontario. July 2003. Ontario Low Water Response.

watershed. The Drainage Act, part of Ontario legislation, administered by the Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA), allows for the creation and maintenance of municipal drains. Over time, many agricultural ditches have required maintenance or repair activities in order to allow for the ditches to function properly, or as they were originally intended. Formal approvals are required by law prior to allowing these maintenance or repair activities to occur.

Due to the demand for the maintenance of municipal drains and the required approvals, several agencies have developed a Fisheries Act Class Authorization Process. The intent of this process was and is to streamline the approval process while protecting sensitive fish populations and habitat. This initiative is only applicable to open municipal drains. It was federally funded by Fisheries and Oceans Canada (DFO) and is known as the Municipal Drain Classification Project (MDC).[86]

The MDC initiative has been completed by all Conservation Authorities (CAs) in Southwestern Ontario. The classification scheme was standardized and consistently applied to municipal drains by all CAs. Some CAs extended this scheme to the natural or non-municipal drains within their watershed.

Aquatic biologists assessed the sensitivity of fish habitat in open municipal drains based on stream flows (permanent or intermittent), water temperature (warm or cool/cold water), habitat, and indicator fish species (baitfish, trout, pike, bass, etc.). The drains were then categorized to enable class authorization of maintenance activities in open surface drains that have resilient (or little) fish habitat, while protecting drains that support significant or sensitive fish habitat.[87] The MDC has evolved since its inception to incorporate additional considerations, specifically species at risk and their habitat. **Table 2.3.3.1-1: Fisheries Act Classifications** summarizes the current derivation of the classification scheme.

Table 2.3.3.1-1: Fisheries Act Classifications[88]

Municipal Drain Classification*	Criteria			
	Stream Flow	Thermal Regime	Sensitive Species or their Habitat	Time since last full cleanout
A	Permanent	Cold/Cool	Not Present	Not Applicable
B	Permanent	Warm	Present	Less than 10 years
C	Permanent	Warm	Not Present	Not Applicable
D	Permanent	Cold/Cool	Present	Not Applicable
E	Permanent	Warm	Present	More than 10 years
F	Intermittent or Ephemeral	Neither	Not Present	Not Applicable
N	Either	Either	Either	Not Applicable
T	Unknown	Unknown	Not Applicable	Not Applicable
U	Unknown	Unknown	Unknown	Unknown

Drain Classifications:

N: Natural or not municipal drains

[86] Evanitski, C. The Drain Primer, A Guide to Maintaining and Conserving Agricultural Drains and Fish Habitat. Drainage Superintendents Association of Ontario, Fisheries and Oceans Canada and Ontario Federation of Agriculture. www.dfo-mpo.gc.ca/canwaters-eauxcan/infocentre/guidelines-conseils/guides/drain-primer/drain1_e.asp

[87] Upper Thames River Conservation Authority. 2004. UTRCA Water Report. Thames River Recovery Team. 2004. Recovery Strategy for the Thames River Aquatic Ecosystem: 2005-2010. December 2004 Draft. 145 pp. www.thamesriver.on.ca/Species_at_Risk/synthesis_report/Thames_River_Synthesis_report.pdf

[88] Fisheries and Oceans Canada. 1999. Fact Sheet L-2: A Class Authorization System for Agricultural Municipal Drains in the Southern Ontario Region. www.dfo-mpo.gc.ca/regions/central/pub/fact-fait/L2_e.htm

T: Tiled or closed surface watercourses/drains

U: Unclassified/not yet classified

Stream Flow

- Permanent: aquatic ecosystems that have water in them, with a constant inflow and outflow, or with standing or pooled water year round.
- Intermittent or Ephemeral: aquatic systems that are dry for long periods of time.

Thermal Regime[89]

- Cold: water having a temperature of less than 19 ^{o}C
- Cool: water temperatures between 19 and 25 ^{o}C
- Warm: water temperatures greater than 25 ^{o}C

Sensitive Species or their Habitat

- Field observations of habitat and fish or Species at Risk (the species relevant to this watershed are discussed in section 1.4.4).

Time since last full cleanout

- The date of the last recorded full cleanout on a municipal drain will indicate whether it was more or less than 10 years ago.

The municipal drain classifications for all of the Thames Watershed & Region have been completed. However, the watercourse classifications for the portion of the Thames River located within the LTVCA were recorded in a format that requires conversion to the standardized format. The conversion has been partially completed for the LTVCA and is considered a work in progress.

The LTVCA data format and the UTRCA data format are not consistent. Thus, the information and discussion on watershed classifications will be presented separately for each Conservation Authority.

Watershed Classification - Upper Thames River Conservation Authority

UTRCA extended the drain classification criteria to the natural watercourses within its watershed. Data was gathered at locations where the watercourses or drains were crossed by a road. Unfortunately, several small watercourses and drains do not have roads that cross them. In these instances, these watercourses were conservatively classified consistent with the closest downstream watercourse. As access was gained, or as more accurate information was obtained from Municipal Drainage superintendents or field surveys conducted by qualified individuals, this information was included as current data. The MDC project continues to evolve and as data is gathered and incorporated, the drain classifications will reflect the most current information available.

The municipal drain classifications for the UTRCA watershed still require the consistent application of the evolved criteria to the drains. Some of these classifications are expected to change.

Map 20: UTRCA Watershed Watercourse Classification illustrates the classifications which differentiate between municipal drains, natural watercourses (non-municipal drains) and some tiled (closed surface) watercourses. **Table 2.3.3.1-2: Summary of the Upper Thames River Watershed Municipal Drain Classifications (Draft Version)** shows that there are approximately 47% open municipal drains, 28% natural or non-municipal drains, and 25% tiled watercourses in the UTRCA watershed.

[89] Stoneman, C.L. and M.L. Jones. 1996. A Simple Method to Determine the Thermal Stability of Southern Ontario Trout Streams. In Habitat Management Series by Fisheries and Oceans Canada and Ontario Ministry of Natural Resources.

Due to the nature of the mapping component of the MDC to date, a number of watercourses or drains, specifically closed or tiled systems or newly constructed drains, are not identified on the Geographic Information System (GIS) mapping product. Some closed or tiled systems are shown on the map; however, this does not accurately reflect their numbers. Within the last few years alone, a minimum of 10 km of municipal drains have been converted from open surface drainage to closed surface drainage within the UTRCA watershed.[90] This conversion of drainage from open to closed is presumed to have negative impacts on water quality and quantity, although very little scientific assessment has been completed.[91]

Table 2.3.3.1-2: Summary of the UTRCA Watershed Municipal Drain Classifications (Draft Version) indicates that the natural or non-municipal drains represent more than 25% of the length of watercourses in the UTRCA Thames watershed. However, based on a review of **Map 20**, the majority of the natural watercourses are the main rivers including the Thames River, the north, middle and south branches of the Thames and the lower sections of some of the larger tributaries such as the Avon River.

Approximately 24% of watercourses in this watershed provide suitable water quality and habitat conditions for sensitive species. Of those watercourses approximately 6% are municipal drains and 18% are natural watercourses.

Table 2.3.3.1-2: Summary of the UTRCA Watershed Municipal Drain Classifications (Draft Version)

Classifications	Upper Thames	
	# Km's	%
A	116	3
B	4	.1
C	781	18
D	66	1.5
E	167	4
F	891	20
N	1217	28
T	1101	25
U		

Table 2.3.3.1-3: Thermal Regime and Permanency Summary (Draft Version) for the UTRCA Watershed summarizes the stream flows and thermal regimes for the UTRCA watershed, based on the data that was gathered for the Municipal Drain Classifications.

[90] UTRCA. 2005. Hydrology and Regulatory Services Unit.
[91] Veliz, M., and J.S. Richards. 2005. Enclosing Surface Drains: What's the Story? In Journal of Soil and Water Conservation. 60(4): 70a-73a.

Table 2.3.3.1-3: Thermal Regime and Permanency Summary (Draft Version) for the UTRCA Watershed

Thermal Regime and Permanency	Upper Thames	
	# km's	%
Natural Permanent Cold/Cool Water	129	4
Natural Permanent Warm Water	987	31
Natural Intermittent	58	2
Permanent Cold/Cool Water	182	6
Permanent Warm Water	947	30
Intermittent	891	28

Approximately 10% of watercourses in UTRCA are permanent cold/cool water streams with less than half considered to be natural. Approximately 61% are permanent warm water while about 30% are intermittent watercourses. Of the 61% that are warm water, there is an almost equal division between natural watercourses (31%) and municipal drains (30%). Of the roughly 30% of watercourses that are intermittent systems, or dry for most of the year, only 2% are considered natural while 28% are municipal drains.

Watershed Classification - Lower Thames Valley Conservation Authority

From a drainage aspect, an extensive network of drainage ditches has been developed in the LTVCA to dispose of water either on the surface or within the soil to enable more land to be brought under cultivation, to increase yields, to improve crop quality and, in some cases, to permit farmers to work the land earlier in the spring. This network has enabled many hectares of agricultural land to be drained with tile systems. Large areas of land have been reclaimed as farmland in the lower watershed by dyking with associated drainage ditch installation and with pumping stations on some ditches near Lake St. Clair.

While many drainage schemes may be necessary and beneficial, others can cause significant problems. For example, natural storage areas such as swamps and bogs may be drained, reducing the amount of water previously available for natural stream flow and destroying fish and wildlife habitat. The lowering of the water table as a result of drain installation can seriously interfere with nearby shallow wells. Erosion and sedimentation problems can occur both during and after the construction of open drainage ditches. Existing stream bank cover may also be removed during drain installation or maintenance.

The watercourse classifications for the portion of the Thames River located within the LTVCA were recorded in a format that requires conversion to the standardized format. The conversion has been partially completed for the LTVCA jurisdiction. At this time, an analysis similar to that done for the UTRCA area would not provide an accurate representation of the watercourses in LTVCA that have been classified.

Within the LTVCA there are approximately 1,950 drainage works constructed under the Drainage Act of Ontario. In order to classify these drains, the Authority undertook approximately 850 habitat assessments on these drains, temperature assessments at a total of 45 sites and fish sampling at 36 locations. The overall results of the project are found in **Tables 2.3.3.1-4, 5 and 6**.

Table 2.3.3.1-4: Habitat and Temperature Assessments - LTVCA illustrates the number of drains of each classification by political region of the LTVCA. **Table 2.3.3.1-5: Drain Classification - LTVCA** illustrates the number of assessments that were done in each political region and the determination of the assessment. **Table 2.3.3.1-6: Fish Sampling Results in the LTVCA** illustrates the results of the fish sampling undertaken.

Table 2.3.3.1-4: Habitat and Temperature Assessments - LTVCA

Municipality	Political Region	Permanent Flow	Intermittent Flow	Coldwater	Warm water
Chatham-Kent	Camden	7	2	0	9
	Chatham	10	5	0	15
	Dover	28	14	0	42
	Harwich	25	110	0	135
	Howard	31	65	0	96
	Oxford	33	27	0	60
	Raleigh	38	44	0	82
	Romney	0	8	0	8
	Tilbury East	15	47	0	62
	Zone	7	17	0	24
Dutton/Dunwich	Dunwich	39	24	0	63
Lakeshore	Tilbury North	6	16	0	22
	Tilbury West	5	13	0	18
Leamington	Mersea	0	12	0	12
London-Middlesex Centre	Delaware	1	5	0	6
	Westminster	0	2	0	2
Southwest Middlesex	Ekfrid	10	33	0	43
	Mosa	7	24	0	31
Southwold	Southwold	12	11	0	23
Strathroy-Caradoc	Caradoc	2	14	0	16
West Elgin	Aldborough	52	19	1	71

Table 2.3.3.1-5: Drain Classification - LTVCA

Municipality	Political Region	Class A	Class B	Class C	Class D	Class E	Class F
Chatham-Kent	Camden			7			2
	Chatham			10			5
	Dover			25		3	14
	Harwich			25			110
	Howard			31			65
	Orford			33			27
	Raleigh			34		4	44
	Romney						8
	Tilbury East			14		1	47
	Zone			7			17
Dutton/Dunwich	Dunwich			36		3	24
Lakeshore	Tilbury North			3		3	16
	Tilbury West			3		2	13
Leamington	Mersea						12
London-Middlesex Centre	Delaware			1			5
	Westminster						2
Southwest Middlesex	Ekfrid			9		1	33
	Mosa			7			24
Southwold	Southwold			13			11
Strathroy-Caradoc	Caradoc			2			14
West Elgin	Aldborough			50	1	1	20
Totals				**310**	**1**	**18**	**513**
Percentage				**37.29**	**0.12**	**1.54**	**61.05**

Table 2.3.3.1-6: Fish Sampling Results in the LTVCA

• 1 site with a salmonid present (Rainbow Trout)
• 11 sites with top-level predators (Northern Pike, Smallmouth Bass, Largemouth Bass, Yellow Perch) or top-level predator indicator species (Rock Bass, White Crappie)
• 23 sites with baitfish only
• 1 site with no fish present

Fish habitat in Ontario's agricultural drains makes a significant contribution towards sustainable fisheries. Drain maintenance activities can alter essential fish habitat components by changing riparian vegetation, substrate composition and width to depth ratios.

The resiliency of drains can be categorized according to flow, temperature, fish species present, and stability. The most sensitive drains are those with permanent flow, cool or cold water, and top level predator or cold water fish species; or those drains that have not been recently cleaned and may have reached an equilibrium state. Drains are classified as type A-F according to these criteria.

Type A drains have permanent flow, cool/cold or unknown temperature of water and have no trout or salmon species. Under Class Authorization A, bottom cleanouts, debris cleanouts and brushing of side slopes are allowed as long as they meet with specific terms and conditions. The width: depth ratio cannot be increased, the shade producing side cannot be altered, sediment must be controlled, bank vegetation must be replanted and specific timing restrictions must be followed (work must be done when flows are not elevated and fish are not spawning).

Type B drains have permanent flow, warm water, top predator fish species (bass, pike, muskie, crappie), and have been cleaned out within the last 10 years. Under Class Authorization B, bottom cleanouts, debris cleanouts and brushing of side slopes are allowed as long as they meet with specific terms and conditions. The width to depth ratio can be increased as long as the channel is as deep as possible, vegetation can be removed from either bank but must be replanted, sediment must be controlled and specific timing restrictions must be followed (work must be done when flows are not elevated and fish are not spawning).

Type C drains have permanent flow, warm water and baitfish species are present. Under Class Authorization C, full cleanouts, bottom cleanouts, debris cleanouts and brushing of side slopes are allowed as long as they meet with specific terms and conditions. Vegetation can be removed from either bank but must be replanted, bends in the channel must be stabilized, sediment must be controlled and specific timing restrictions must be followed (work must be done when flows are not elevated and fish are not spawning).

Type D drains have permanent flow, cool/cold or unknown water temperature and trout and/or salmon species are present.

Type E drains have permanent flow, warm water and top predator fish species are present.

Type D and E drains are sensitive to drain maintenance. Projects will be evaluated on a project by project basis to determine if the effects of drain maintenance can be mitigated.

Type F drains have intermittent flows. Drain maintenance will not cause a harmful alteration, disruption or destruction of fish habitat as long as work is done in the dry and all disturbed soils are stabilized upon completion of work.

During the MDC project, a significant amount of biological data was collected on municipal drains. Some municipal drainage superintendents were impressed with the diverse fish communities found within their municipal drains. A few drainage superintendents have even stated that municipal drains have been contributing to the productivity of fish populations. Several municipal drainage superintendents have modified their practices and have been employing strategies to enhance and naturalize agricultural drains through natural channel design.

Based on the information that was gathered from the LTVCA portion of the MDC, 852 habitat assessments were completed throughout the watershed. 328 of those were found to have warm water, one was coldwater and 513 were intermittent. 36 of those assessments suggested that further information regarding fisheries was required. 19 of the 36 sites sampled for fish were found to provide suitable habitat and water quality for sensitive species. Once the data transformation of the MDC information is complete, the length of watercourses can be calculated and analysis can be completed in order to compare results between watersheds and SWP regions.

2.3.3.2 Travel Times

The Thames River begins in the high lands of Perth and Oxford counties and flows approximately 280 km to discharge into Lake St. Clair. The change in elevation is about 200 m with large differences in the rate of fall over the course of the river.

The North Thames River from the source to London drops at a fairly uniform rate of approximately 1.3 m/km. The South branch drops more rapidly for the first 32 km, at a rate of 2.1 m/km, and then flattens out to about 0.9 m/km. The Middle branch drops at a rate of about 2.1 m/km. The Middle branch joins the South branch east of London just downstream of Ingersoll. The North and South branches join at the Forks in downtown London forming the main Thames River.

From London to Delaware, a distance of about 18 km, the river begins to level out and drops at a rate of approximately 0.4 m/km. From Delaware and over its course of 174 km to Lake St. Clair the river drops 34 m, or approximately 0.2 m/km. However, most of this occurs in the 126 km from Delaware to Thamesville with a fairly uniform gradient averaging 0.23 m/km. From Thamesville to Chatham for a distance of 19 km, the river only drops about 1.2 m with an average gradient of 0.06 m/km.

From Chatham to Lake St. Clair, a distance of 29 km, there is less than 30 cm difference in elevation providing a drop of about 0.01 m/km. The water levels in this section of the river are controlled by the level of Lake St. Clair and, for all intents and purposes, remain the same as the lake level during periods of low flow.

Table 2.3.3.2-1: Travel Time Tables for Thames River[92] provides estimates of the times in various sections of the Thames for flood and normal flow conditions. The lower portion of the river has very little difference for travel time between flood and normal flow conditions. The higher gradient for the upper part of the river is illustrated by the change in travel time during flood conditions.

Table 2.3.3.2-1: Travel Time Tables for Thames River

Approximate Travel Time Table		
Location	**Normal Travel Time (hours)**	**Flood Stage Travel Time (hours)**
North Thames River, upstream Mitchell to Forks of Thames	32	22
Thames River, Tavistock to Forks of Thames	36	26
Thames River, Forks to Delaware	12	6
Delaware(Byron) to Thamesville	70	60
Thamesville to Chatham	12	12
Chatham to the Mouth	12	12
Total, Tavistock to Mouth	**160**	**138**

2.3.3.3 Floodway Area

Flooding of rivers and streams typically occurs following the spring freshet but storm events anytime of the year may cause increased runoff and flooding. The ‘flood plain’ (flooding hazard limit) for rivers and streams is defined as the area adjacent to the watercourse that would be inundated by a flood event. The ‘floodway’ of a river or stream is the area of the flood plain required to allow safe passage of the high

[92] Data from UTRCA HEC-RAS models.

stream flows associated with the flood event. The 'flood fringe' is the remaining portion of the flood plain.

In Ontario, either storm centred events, observed events or a flood frequency based event may be used to determine the extent of the flooding hazard limit[93] (previously defined as the regulatory flood criteria). Frequency based events are normally calculated as incidents that have a return of at least once every 100 years. A storm centred event refers to a major storm of record such as Hurricane Hazel. An observed event is a flood that has been experienced in a particular watershed and that has produced flood levels greater than those expected for frequency and storm centred events.

The Flooding Hazard Limit (Regulatory) Flood on the Thames River is equivalent to the historic flood that occurred in April of 1937. This flood corresponds to one that would occur once every 250 years[94].

Flooding in the Upper Thames River Basin

The UTRCA is responsible for the regulation of approximately 500 km^2 of river valley lands[95], which is predominantly the flood plain of the Thames River and its major tributaries. The major flood prone areas in the upper Thames River basin are generally all on the main branches of the river. These include the communities of Mitchell, St. Marys, Ingersoll, London, Woodstock and, to a lesser extent, Stratford. There are some additional smaller flood prone areas along tributary watercourses.

The UTRCA has significant flood control infrastructure throughout its jurisdiction, including dykes in London and St. Marys, flood control dams upstream of St. Marys, Woodstock and London, and flood control channels in Ingersoll, Mitchell and Stratford.

London

One of the most significant flood prone areas in the UTRCA watershed is the West London area. Some 1500 buildings are protected by a dyke to approximately the 1:100 year flood level. Also, the Fanshawe Dam located on the North branch of the Thames provides flow control and flood protection. A special policy is in place to allow the area to be economically viable.

St. Marys

Downtown St. Marys is protected by a flood wall to the 1:250 year level. A special policy is in place to allow the area to be economically viable.

Ingersoll

The town of Ingersoll has some significant flooding issues associated with both the Thames River proper and with the many sizable tributaries that enter the Thames River within its boundaries. The first major flood control work completed by the UTRCA was the construction of the Ingersoll Channel in 1950, which in effect straightened out and channelized the river, allowing flood waters to be conveyed efficiently downstream. Large tributaries entering the Thames River within Ingersoll include:

- Halls Creek
- Henderson Creek
- Sutherland Drain
- Whiting Creek
- Murphy Drain

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[93] OMNR. Understanding Natural Hazards, River and Stream Systems. Ontario Ministry of Natural Resources Publications.

[94] UTRCA. 1987. Technical Report to Support the Use of the 1937 Flood as the Historical Event for Flood Plain Management Purposes in the UTRCA.

[95] UTRCA. 2006. Ontario Regulation 157/06: Regulation of Development, Interference with Wetlands and Alterations to Shorelines and Watercourses.

These creeks all travel through the urban areas of Ingersoll, and all have sizable flood plains and flood damages associated with them.

Mitchell

The Town of Mitchell has some minor flood damages associated with it from the North Thames River, and also from Whirl Creek, which enters the North Thames in Mitchell. Improvements made to the channel and to bridges in the town over the years improved water conveyance capacity, thus lessening the amount of flood damages. Also, many properties flooded in 1937 were since purchased, reducing the amount of flood damages in the present time.

Woodstock

The City of Woodstock has relatively minor flooding concerns, mainly associated with the confluence of the Thames River and Cedar Creek at the northwest corner of the city. Pittock Reservoir, on the Thames River in Woodstock helps to alleviate flood damages at this confluence. Generally, development has avoided the flood plain of the Thames River in Woodstock, and most of the few properties in Woodstock subject to flooding are on the Cedar Creek.

Stratford

Stratford has the Avon River, a major North Thames River tributary, running through it. Due to efficient flood plain management techniques controlling development, it experiences little in the way of flood damages.

Agricultural Lands

Agriculture is the predominant use of land in the watershed and flooding is a concern for this. However, very little data exists on the extent of agriculture flood damage, both in terms of a dollar value, and spatial extent.

Flooding in the Lower Thames River Basin

The LTVCA is responsible for the regulation of the flood prone areas in the lower Thames River watershed. During the 1937 flood (1:250 year flood), water levels generally remained in the valley of the Thames River from Delaware to just upstream of Thamesville. Even though the flood waters remain within the river valley, many hectares of land are flood prone under these conditions.

From just above Thamesville downstream to Chatham, the river definitely leaves its banks under Regulatory Flood conditions. In this region, the flood waters still remain generally within the actual river valley; however, the flood plain widens significantly. Both Thamesville and Chatham are urban centres that require special flood plain policies to remain socially and economically viable. Also, the largely rural area below Chatham to the mouth of the Thames requires flood protection and development controls.

Thamesville

South of the CNR railway, the entire Thamesville area, with the exception of currently developed lots, is considered a floodway of the Thames River. Within this floodway area a permit from the Conservation Authority is required for any undertaking. The urban area north of the CNR railway in Thamesville is flood plain, where new development, alterations or additions are allowed provided there is no increase in flood susceptibility.

Chatham

Within the Chatham urban area, the floodway of the Thames River and McGregor Creek is defined to be all lands within 22 metres of the water's edge of these watercourses. Within this floodway area a permit is required by the Conservation Authority for any undertaking.

The primary flood plain area in Chatham is the south Chatham urban area. Development in these flood plain areas of the Thames River, McGregor Creek and Indian Creeks is treated similarly to the flood plain area in Thamesville. In this area, new development and revisions to existing structures are allowed provided the new development is flood proofed with no increase in flood susceptibility.

Rural Areas below Chatham

Downstream of Chatham, there are large areas on either side of the Thames River that are flood prone under ice jam conditions. The area is generally agricultural with some residential development immediately adjacent to the river and in the Lighthouse Cove community at the mouth of the river.

These low lying areas have generally been protected by dyking that has been constructed to heights that are believed to contain river flows under ice jam conditions. However, the dykes are still prone to failure or flow conditions that are higher than the design standard. The dyked areas, as well as the river channel downstream of Chatham, are able to contain river flows under Regional Storm flows provided the river is ice free. Development is allowed in these areas provided adequate flood proofing is undertaken.

Lakeshore Flooding

There are significant areas within the LTVCA that are flood prone due to flooding along the Lake Erie and Lake St. Clair shorelines. Shorelines along large inland lakes are subject to flooding, erosion and dynamic beach hazards[96]. A shoreline classification system has been developed to determine the factors and processes that influence the severity of potential hazards.

Flooding on the Great Lakes can be caused by weather systems with sustained high winds from critical directions. These conditions are worsened if the lakes are also at high lake levels. There have been high lake level eras in the late 1940s, the mid 1950s and the era from 1973 to 1988. Another brief high level period occurred in the 1990s.

For Great Lakes flood controls, a combination of the highest known water level and the strongest wind "setup" is used to establish the flood level. Along shorelines subject to wave action, the area further inland covered by wave uprush must be taken into consideration. Other water related hazards that should be taken into account along the lake shoreline are ship-generated waves, ice piling and ice jamming.

Erosion hazards are determined using the erosion rate and an allowance for slope stability. Dynamic beach hazards occur along shorelines where elevations can change due to the build-up or erosion of sand, cobbles and other beach deposits. Areas on the Great Lakes that experience chronic flood and erosion damages were typically constructed during low lake levels.

Lake St. Clair

Significant agricultural areas within the communities of Dover, Lakeshore and Tilbury East are prone to flooding from the waters of Lake St. Clair. The dyking that protects these areas was rebuilt in the 1970s and 1980s. Since this initiative these areas have generally been protected from lake oriented flooding.

The community of Lighthouse Cove is prone to some flooding from storms but the flooding is generally low level and of short duration. Erosion related to storm events is a more significant issue. However, since the high lake level era in the 1970s, there have been significant erosion control works undertaken both on the dykes and on the shoreline adjacent to residential areas to address this issue.

[96] OMNR. Understanding Natural Hazards, Great Lakes-St Lawrence River System and Large Inland Lakes. Ontario Ministry of Natural Resources Publications.

Lake Erie

Approximately 650 hectares of agricultural land in south Harwich, as well as numerous homes abutting the lakeshore in south Harwich, Erie Beach and Erieau, are prone to flooding and erosion from high lake levels on Lake Erie. A significant dyking project was undertaken adjacent to the McGeachy Pond Conservation Area and a portion of Erie Shores Drive in the 1970s in order to help protect these agricultural lands from flooding.

A more comprehensive project has been proposed to protect both the numerous homes on Erie Shores Drive and the agricultural properties north of Erie Shores Drive, but a suitable funding formula has not been found to construct the project.

2.3.3.4 Mean Monthly Flows at Representative Gauges

The location of the many stream gauges operated within the Thames River watershed is provided on **Map 21: Stream Flow and Water Level Monitoring Stations**. The information from six locations has been used to plot the mean monthly and annual flows for various sections of the Thames River watershed. The locations and a brief description of these representative stream flow stations are provided in **Table 2.3.3.4-1: Representative Stream Flow Stations for Thames River Basin**.

Table 2.3.3.4-1: Representative Stream Flow Stations for Thames River Basin

Gauging Location	Rationale
North Thames River near Mitchell	Headwater of North Branch, 50+ years of record
Thames River at Innerkip	Headwater of Main Branch, 25+ years of record
Middle Thames River at Thamesford	Large (300 km^2) unregulated central subwatershed, 65+ years of record
Thames River at Byron	Outlet of Upper Thames River watershed, 75+ years of record
Thames River at Chatham	Water Level gauge at downstream end of Thames watershed, 60+ years of record
McGregor Cr. near Chatham	Tributary of lower Thames River, 20+ years of record

The mean monthly stream flow characteristics and the minimum, maximum and mean annual flows are plotted out for each of these stream flow stations in figures below[97]. These gauges are representative of the watershed as a whole; however, we should keep in mind that the hydrology for all of these stations is dynamic with time.

Figure 2.3.3.4-1: Thames River near Mitchell: The headwater gauge at Mitchell is affected by systematic tile drainage that has been installed, likely since the gauge was established in 1953. This process certainly continues altering the characteristics of baseflow and runoff. This is true for all of the indicator stations.

Figure 2.3.3.4-3: Middle Thames River at Thamesford: The gauge at Thamesford is downstream of a dam. While the dam does not have much effect in attenuating flood peaks, it may have consequences in terms of baseflow and evaporation.

Figure 2.3.3.4-4: Thames River at Byron: The gauge at Byron has all of the effects of any changes upstream, including all tile drainage installed upstream and, most significantly, the installation of the Fanshawe, Wildwood and Pittock dams in 1953, 1965, and 1966 respectively. As discussed in more detail

[97] Stream flow data taken from Environment Canada HYDAT database, 2002 edition.

later, operation of these dams has altered the flow pattern and data prior to 1967 is not included in the plot for the Byron gauge.

Figure 2.3.3.4-5: Thames River at Chatham: The station at Chatham is not used to measure stream flow since it is influenced by Lake St. Clair. Only water levels are recorded at this location.

Figure 2.3.3.4-6: McGregor Creek near Chatham: The gauge on McGregor Creek near Chatham provides information on the variation in stream flow for a smaller local watercourse.

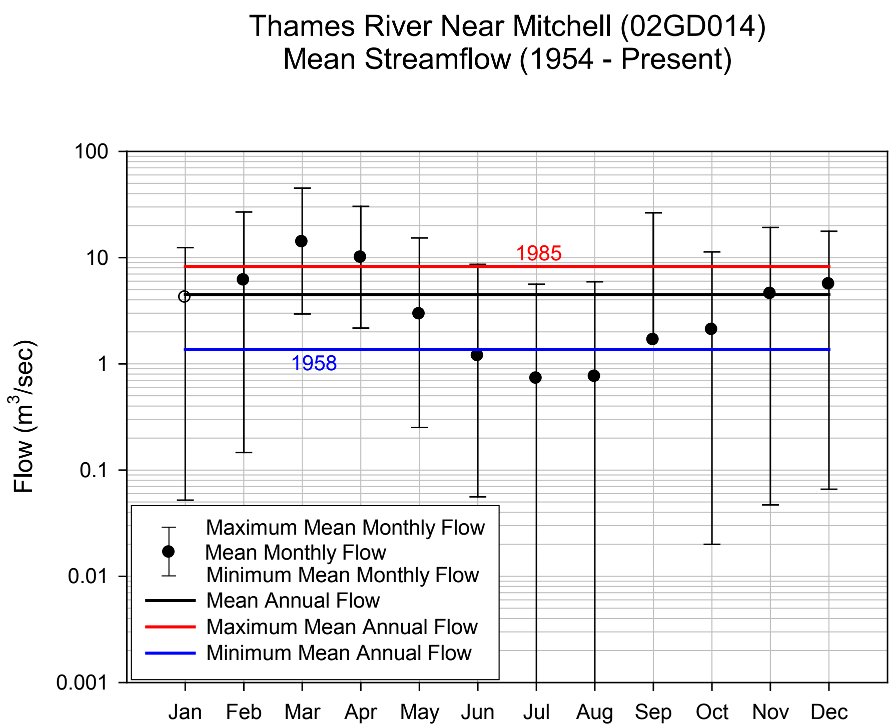

Figure 2.3.3.4-1: **Thames River near Mitchell**

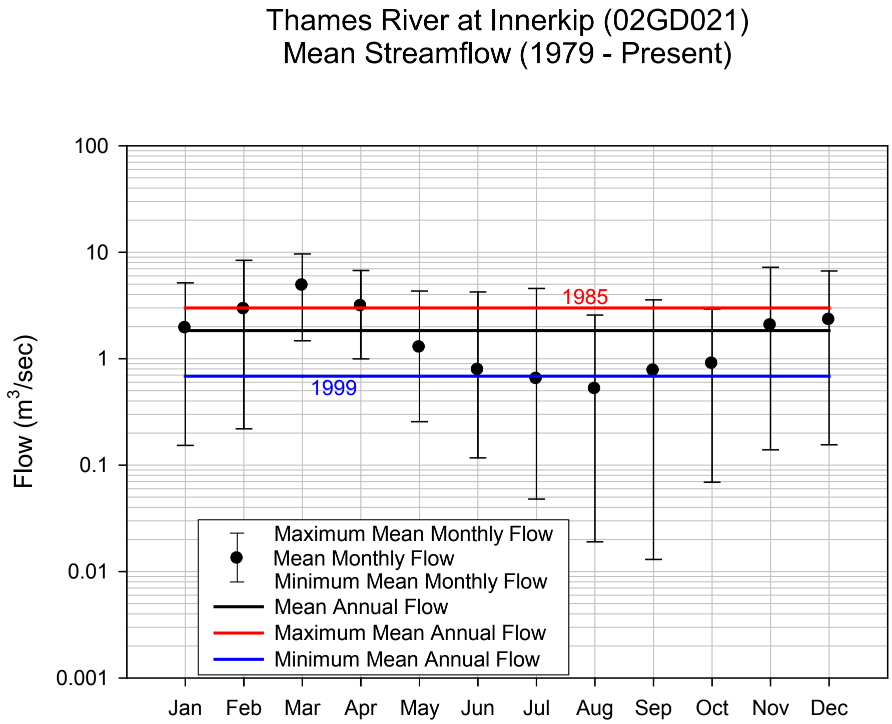

Figure 2.3.3.4-2: **Thames River at Innerkip**

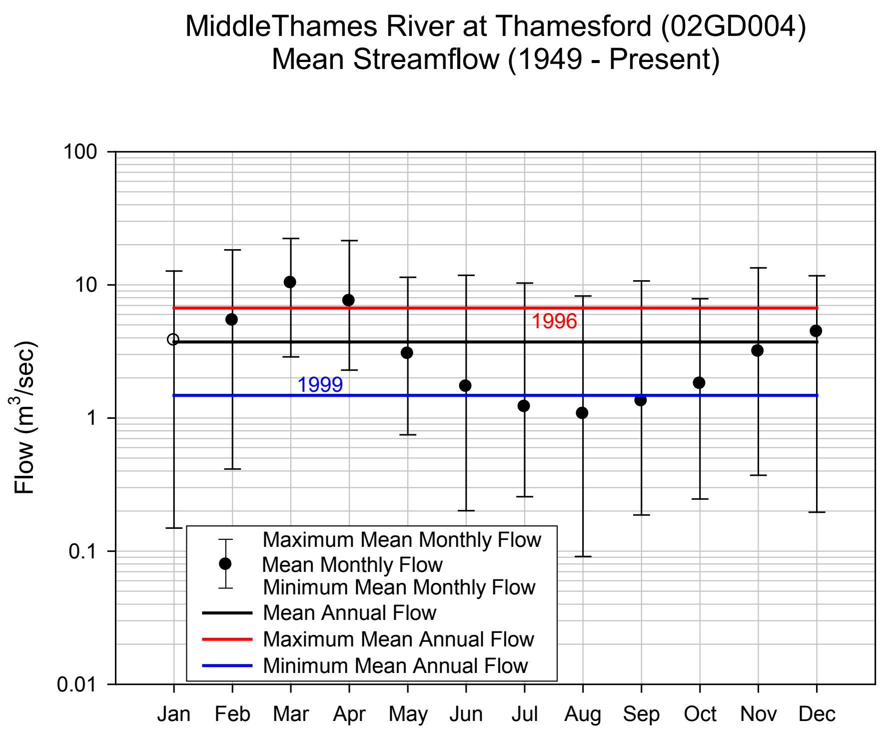

Figure 2.3.3.4-3: **Middle Thames River at Thamesford**

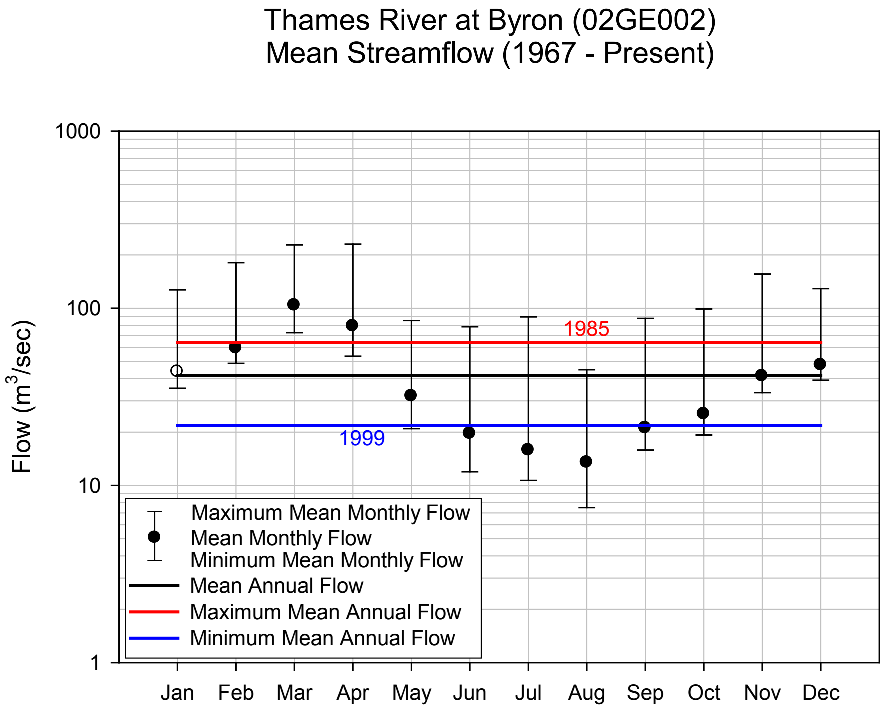

Figure 2.3.3.4-4: **Thames River at Byron**

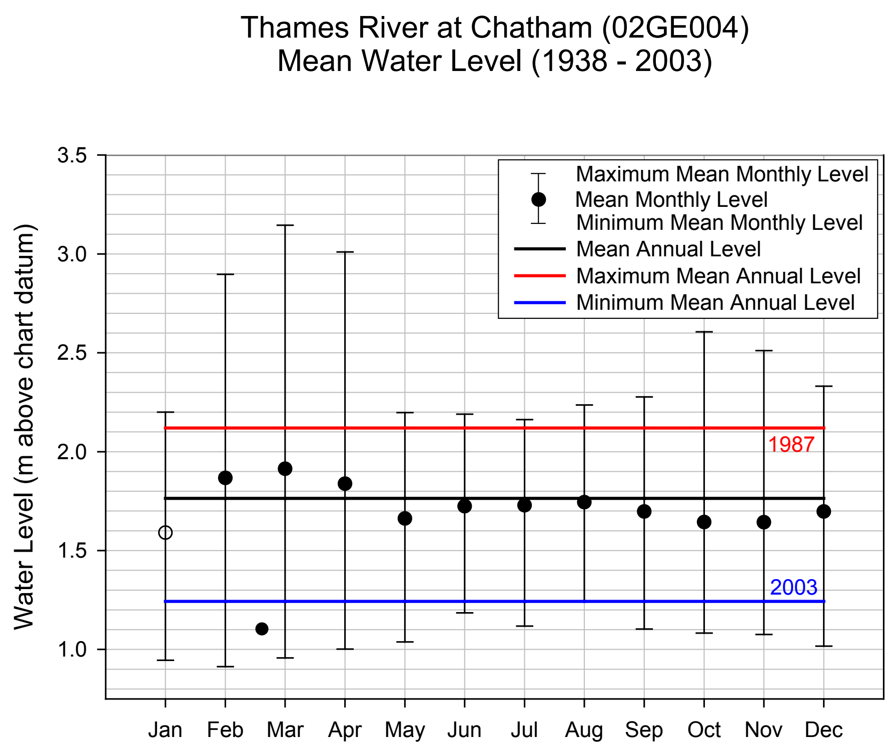

Figure 2.3.3.4-5: **Thames River at Chatham**

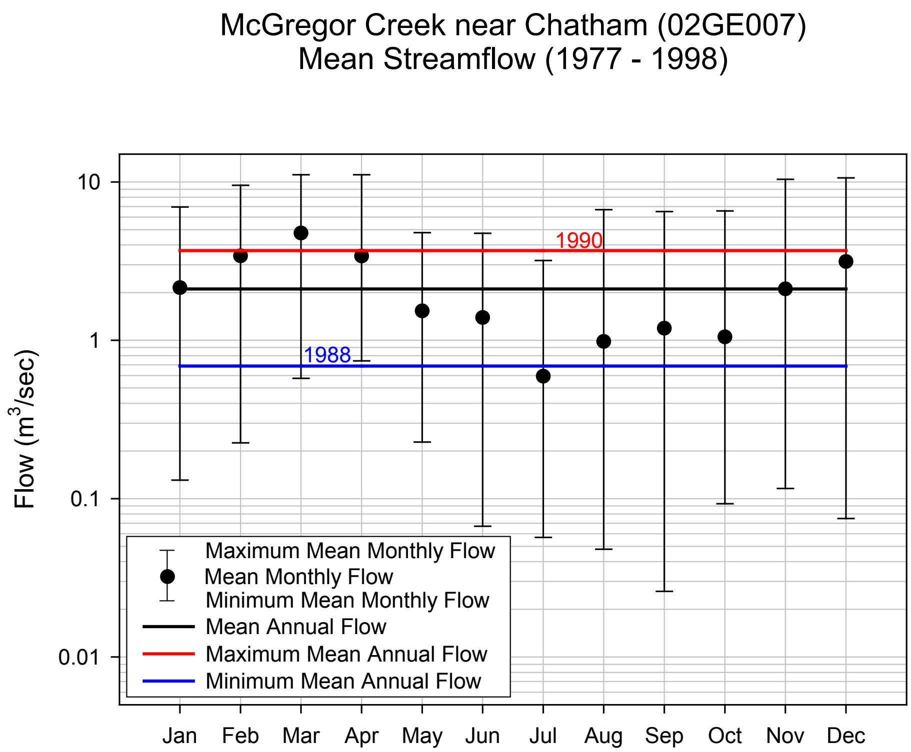

Figure 2.3.3.4-6: McGregor Creek near Chatham

2.3.3.5 Surface Water Monitoring

The upper Thames watershed has had at least seasonal water quantity monitoring at stations on the larger tributaries since 1914[97]. **Table 2.3.3.5-1: Active Stream Gauges in UTRCA Watershed** and **Table 2.3.3.5-2: Active Stream Gauges in LTVCA Watershed** outline active stream flow stations and their periods of record for the upper and lower Thames River watershed respectively. **Table 2.3.3.5-3: Discontinued Stream Gauges in Thames River Watershed** lists discontinued stream flow stations, and **Table 2.3.3.5-4: UTRCA Monitored Reservoir Water Levels** provides a list of reservoir level monitoring stations. **Map 21: Stream Flow and Water Level Monitoring Stations** shows their locations.

Table 2.3.3.5-1: Active Stream Gauges in UTRCA Watershed

Stream Flow Station Name	Environment Canada Station number	Year Data Begins	Year Data Ends	Period of Record (yrs)	Comment
Thames River near Ealing	02GD001	1915	2005	91	
North Thames River Below Fanshawe Dam	02GD003	1915	1998	84	Became water level only in 1998. Returned to full flow in 2004.
Middle Thames River at Thamesford	02GD004	1938	2005	68	
North Thames River at St. Marys	02GD005	1938	2005	68	
Medway River at London	02GD008	1945	2005	61	
Trout Creek near St. Marys	02GD009	1945	1991	47	Discontinued in 1991. Re-established in 2005
Fish Creek near Prospect Hill	02GD010	1945	1995	51	Discontinued in 1995. Re-established in 2005
Cedar Creek at Woodstock	02GD011	1951	2005	55	
North Thames River near Mitchell	02GD014	1953	2005	53	
North Thames River near Thorndale	02GD015	1953	2005	53	
Thames River at Ingersoll	02GD016	1938	2005	68	
Avon River below Stratford	02GD018	1964	2005	42	
Trout Creek near Fairview	02GD019	1966	1998	33	
Waubuno Creek near Dorchester	02GD020	1965	2005	41	
Thames River at Innerkip	02GD021	1978	2005	28	
Avon River above Stratford	02GD026	1994	1994	1	Used for water quality study in 1994 only, re-established in 2005
Reynolds Creek near Putnam	02GD027	2002	2005	4	
Stoney Creek at London	02GD028	2002	2005	4	
Thames River at Byron	02GE002	1914	2005	92	
Dingman Creek below Lambeth	02GE005	1965	2005	41	
Oxbow Creek near Kilworth	02GE008	2002	2005	4	

Table 2.3.3.5-2: Active Stream Gauges in LTVCA Watershed

Stream Flow Station Name	Environment Canada Station number	Year Data Begins	Year Data Ends	Period of Record (yrs)	Comment
Thames River at Chatham	02GE004	1938	2005	67	Water Level only gauge due to influence of Lake St. Clair
Thames River at Thamesville	02GE003	1938	2005	67	2002 station became water level only
Thames River near Dutton	02GE006	1971	2005	34	1998 station became water level only
McGregor Creek near Chatham	02GE007	1977	2005	28	1999 station became water level only

Table 2.3.3.5-3: Discontinued Stream Gauges in Thames River Watershed

Stream Flow Station Name	Environment Canada Station number	Year Data Begins	Year Data Ends	Period of Record (yrs)
Thames River at Woodstock	02GD012	1952	1998	47
Wye Creek near Thorndale	02GD013	1953	1991	39
Nissouri Creek near Embro	02GD022	1987	1993	7
Thames River near Tavistock	02GD023	1987	1999	13
Webber Drain at Highway No. 59 (Pittock Control)	02GD024	1988	1992	5
Goring Drain at Concession No. 13 (Pittock Test)	02GD025	1988	1992	5
O.A.C. Farm Gauge No. 2 near Merlin	02GF001	1961	1977	16

Table 2.3.3.5-4: UTRCA Monitored Reservoir Water Levels[98]

Reservoir Station Name	Year Data Begins	Year Data Ends	Period of Record (yrs)
Wildwood Reservoir	1984	2005	22
Fanshawe Reservoir	1984	2005	22
Pittock Reservoir	1984	2005	22
R.T. Orr Dam	2003	2005	3
Mitchell Dam	2004	2005	2

2.3.3.6 Dams in the Thames River Watershed

The Thames watershed, like most watersheds in Southern Ontario, has many dams and other barriers of varying sizes throughout its boundaries. Many dams and reservoirs are highly valued by their local communities for their recreational and aesthetic uses as well as their historical significance. Other

[98] Reservoir level information taken from UTRCA data management system records.

structures are important for their role in flood control or flow augmentation. However, dams and other barriers can also have major negative impacts on aquatic ecosystems. The adverse effects include barring migration of fish and wildlife, increasing soil deposition and erosion, altered water quantity and quality, eutrophication (excess nutrients cause excessive algae growth and result in lack of oxygen), and wildlife mortality[99]. Dams and barriers in the watershed are shown in **Map 22: Watercourse Dams and Barriers**.

Most dams and barriers are small and privately owned, and little exists in the way of detailed information for these structures. However, some structures are larger and thus more significant, including several operated by the UTRCA and by the LTVCA. Generally more detailed information is known about these structures, and is summarized in **Table 2.3.3.6-1: Dams in UTRCA Watershed Owned by Conservation Authority** and **Table 2.3.3.6-2: Dams in LTVCA Watershed Owned by Conservation Authority**. There are also some significant privately owned dams and they are listed in **Table 2.3.3.6-3: Significant Privately Owned Dams in UTRCA watershed**.

Table 2.3.3.6-1: Dams in UTRCA Watershed Owned by the Conservation Authority[100]

Dam Name	Approximate Drainage Area (km^2)	Approximate Normal Storage Volume (ha-m)	Dam height (m)	Date Built
Wildwood Dam	140	1780	16	1965
Fanshawe Dam	1450	1235	28	1954
Pittock Dam	247	400	12.5	1966
Mitchell Dam	176	22.8	8.99	1964
R.T. Orr Dam	88.8	?	5.2	1964
Wildwood Ducks Unlimited Weir	92	18.5	2.4	1980
Dorchester Mill Pond Dam	23	14	5	1810
Shakespeare Dam	1	9	3.4	1952
Embro Dam	7	3	4.5	Unknown
Harrington Dam	12	2	4	1846
Dorchester CA Dam	7	2	3	1957
Fullarton Dam	4	2	3.4	1955
Centreville Dam	13	1	5.5	Unknown

Table 2.3.3.6-2: Dams in LTVCA Watershed Owned by the Conservation Authority[101]

Dam Name	Approximate Drainage Area (km^2)	Surface Area (ha)	Dam height (m)	Date Built
Sharon Creek Dam		400	13.7	1969
Indian/McGregor Creek	265	0	6	1993

[99] World Commission on Dams. 2000.
[100] Acres International. Dam Safety Assessments, 2002 to 2005.
[101] UTRCA. 1991. Dam Inventory and Reservoir Assessment.

Table 2.3.3.6-3: **Significant Privately Owned Dams in UTRCA Watershed**[102]

Dam Name	Approximate Drainage Area (km^2)	Surface Area (ha)	Dam height (m)	Date Built
Arva Dam	172	8	4.5	?
Thamesford Dam	290	11	5.8	1809

Several of the Conservation Authority managed structures are considered flood control and/or flow augmentation structures. Operation of the five largest UTRCA dams and the LTVCA Indian/McGregor dam) is discussed below.

Wildwood and Pittock Dams

Wildwood and Pittock dams are both large structures that have the dual purposes of flood control and flow augmentation. As a side benefit, they also create recreational opportunities for their local communities. Wildwood is located on Trout Creek, a tributary of the North Thames River, upstream of St. Marys. Pittock is on the South Thames River in Woodstock.

These reservoirs are filled with spring snowmelt runoff and rain to their summer holding level. They are slowly drawn down over the course of the summer and early fall to augment the low flows often found in the river during this period. Water levels are guided by the curves shown in **Figure 2.3.3.6-1: Wildwood Reservoir Operation Guidelines** and **Figure 2.3.3.6-2: Pittock Reservoir Operation Guidelines**.

Both of these structures provide significant flood control benefits during the fall and spring when they are at low levels. Wildwood Reservoir controls approximately 140 sq. km. of drainage area, and Pittock 254 sq. km. When they are full in early summer, they still retain some flood control volume. This increases as flow augmentation lowers the reservoir levels. When Wildwood Reservoir is at its winter holding level, it has an available storage capacity of approximately 140 mm of upstream runoff. In the summer, it still retains about 50 mm of runoff capacity. Similarly for Pittock Reservoir, flood capacity in the winter is about 80 mm of upstream runoff, and in the summer, about 55 mm.

Traditionally flood risk is at its greatest during the period when the reservoirs are empty (late winter and fall), and at a minimum during the months when they are full (summer). This may change, however, as most climate change models are predicting a shift to more annual precipitation, with less occurring in the winter that in the past and more in the summer.[103]

Both Wildwood and Pittock Reservoirs are subject to significant blue-green algae blooms due to phosphorous concentrations, and are considered eutrophic, Wildwood less so than Pittock. Furthermore, water quality and mass balance modelling of these two reservoirs, indicates that Wildwood likely acts as a phosphorous sink (absorbs phosphorous), while Pittock acts as a source (adds phosphorous) from its sediments[104].

Fanshawe Dam

Fanshawe Dam is another large structure in the upper Thames watershed. Located in northeast London near the outlet of the North Thames River, this structure has a large drainage area. Unlike Wildwood and Pittock Reservoirs, Fanshawe is not used to augment river flow to any great degree. It is primarily for flood control and provides the side benefits of recreation. Also of note is the small hydro electric

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[102] Ecologistics. 1981. A Feasibility Study of the Removal or Modification of the Thamesford and Hunt Dams.
[103] Environment Canada. 2004. Climate Change and Variability in Canada: Past, Present and Future.
[104] Freshwater Research. 2005. Reservoir Water Quality Treatment Study.

generator that was installed in 1984. It produces up to 500 kW, and generally operates for most of the year.

Operation guidelines for Fanshawe are shown in **Figure 2.3.3.6-3: Fanshawe Reservoir Operations Guidelines**. Fanshawe reservoir is normally kept at a level slightly above the sill of the dam, to maximize the amount of available flood storage. In the event of a flood, the suitable operations for the dam gate are determined and the water level is allowed to raise an appropriate amount, generally guided by the curve in the figure. At the end of the flood event, the water levels are then allowed to fall back to their normal range, usually within 0.5 m of the sill. Fanshawe Reservoir controls most (1440 km^2) of the North Thames River drainage area. When at its normal (low) water level, Fanshawe has the capacity to store approximately 25 mm of upstream runoff.

Similar to both Pittock and Wildwood reservoirs, Fanshawe Reservoir is subject to blue-green algae blooms given the right conditions in the summer months. Like Pittock Reservoir, mass balance and water quality modelling shows that Fanshawe also acts as a phosphorous source, contributing to water quality degradation downstream[104].

Mitchell and R.T. Orr Dams

The Mitchell Dam is located in the town of Mitchell on the North Thames River and the R.T. Orr Dam is in the City of Stratford on the Avon River. These are medium sized structures. Both are partially lowered during the winter and brought back to a higher holding level for the summer. These reservoirs have little storage capacity. Thus, they have no flood control benefit and do not augment stream flow. They are generally used to create artificial lakes in their communities, which are valued for minor recreational benefits (boating, fishing) and aesthetic value.

It is suspected that these reservoirs also contribute to phosphorous loading and associated water quality issues in the river downstream[104].

Indian/McGregor Creek Dam

The Indian/McGregor Creek Dam located in Chatham does not act as a true dam since flows from the upstream watershed normally pass through the structure. This dam is designed to protect the south part of the community from cresting flood waters in the Thames River. The dam is closed when flood level flows come down from the upper Thames watershed. The need to operate the structure only occurs occasionally (estimated to be once every 5 years) but is a critical component of flood control in the lower Thames watershed.

2.3.3.7 Tile Drainage in the Thames River Watershed

The Thames River watershed is largely agricultural in nature and over the years, large portions of the land in its rural areas have been tile drained in both a systematic and random fashion. Tile drainage allows farmers to get onto the land earlier in the spring than they would otherwise be able to, and to farmland that would otherwise be unusable.

Table 2.3.3.7-1: UTRCA Tile Drainage Areas and **Table 2.3.3.7-2: LTVCA Tile Drainage Areas** summarize the areas in both the Upper and Lower Thames River jurisdictions that are tile drained in terms of actual areas and the percentage of the watersheds. In both regions, nearly 50% of the total land area is tiled drained.

Table 2.3.3.7-1: UTRCA Tile Drainage Areas

Tile Drainage Type	Area (km^2)	% of total watershed area
Random	668.0	19.4%
Systematic	960.2	27.9%
Combined Total	1628.2	47.2%

Table 2.3.3.7-2: LTVCA Tile Drainage Areas

Tile Drainage Type	Area (km^2)	% of total watershed area
Random	354.6	10.9%
Systematic	1053.9	32.3%
Combined Total	1408.5	43.2%

Tile drainage has a large effect on the natural hydrological cycle. It intercepts infiltration which would otherwise find its way into groundwater aquifers and also changes the runoff-response characteristics of a watershed. Tile drainage has been used historically to drain wetlands that play an important role in the hydrologic cycle, both by attenuating flood flow peaks, and by augmenting summer low flows, by storing water.

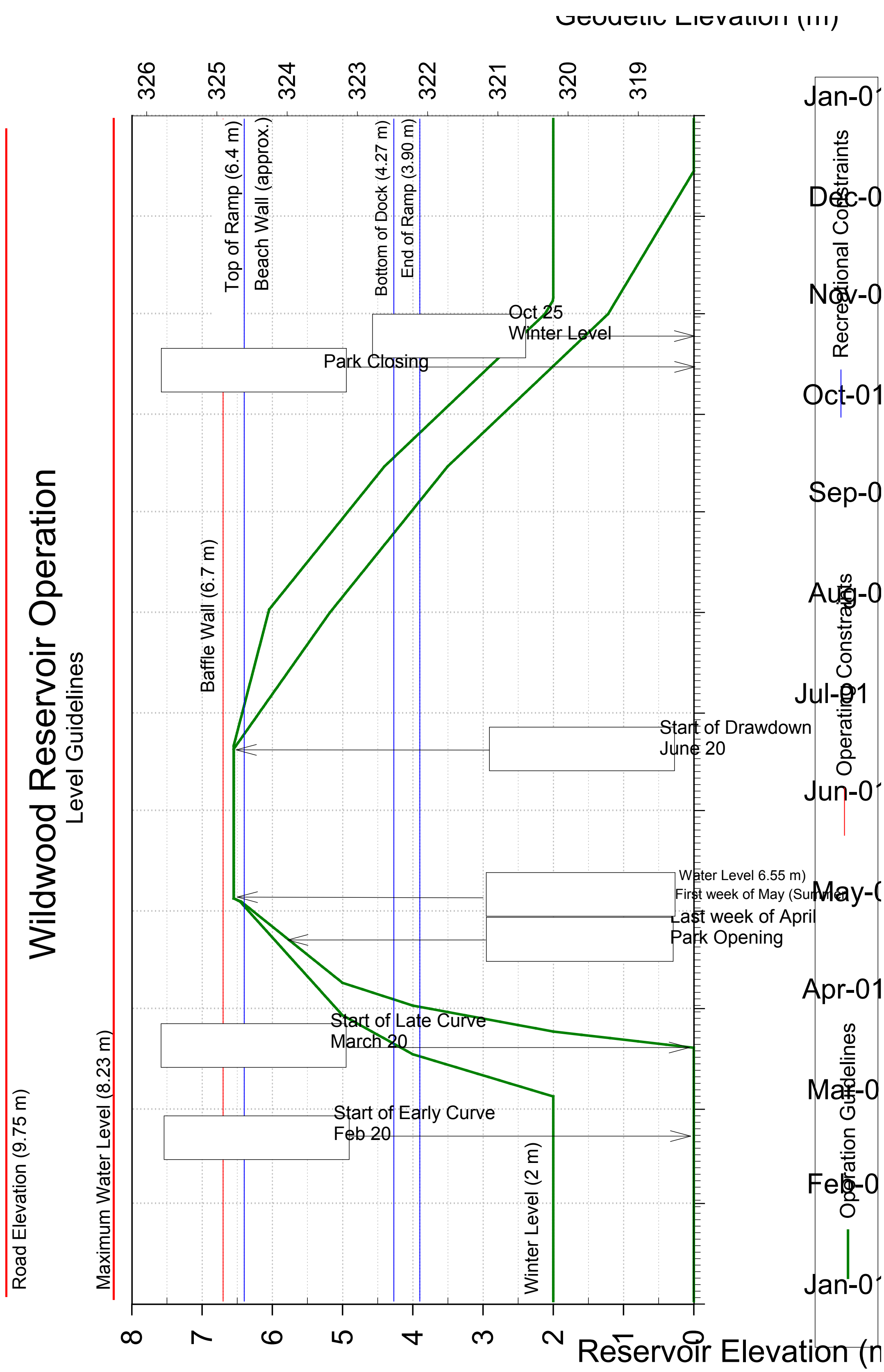

Figure 2.3.3.6-1: **Wildwood Reservoir Operation Guidelines**

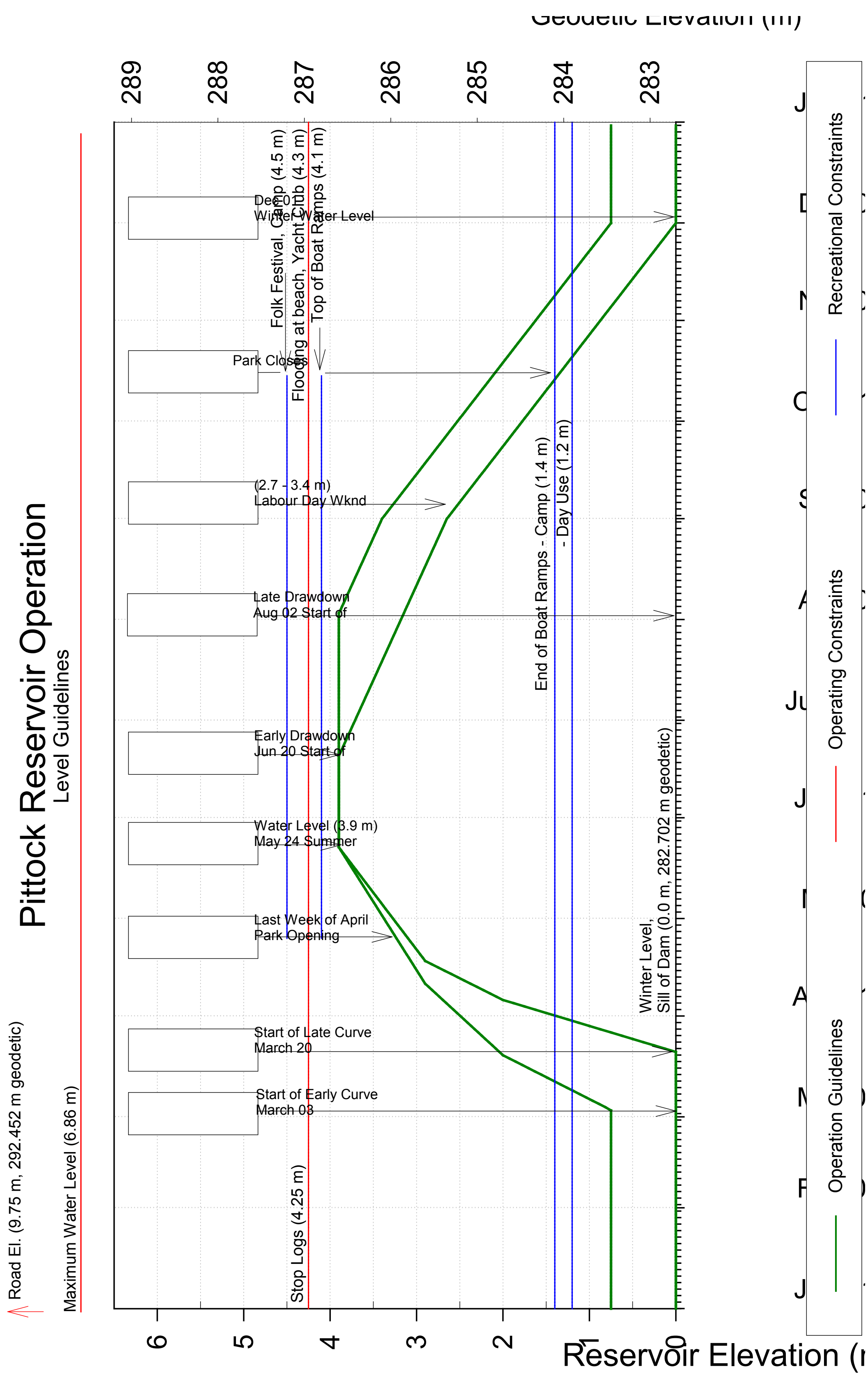

Figure 2.3.3.6-2: **Pittock Reservoir Operation Guidelines**

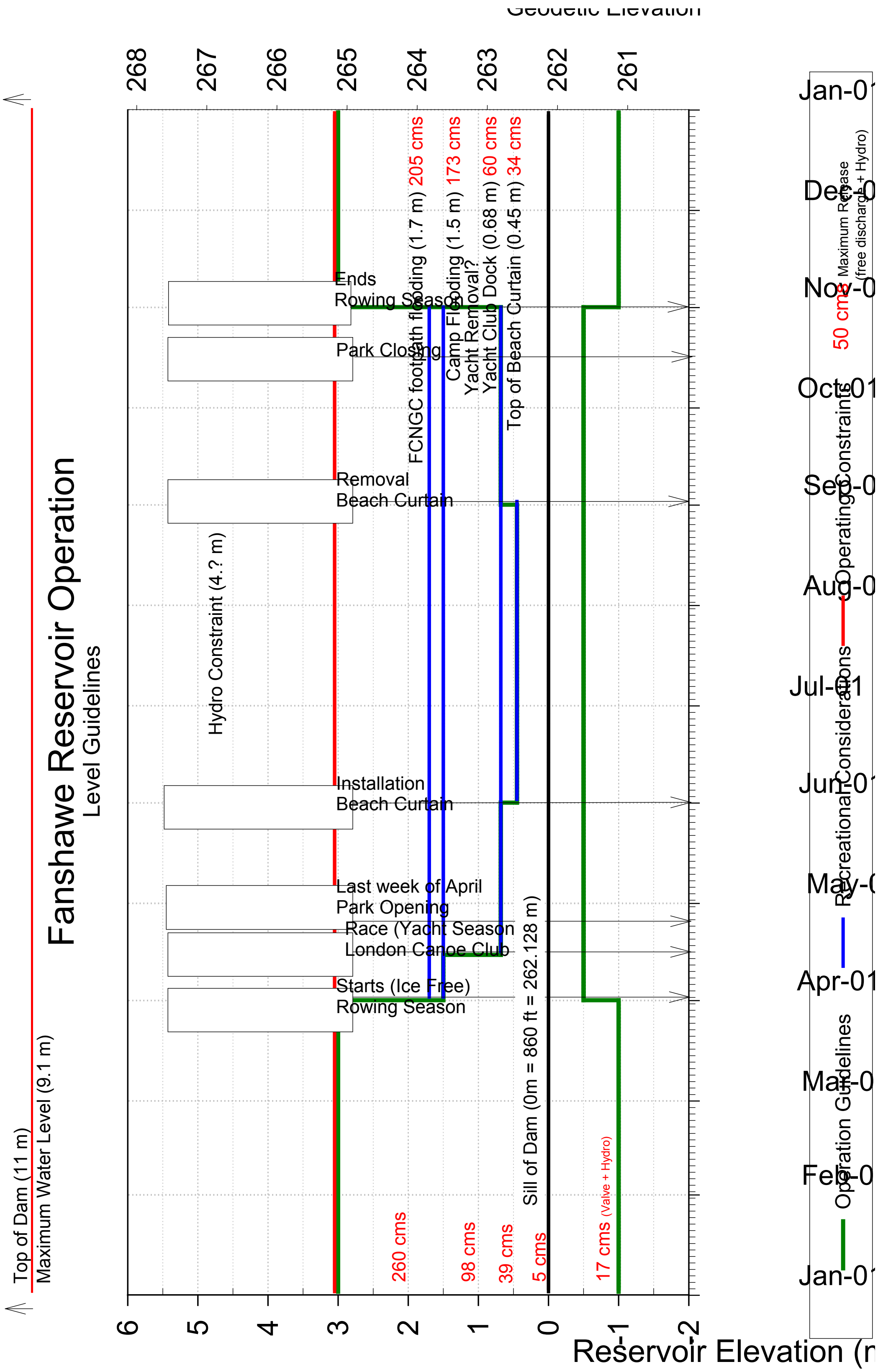

Figure 2.3.3.6-3: Fanshawe Reservoir Operations Guideline

2.4 Naturally Vegetated Areas

Terrestrial ecology involves a wide variety of habitats ranging from wetlands to upland forest. Discussion of the terrestrial ecology has been divided into three types of habitat: wetlands, riparian zone and woodlands/forest. The 'riparian zone' is the land adjacent to water bodies. It is usually saturated with groundwater or intermittently flooded with surface water, resulting in the presence of vegetation adapted to life in this transition area.

As shown in **Map 2: Major Subwatershed Delineations**, the Thames River drainage area makes up approximately 87% of the combined UTRCA and LTVCA watersheds. The area draining to Lake St. Clair is approximately 2% and the area draining to Lake Erie is about 11% of the combined watersheds. To assess environmental information, monitor environmental change and target rehabilitation work, the UTRCA and the LTVCA undertake monitoring and reporting by focusing on several small subwatersheds. This division allows closer examination of terrestrial and aquatic differences between smaller catchment areas.

In the UTRCA, there are 28 subwatersheds that are either major tributaries or sections of the main branches of the Thames River. In the LTVCA, there are 38 subwatersheds that are tributaries of the Thames River, sections of the main Thames River or individual tributaries and drainage areas that discharge directly to Lake Erie or Lake St. Clair.

2.4.1 Wetlands

Wetlands are natural habitats where land and water come together. They occur along lakes, rivers and streams and intermittently across the landscape in other areas where the water table is close to the surface. Wetlands provide critical habitat for many species of wildlife, especially amphibians. They also store and filter water, act as a carbon sink, and filter the air.

There are a variety of wetlands including:
- swamps dominated by trees and shrubs;
- marshes where emergent plants such as cattails, rushes and sedges dominate;
- bogs characterized by substantial peat accumulation, high water tables and acidic loving vegetation; and
- fens, which are similar to bogs but support marsh-like vegetation including sedges and wildflowers.

Wetlands in Southern Ontario have been listed as one of the most threatened ecosystems in Canada. Only recently have the profound implications of these losses become apparent, as wetland loss has been connected with, for example, increased flooding, poor water quality, desertification and declines in fish and wildlife.[105]

Environment Canada (2004)[106] recommends over 10% of each major watershed and 6% of subwatersheds be in wetland habitat. It is also recommended that wetlands be restored to the original percentage in the watershed if possible.

Upper Thames River Conservation Authority

The original amount of wetland cover is unknown but some attempts are being made to estimate this figure through soils mapping. The vast majority of the remaining wetlands in the UTRCA are classified as

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[105] Department of Energy and Resources Management. 1966. Lower Thames Valley Conservation Report Summary.
[106] Environment Canada. 2004. How Much Habitat is Enough? A Framework for Guiding Habitat Rehabilitation in Great Lakes Areas of Concern. 2nd ed.

deciduous swamps or mixed deciduous-coniferous swamps that are dominated by trees and shrubs such as silver maple, ash, willow, dogwood and cedar. Other wetland types such as marsh, bog and fen, are relatively rare here although there are no exact area measurements by wetland type. Many swamps contain small pockets of marsh vegetation where emergent plants such as cattails, rushes and sedges dominate, but there are no large marsh sites. Bogs and fens are also very rare. There are a couple of kettle bogs in the London area.

Map 23a: Percent Wetland Cover (UTRCA) shows the location of the 81 evaluated wetlands within the watershed. The wetlands were evaluated under *Ontario Wetland Evaluation System.*[107] The total area of wetland cover (evaluated wetlands) is about 57 sq. km and is less than 2% of the conservation authority's watershed area. Since most wetlands are swamps, they are also considered to be woodlands and represent about 14% of the woodland cover in the watershed as summarized in **Table 2.4.1-1: UTRCA Wetland & Woodland Cover**.

Table 2.4.1-1: UTRCA Wetland & Woodland Cover

Upper Thames River CA	Area (sq km)	% of Watershed	% of Woodland
Watershed	3447	--	--
Woodland Cover	413	12.0	--
Wetland Cover	57	1.7	14

The UTRCA is currently locating other wetlands that have not been previously identified/evaluated using several mapping layers and ortho-imagery. Small pockets of swamp vegetation probably exist in numerous woodlots throughout the watershed.

Map 23a: Percent Wetland Cover (UTRCA) shows the percent wetland cover for each subwatershed in the UTRCA. The majority of the subwatersheds have low to very low wetland cover remaining. Overall, wetland cover averages 1.7% with a high of 9.7%. The subwatersheds with the highest wetland cover are Black Creek (north of Stratford), Dorchester (east of London) and Komoka (west of London). All of these areas contain large wetland complexes.

Lower Thames Valley Conservation Authority

Only two types of wetlands, treed swamps and marshes, have been identified within the LTVCA's boundaries. The largest percentage of treed swamps is located in West Elgin. Marsh habitats are located in the eastern (Chatham-Kent) portion of the region on the north shore of Rondeau Bay, in Rondeau Provincial Park, in isolated marshes located near the mouth of the Thames River, and along the eastern shore of Lake St. Clair including the notable St. Clair National Wildlife Area.

Historically, wetlands covered a major portion of the lower Thames River watershed near the river's outlet into Lake St. Clair. These wetlands covered large parts of the communities of Dover, Raleigh and Tilbury East, in Chatham-Kent; and lands in the Town of Lakeshore. These lands formed the flood plain for the river during spring flood events and marsh habitat was prevalent as a result of the seasonal flooding. Wetlands were also located inland along the river and along the eastern shoreline of Lake St. Clair in the community of Dover.

The predominant soil type is Brookston clay or clay loam. This soil is poorly drained, fairly high in organic matter and with a level surface. Because climate favours this part of Ontario for growing certain

[107] OMNR. Ontario Wetland Evaluation System, Southern Manual. 2nd (1985) and 3rd (March 1993) editions.

cash crops, the poor natural drainage can be overcome profitably, and extensive artificial drainage has been installed. These artificial drainage areas have been extended to include large areas of land that were historically below the static level of Lake St. Clair. There is an extensive system of tile drains, drainage ditches, dykes and pumping systems along the Thames River and other major drainage areas such as Baptiste Creek and Jeannette's Creek. Of course, the construction of these systems has resulted in the loss of large areas of marsh type wetlands[108].

Within the LTVCA watershed, a total of 50 known wetlands have been identified, 26 within the Municipality of Chatham-Kent, 16 in Elgin County, two in Essex County and six in Middlesex County. Elgin and Middlesex Counties have a majority of upland treed swamps, while Chatham-Kent and Essex have marsh habitats due to the low lying nature of the lands adjacent to Lakes Erie and St. Clair. **Map 23b: Percent Wetland Cover (LTVCA)** provides an overview of the wetlands.

Ever since the MNR last evaluated wetlands, these areas have been altered (reduced) significantly. In some cases, wetlands have been reduced to less than half their original size between the times of their evaluation in comparison to the latest aerial mapping. One can speculate that this has come about due to the low water level conditions that have prevailed in recent years and the lack of a tree cutting bylaw in some municipalities.

Wetlands comprise 49.7 sq. km, or just 1.5% of the LTVCA watershed area as shown in **Table 2.4.1-2: Distribution of Wetlands and Woodlands within the LTVCA**. This percentage is well below the 10% for major watersheds and 6% for subwatersheds recommended by Environment Canada. Unfortunately, due to the flat, arable nature of the area and the longer growing season, the retirement of agricultural lands back into wetlands is unlikely to occur and it is unlikely that the watershed will ever reach Environment Canada's recommended percentages.

Table 2.4.1-2: Distribution of Wetlands and Woodlands within the LTVCA

	Area (sq km)	Wetland (sq km)	Wetland (%)	Woodland (sq km)	Woodland (%)
Thames River Watershed	2,280	11.6	0.5	279.8	12.3
Lake St. Clair Watershed	174	12.6	7.3	1.5	0.9
Lake Erie Watershed	820	25.5	3.1	145.0	17.7
Entire LTVCA Watershed	3,274	49.7	1.5	426.3	13

The highest percentage of wetlands within the watershed is along the eastern shoreline of Lake St. Clair and several complexes in the community of Tilbury East near the outlet of the Thames River into Lake St. Clair. In the Lake Erie watershed, the Rondeau Bay wetland in the community of Harwich and Brock Creek in West Elgin are the significant wetlands. Other than these large blocks of wetlands, the remaining wetlands are small isolated pockets scattered throughout the watershed.

From aerial mapping that was undertaken in 2001 and 2003, it is apparent that there are other treed wetlands scattered across the LTVCA watershed that have not yet been identified and evaluated by the Ministry of Natural Resources. Currently, there are no means available to evaluate these potential wetlands.

[108] North American Wetlands Conservation Council (Canada). 1999. Wetlands and Government, Policy and Legislation for Wetland Conservation in Canada. Issues Paper No. 1999 – 1.

2.4.2 Riparian Zone

The area of land adjacent to streams is often called the riparian zone or buffer zone. The riparian zone has been defined as "areas adjacent to a stream that are saturated by groundwater or intermittently inundated by surface water at a frequency and duration sufficient to support the prevalence of vegetation typically adapted for life in saturated soil"[109].

Natural or permanent vegetation adjacent to streams and rivers improves conditions for aquatic health. These adjacent lands provide shade and cool the water; vegetative matter to the watercourse and surrounding soils; a diverse array of habitat types both aquatic and terrestrial; an erosion buffer from the streams seasonal floods; and many other benefits for water quality and quantity.

Environment Canada (2004)[106] recommends that streams have at least a 30 metre wide naturally vegetated area on both sides. It also recommends that 75% of stream length be naturally vegetated.

Upper Thames River Conservation Authority

To estimate riparian cover along every watercourse in the UTRCA subwatersheds, GIS technology was used (digital NTS maps at 1:50,000 scale). This methodology is limited to measuring woodland cover in the riparian zone since non-woodland vegetation such as grassland is not discernable on the maps.

A number of assumptions had to be made in order to calculate the riparian cover since the watercourses were represented as thin blue lines on the available mapping. Adjustments had to be made to account for the actual width of the watercourse. For small (first to third order) streams, the width of the watercourse was assumed to be 10 metres and the riparian buffer boundary was assumed to be 35 metres from the watercourse (blue line) marked on the map. For larger (fourth order and higher) streams, the width of the watercourse was assumed to be 20 metres and the riparian buffer boundary was placed 40 metres from the watercourse (blue line). Using these assumptions, the amount of woodland cover was measured within these buffer zones and a percentage calculated for each subwatershed.

Map 24: Percent Riparian Woodland Cover (UTRCA) shows the estimated cover for each subwatershed. The values ranged from a low of 6.1% to a high of 31.8% with an overall average of 21.14%. The lowest riparian woodland/forest cover occurs in the headwaters area of the North Branch of the Thames River in rural Perth County (North Mitchell and Whirl Creek). The highest cover is in the Dorchester watershed (east of London) and the River Bend and Oxbow Creek watersheds west of London.

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

New mapping products such as satellite and infra-red imagery and Southern Ontario Land Resources Information System (SOLRIS) may allow riparian cover to be calculated more finely in the future.

Lower Thames Valley Conservation Authority

Within the LTVCA's jurisdiction, both urban and rural land uses have resulted in a loss of a vegetated riparian zone of forested, prairie habitat and wetland land forms. In some areas of the region, streams have been diverted, straightened and vegetation removed from the entire length and width of the channel.

In rural areas, this alteration to the riparian zone is in response to a need to increase farmland capacity and a necessity for quick drainage after a seasonal flood or storm event. In urban areas, development tends to

[109] OMNR. June 1994. Natural Channel Systems, Approach to Management and Design.

remove natural vegetation from the system as watercourses become covered to conserve space. Lands adjacent to a stream are replaced with paved surfaces or manicured lawns with sparse woody plantings. The resulting monoculture of vegetative species limits the quantity and quality of wildlife habitat opportunities along these stretches of altered waterways. Streams that remain in an urban setting are also affected by rapid runoff from hardened urban surfaces and the urban propensity to trim vegetation along watercourses.

In the eastern part of the LTVCA area, there are many incised watercourses that cut through the higher elevation surrounding lands. These result in extensive riparian cover as these ravines are unsuited for urban or rural development as shown in **Figure 2.4.2-1: LTVCA - Extensive Riparian Buffers around Watercourses**. Thus, Elgin and Middlesex Counties have more stream corridor vegetation than Essex and Chatham-Kent. Also, both Elgin and Middlesex Counties have tree cutting bylaws, while Essex and Chatham-Kent have no means of woodlot protection.

Figure 2.4.2-1: LTVCA - Extensive Riparian Buffers around Watercourses

From approximately Thamesville west to the mouth of the Thames River at Lake St. Clair, the drop in gradient is minimal as there is almost no slope. This low gradient has resulted in minimal buffers adjacent to stream systems as the land adjacent to the watercourses is more accessible. Channels that used to meander or form wetland pockets have been straightened to allow for straighter row-cropping and low areas drained and filled in for urban development, as shown in **Figure 2.4.2-2: LTVCA - Lack of Riparian Zones along Waterways**.

Figure 2.4.2-2: LTVCA - Lack of Riparian Zones along Waterways

From historic records, it is known that very little to no riparian forest cover was present downstream of the City of Chatham. From Chapter 1 of Hamil's "The Valley of the Lower Thames,"[110] we have this quote:

"The great marshes and plains of Dover and Tilbury spread eastward along the banks of the river for six miles from Lake St. Clair. Then the trees began, but on the south, the plains continued almost to the Forks at Chatham, at a distance of less than a mile from the stream, and with an average width of three to four miles. On the north, the prairies extended along the shore of Lake St. Clair and the Chenal Ecarte to the River Sydenham and for several miles inland. The grasses there grew rank and luxuriant to a height of four or five feet … The remainder of the Lower Thames area was covered with a dense forest, inter-mixed with bogs and swamps, and open beaver meadows."

Recovery of any percentage of riparian cover in the western portion of the LTVCA watershed, especially for the lower Thames River, will not likely occur. This is due to the current use of the lands for high value agricultural crops and the urban and rural pressures affecting these lands. However, stream corridors are seen as suitable locations for replanting efforts through good conservation methods.

2.4.3 Woodlands/Forest

Forests provide numerous functions including protecting and building the soil, giving off oxygen and absorbing air pollutants, moderating local climate, protecting groundwater and providing habitat for wildlife. Environment Canada (2004)[106] recommends at least 30% of a given watershed be in forest cover, primarily to support wildlife species.

The Thames River and Region watershed lies within the transition zone of the Carolinian Life Zone or Southern Mixed Deciduous Forest to the south and the Lower Great Lakes – St. Lawrence Forest to the north. The diversity of plant species is extremely high. Common forest trees include sugar maple, American beech, red oak, basswood and white ash. Less common, southerly species include black walnut,

[110] Department of Energy and Resources Management. 1966. Lower Thames Valley Conservation Report Summary.

butternut, black cherry and sycamore. Conifers make up only a small percent of the tree diversity although many small conifer plantations have been planted over the last 50 to 80 years.

Over the past century, several diseases and pests introduced by man have had a significant impact on the local tree species. The American Chestnut was destroyed by chestnut blight, caused by an Asian bark fungus accidentally introduced to America on imported Asiatic chestnut trees. The Blight was probably imported into North America from Asia in the early 1900s. Similarly, the American Elm has been seriously affected by an introduced fungal disease, Dutch Elm Disease, with heavy mortality. The disease was accidentally introduced into North America in 1931, in shipments of logs from the Netherlands destined for use as veneer.

More recently, the Emerald Ash Borer,[111] which is native to China and eastern Asia, has left a path of destruction in Essex County in southwestern Ontario (as well as southeastern Michigan, northern Ohio and Indiana). It has been found in Chatham-Kent and Elgin County. Its significance for woodlands in the region is not yet known but ash trees form an important part of the local tree cover in many woodlots.

Upper Thames River Conservation Authority

Hardwood forests covered the majority of the upper Thames River watershed prior to European settlement[112] with smaller pockets of grassland and savanna habitat. Other than the prairie habitat and marsh complexes located in the lower reaches of the watershed, much of the lower Thames River watershed also consisted of dense hardwood forests at one time. Today, the woodland/forest cover is highly fragmented, existing as small woodlots separated by agricultural fields, urban development and other land uses.

The overall percentage of woodland/forest cover in the upper Thames watershed is approximately 12% and the individual subwatersheds have values ranging from 5 to 21%. These figures were measured using GIS technology and 1994 digital NTS maps at a scale of 1:50,000. Woodlots under 1 ha in size are not discernible on the NTS maps and were not included in the analysis.

Map 25a: Percent Woodland Cover (UTRCA) illustrates the distribution of woodlots across the upper Thames watersheds. The subwatersheds are colour-coded according to the range of percent woodland/forest cover they possess. The percentage ranges were taken from *Watershed Reporting: Improving Public Access to Information* (Conservation Ontario et al. 2003)[113].

The lowest amount of woodland/forest cover (4.9%) is in the North Mitchell watershed, which is the headwaters of the North Branch of the Thames in Perth County. A large number of subwatersheds also have relatively low woodland/forest cover with less than 12%. These are found throughout the upper Thames in both rural and urban subwatersheds.

The subwatershed with the highest amount of woodland/forest cover is Dorchester, owing to the presence of the large Dorchester Swamp and North Dorchester Swamp Complexes. Komoka and River Bend, two small watersheds west of London, also have above average woodland/forest cover levels. The largest woodland/forest tract is Ellice Swamp (1014 ha), located north of Stratford.

Over 70% of the woodlots in the upper Thames watershed are less than 10 hectares. **Table 2.4.3-1: UTRCA Woodlot Size** provides a summary of woodlots in the upper Thames. Due to the practice of clearing the acreage closest to the concession road for farming, many woodlots represent the 'back 40' of farms and are distributed in a linear fashion parallel to the roads.

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[111] Canadian Food Inspection Agency website: Emerald Ash Borer, www.inspection.gc.ca

[112] UTRCA. 2001. The Upper Thames River Watershed Report Cards, 2001.

[113] Conservation Ontario, Rideau Valley Conservation Authority and Upper Thames River Conservation Authority. 2003. Watershed Reporting: Improving Public Access to Information. Part of the "Innovations In Watershed Stewardship" series.

Table 2.4.3-1: UTRCA Woodlot Size

Woodlot Size		% of Total Number of Woodlots
Very Small	< 4h	49.8
Small	4 – 10 ha	21.8
Moderate	10 – 30 ha	17.4
Large	30 – 40 ha	2.3
Very Large	> 40 ha	8.8

The overall woodland/forest cover in the upper Thames falls short of the Environment Canada recommendation that at least 30% of a given watershed be in forest.

Lower Thames Valley Conservation Authority

Other than the prairie habitat and marsh complexes located in the lower reaches of the watershed, the majority of the lower Thames River valley consisted of dense hardwood forests at one time. Species typically recorded during early surveying efforts included maple, beech, red and white oak, elm, black ash, white ash, walnut, cherry, basswood, willow, hickory, butternut, birch, sycamore, tulip and sweet chestnut, to name a few. Tamarack swamps were noted throughout the watershed; this species is the only conifer observed[110] in the survey records. It is interesting to note that pine was not a major forest species in the area at the time of the survey. Although some pockets of pine were located on Pointe aux Pins at Rondeau Bay and near Delaware, these were quickly cut down and shipped to Detroit and beyond.

The LTVCA watershed lies entirely within what is known as the Carolinian life zone. Forests with unusually named trees – Sassafras, Tulip-tree, Pawpaw, Kentucky Coffee-tree, Pignut Hickory, and Cucumber Magnolia, among others – give the region a distinctly southern character, while pockets of tallgrass prairie and oak savanna support species more typically associated with grasslands to the south and west.[114]

Today, wooded/forest cover ranges from 18% in Elgin County, 12% in Middlesex, and 7% in Essex to less than 3% in Chatham-Kent. Even though the percentage of cover is low, especially in the two most southwestern counties of Ontario, this portion of Ontario has the most diverse forest species of all of Canada.

In the LTVCA watershed, there is a dramatic difference between the counties of Elgin and Middlesex in the east to Essex and Chatham-Kent in the west. Elgin and Middlesex both have tree cutting bylaws, while Essex and Chatham-Kent have no means of woodlot protection.

There are approximately 426 sq. km of woodland/forest cover within the entire LTVCA watershed, equating to 13% of the total watershed. This percentage is well below the 30% coverage that is recommended by Environment Canada. **Table 2.4.3-2: LTVCA Percentage of Woodland/Forest Cover by Subwatershed** indicates the number of subwatersheds by their percentage of woodland/forest cover.

[114] Johnson, Lorraine. 2005. Carolinian Canada Signature Sites. Carolinian Canada Coalition.

Table 2.4.3-2: LTVCA Percentage of Woodland/Forest Cover by Subwatershed

Forest Cover (%)	No. of Subwatersheds
0 – 10%	16
11 – 20%	10
21 – 30%	7
31 – 40%	4
41 – 50%	1

As shown in the table, the majority of subwatersheds has less than 10% cover and only one area has over 40% woodland/forest cover. **Map 25b: Percent Woodland Cover (LTVCA)** illustrates the distribution of woodlots across the watershed. However, several subwatersheds not only meet the 30% recommendation, but well exceed it as shown in **Table 2.4.3-3: LTVCA Subwatersheds with greater than 30% Woodland/Forest Cover**.

Table 2.4.3-3: LTVCA Subwatersheds with greater than 30% Woodland/Forest Cover

Subwatershed	Forest Cover (%)	Municipality
Brock Creek	49.5	West Elgin
Skunk's Misery area	39.7	Southwest Middlesex
Hookaway Drain & watershed	38.1	West Elgin
Millstream & watershed	34.6	Strathroy-Caradoc
Clear Creek	32.5	Chatham-Kent
Ashton Drain	30.0	Chatham-Kent

The north shore of Lake Erie within the Municipality of West Elgin has the highest percentage of woodland/forest cover of the entire watershed. The majority of these woodlots are associated with Provincially Significant Wetlands. In general it seems that tree cutting bylaws play a significant role in maintaining the forest cover in Elgin and Middlesex Counties.

2.5 Aquatic Ecology

In the Thames Watershed & Region, the wide variety of habitats, favourable climate, nutrient-rich waters, and connection with the Great Lakes result in a particularly diverse aquatic community. There are records of approximately 94 species of fish, 34 species of freshwater mussels, and 30 species of reptiles and amphibians. Twenty-seven of these aquatic species have been federally designated as Species At Risk (SAR).

The species living within the aquatic environment are the first to feel the effects of an adverse impact such as impaired water quality. In many cases, aquatic species are monitored to measure the extent of contamination and the state of the water conditions. It is important to have baseline surveys and consistent monitoring programs in place to ensure accurate reporting of current conditions and insight into changing conditions or trends.

Aquatic ecosystems include watercourses (streams, rivers, and drains), water bodies (lakes, reservoirs, and ponds), and wetlands. These systems provide food for sustenance, cover for protection, and habitat for reproduction. They provide habitat for all life stages of aquatic organisms and for some specific life stages of semi-aquatic species. For some species, they may also provide corridors for movement.

Many aquatic species are generalists and can be found in a variety of habitats while others are specialists that are only found in specific habitats. An aquatic community of plants, fish, and invertebrates can provide an excellent indication of ecosystem health. More specifically, benthic macroinvertebrates (BMI) associated with the bottom of a water body have well known tolerances for water and habitat quality Thus, benthic macroinvertebrates[115] can provide an indication of water quality impairment or habitat disruption[116]. Indicator species aid in identifying areas in need of protection and targeting those in need of restoration or rehabilitation.

An aquatic ecosystem is a function of both living and non-living components, as well as the natural and unnatural stresses placed upon them. The landscape (soils, valleys, etc.) forms the non-living portion of the aquatic ecosystem, and shapes the potential habitat conditions for the living portion of the aquatic ecosystem. The quality and the quantity of habitat available determine the type of aquatic community that will occupy a given aquatic ecosystem. The living component of the aquatic ecosystem is comprised of the organisms living in the aquatic portion and those that impact the aquatic habitat. Each component plays a vital role in the aquatic ecosystem.

Habitat and habitat conditions are influenced by the characteristics of a stream including the riparian zone, flood plain, stream morphology and catchment area. A complex combination of these factors determines the type of aquatic community and the species that will be found at different locations. In a stream, factors such as substrate type, channel gradient, depth, velocity of flow, and the presence of riffles and pools influence the aquatic community.

A substrate (bottom) that has a variety of particle sizes and is not dominated by one size class (i.e. silt) will provide interstitial spaces for benthic macroinvertebrates to live and move about. A clean, oxygenated substrate greatly increases the biological activity in a given stream and enhances water exchange between surface and subsurface (hyporheic) zones. The hyporheic zone is the biologically active area below the surface of the streambed. This zone can extend a considerable distance downward and laterally beneath the flood plain. A functional hyporheic zone will have extensive BMI and bacterial activity that is essential for nutrient uptake and cycling in an aquatic ecosystem.[117] It allows the vertical migration necessary for many sensitive BMI species to complete their life cycles and provides essential habitat for many fish species to feed and reproduce.

The land adjacent to the stream (riparian zone or the flood plain) is home to the vegetation that supplies shade, acts as a food source in the form of leaves and terrestrial insects, filters pollutants and sediment, and provides in-stream habitat with woody debris. Other flood plain functions include sediment and nutrient exchange, floodwater storage, groundwater recharge and discharge, and flow augmentation.

The catchment (area draining into) of a given stream largely determines its water quality and quantity. Flow is influenced by the amount of forest cover, stream channelization, land drainage, irrigation, and impoundments. Land use influences water quality variables such as temperatures, chemical composition, pollutants, nutrients, and sediment loads. These are particularly evident where agricultural best management practices (BMPs) have reduced agricultural land use impacts.

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[115] Hilsenhoff, W.L. 1998. Rapid field assessment of organic pollution with a family-level biotic Index. In Journal of the North American Benthological Society 7: 65-68.
[116] Cummins, K.W. 1992. Invertebrates. In Calow, P. and G.E. Petts (Ed.). The Rivers Handbook Volume 1, p234-250.
[117] Bolton, S., and B. Shellburg. 2001. Ecological issues in flood plains and riparian corridors. Center for Streamside Studies.

A balanced natural stream will have adequate stream power to ensure that the amount of sediment entering will also exit a given stream reach. Where stream power exceeds channel characteristics, excessive erosion results. The other extreme causes excessive silt deposition. Siltation destroys stream morphology (the presence of riffles and pools), reduces BMI habitat, and limits the exchange of water between surface and subsurface zones. The presence of riffles and pools provide the varieties of habitat essential for the survival of many aquatic organisms. Stream morphology also facilitates the movement of water between the surface and subsurface areas and influences habitat through its impact on sediment transport.

The Thames River is situated in a highly developed part of southern Ontario. The aquatic community faces many pressures from urban and rural land uses and human activities. As discussed in **Section 2.3.3.1: Watercourse Classification**, most of the watercourses have been greatly altered by human influences. On larger watercourses, many of the influences accrue from urban development, including channel alteration, bank hardening, storm water runoff, and sewage effluent input. Rural influences often involve smaller watercourses where habitat changes and alterations such as drains and channelization are aimed at improving agricultural operations. In general, species that prefer clear, fast flowing water are declining[118] while those favouring turbid (less clear) conditions are increasing in abundance[119].

Channelization of streams or watercourses allows for the quick removal of rain and snowmelt. Channelization results in enlarged channels that are designed to contain extreme flows but are not designed for the normal flows that are experienced at other times of the year. In an urban setting, channel alteration, loss of riparian cover and bank hardening all impact the aquatic community. Enlarged channels exceed the stream power of normal flows and, when coupled with silt eroded from adjacent agricultural fields, produce heavily silted channels that require regular maintenance to recover channel capacity.[120] A baseflow (normal flow) channel is often formed within the oversized channel and is evidence that the stream is attempting to restore its function naturally. Unfortunately, these channels are still presumed to require regular maintenance to restore the capacity.

A large percentage of intermittent or ephemeral systems in both the UTRCA and LTVCA watersheds are drains. Intermittent streams are generally thought to be unproductive or nuisance troughs that may convey water for part of the year. In recent years, many of these intermittent watercourses have been converted to closed systems. The trend to closed drain systems has altered the hydrograph, hydrologic regime and fluvial dynamics of the receiving watercourses and has led to an increase in erosion in downstream watercourses.

Intermittent systems actually provide a significant function to the watershed. They provide fish habitat when wet and, in many cases, significant spawning areas during spring flooding. Some drains have pooled refuge areas (as evident in the upper Thames watershed) and support habitat generalist species. These drains still support aquatic communities that primarily consist of tolerant BMI and fish species. These are particularly evident where agricultural best management practices (BMPs) have reduced agricultural impacts.

Much of the headwaters, particularly intermittent drains, have remnant pools that provide refuge areas for a variety of the more tolerant or hardy aquatic species. However, changes such as cobble being removed

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[118] Cudmore, B., C.A. MacKinnon and S.E. Madzia. 2004. Aquatic species at risk in the Thames River watershed, Ontario. In Can. MS Rpt. Fish. Aquat. Sci. 2707: v + 123 p. www.thamesriver.on.ca/Species_at_Risk/manuscript_report/Thames_Species_at_Risk_Msrpt_Report.pdf

[119] Holm, E. and E.J. Crossman. 1986. Report on the search for an Ontario population of *H. x-punctata* and on a search for the species. Royal Ontario Museum Report to Ontario Ministry of Natural Resources.

[120] Landwehr, K., and B. Rhoads. 2003. Depositional Response of a Headwater Stream to Channelization. In River Research Applications, 19:77-100.

from the channels and the lack of pool riffles result in aquatic communities limited to hardy warm water species.

In a few isolated headwater locations in the Thames, conditions allow more sensitive cold water communities to persist. The contributing factors include the presence of groundwater discharge, riparian vegetation and shading, headwater wetlands, and usually an undisturbed natural channel (although several drains support cold water communities). Sensitive BMI species, such as stoneflies and some caddisflies, are indicators of a high quality aquatic habitat or ecosystem. Cold water fish species, such as trout and sculpin, that require well-oxygenated cool or cold flows year-round, can be found in these headwater streams.

Moving downstream from the headwaters to medium-sized Thames tributaries, overall aquatic habitat generally improves as the stream size increases. Most medium-sized streams have natural channels or, if channelized, their stream power is often more in balance with the channel characteristics. Riffle/pool sequences have redeveloped with a firm (cobble/gravel/sand) substrate similar to that found in most natural watercourses. Most have an evident, well-defined flood plain with varying levels of disruption. A few have relatively undisturbed riparian vegetation and others are pastured or are idle pasture. The areas with idle pasture are now undergoing the slow process of natural succession or regeneration.

Influences on these streams are silt, nutrient and pollutant inputs, both from neighbouring land use and from upstream sources. However, the improved habitat allows development of a complex and productive aquatic community with flood plain and hyporheic zone interactions. This enhances nutrient utilization and cycling. A diverse aquatic community is generally present, often including many mid-tolerant and the occasional sensitive BMI. In addition, most streams support a diverse fish community that may include top-level predators and Species at Risk (SAR). A few streams that have significant groundwater inputs support native brook trout or introduced brown trout populations.

Further downstream, the larger tributaries and the three main Thames branches generally support aquatic communities of increased complexity and stability. For the most part natural stream morphology and undisturbed flood plain is evident. The less impacted sections include much of the north Thames, portions of the middle and south Thames, and a few larger tributaries. These support very diverse and productive aquatic communities. The communities of BMI are largely comprised of mid-tolerant and a few sensitive species. Top-level predators and species that require relatively clear flows and clean substrates to survive are well represented within the fish community. These river and stream reaches also provide habitat for a large proportion of the surviving fish, reptile and freshwater mussel SAR found in the Thames. However, many of these larger watercourses are influenced by urban development, including channel alteration, bank hardening, stormwater runoff, and sewage effluent input.

From London downstream to the Delaware area, the flow and habitat conditions for the river are much like the upper branches but at a larger scale.

From Delaware to the Thamesville area and on to near Chatham, the main Thames is characterized by somewhat turbid and very stable flows. Both the flow augmentation from flood control structures on the main branches of the Thames, and the large input of Great Lakes water in the form of treated sewage effluent by the City of London, contribute to the consistency of these. Much of this stretch is fairly slow flowing, relatively deep and with soft substrates dominated by sand and silt. Occasional shallower stretches with accelerated flows and coarser substrates ranging from gravel to cobble are critical areas for the survival of significant freshwater mussel populations. These areas are also important fish feeding and spawning areas. This portion of the river supported a large but declining run of walleye and was once home for all six endangered freshwater mussel species recorded in the Thames. It is also the location of the only two Canadian records for the extirpated gravel chub. Species At Risk that are still present in this area include the endangered northern madtom and the threatened eastern sand darter.

The last stretch of the Thames flowing from Chatham to Lake St. Clair is characterized by somewhat lake-like conditions. It is deep and slow flowing with a very soft sand and silt substrate. Much of the channel is constrained between earthen dykes and is influenced by levels in Lake St. Clair. Ecologically, it supports a fish community adapted to slow flowing, turbid waters. It is an important travel conduit between Lake St. Clair and upstream spawning habitat and some migratory aquatic species travel to the Thames from Lake Huron and Lake Erie.

The LTVCA watershed also includes areas that drain to either Lake St. Clair or Lake Erie. Much of the same discussion regarding aquatic ecology holds for these areas as well. The presence of works constructed under the Drainage Act is more a function of agricultural cropping practices, soil type and political economy than a function of the watershed in which the works are located. Therefore, many streams in the Lake Erie and Lake St. Clair watersheds have seen similar modifications to enhance farm drainage, sometimes to the detriment of fish habitat.

The area draining to Lake St. Clair is low lying marshy land that has an extensive network of drains that are pumped. The area draining directly into Lake Erie is somewhat different in that many of the streams leading into it are often in deeply incised valleys that prohibit economic modifications, which allows some Lake Erie species better access to them.

The following sections provide information on aquatic monitoring programs and attempt to identify areas where data gaps exist or further information is required.

2.5.1 Fish

Fish have adapted to various habitat conditions and food preferences. They play a crucial role in the aquatic food chain, providing food for other fish and wildlife, as well as for humans. Some relatively sedentary species of fish stay in one location while others travel kilometres from Lake Huron, Lake St. Clair, and Lake Erie into the Thames River.

Typically, diverse fish communities signify relatively healthy aquatic ecosystems. Fish are excellent indicators of ecosystem health due to their specific habitat requirements, varying water quality tolerances, and ability to accumulate substances.

The Thames River and its tributaries support one of the most diverse fish communities in Canada. Records exist for approximately 94 fish species in the watershed, which represents more than half of all of Ontario's 165 species. Currently, 13 of the 94 species found throughout the Thames River watershed are considered Species At Risk. **Table 2.5.1-1: Thames River Fish Species Summary** lists the species recorded in the Thames River Watershed.

There have been 39 fish species found in the Lake St. Clair tributaries and 57 species in the Lake Erie tributaries of the LTVCA watershed. **Table 2.5.1-2: LTVCA Lake Erie Tributaries Fish Species Summary** and **Table 2.5.1-3: LTVCA Lake St. Clair Tributaries Fish Species Summary** provide lists of the species found in these watershed areas.

Table 2.5.1-1: Thames River Fish Species Summary

Table 2.5.2-1: Thames River Fish Species Summary

Species (Common Name)	Species (Scientific Name)	Thames Abundance	Sensitive	Coldwater	Native	Migrant	Target	COSEWIC Status
Alewife	*Alosa pseudoharengus*	Rare	☐	☑	☐	☑	☐	
American brook lamprey	*Lampetra appendix*	Uncommon	☐	☑	☑	☐	☐	
Bigmouth Buffalo	*Ictiobus cyprinellus*	Rare	☑	☐	☑	☑	☐	Special Concern
Black Buffalo	*Ictiobus niger*	Rare	☐	☐	☑	☐	☐	Special Concern
Black Bullhead	*Ameiurus melas*	Common	☐	☐	☑	☐	☐	
Black Crappie	*Pomoxis nigromaculatus*	Uncommon	☐	☐	☑	☐	☑	
Black Redhorse	*Moxostoma duquesnei*	Uncommon	☑	☐	☑	☐	☐	Threatened
Blacknose Dace	*Rhinichthys atratulus*	Abundant	☐	☐	☑	☐	☐	
Blacknose Shiner	*Notropis heterolepis*	Uncommon	☑	☐	☑	☐	☐	
Blackside Darter	*Percina maculata*	Abundant	☐	☐	☑	☐	☐	
Bluegill	*Lepomis macrochirus*	Common	☐	☐	☑	☐	☐	
Bluntnose Minnow	*Pimephales notatus*	Abundant	☐	☐	☑	☐	☐	
Brassy Minnow	*Hybognathus hankinsoni*	Uncommon	☐	☐	☑	☐	☐	
Brindled Madtom	*Noturus miurus*	Rare	☐	☐	☑	☐	☐	
Brook Silverside	*Labidesthes sicculus*	Uncommon	☐	☐	☑	☐	☐	
Brook Stickleback	*Culaea inconstans*	Abundant	☐	☐	☑	☐	☐	
Brook Trout	*Salvelinus fontinalis*	Uncommon	☑	☑	☑	☑	☑	
Brown Bullhead	*Ameiurus nebulosus*	Uncommon	☐	☐	☑	☐	☐	
Brown Trout	*Salmo trutta*	Uncommon	☑	☑	☐	☑	☑	
Central Mudminnow	*Umbra limi*	Abundant	☐	☐	☑	☐	☐	
Central Stoneroller	*Campostoma anomalum*	Abundant	☐	☐	☑	☐	☐	
Channel Catfish	*Ictalurus punctatus*	Common	☐	☐	☑	☑	☑	
Chinook Salmon	*Oncorhynchus tshawytscha*	Rare	☑	☑	☐	☑	☑	
Coho Salmon	*Oncorhynchus kisutch*	Rare	☑	☑	☐	☑	☑	
Common Carp	*Cyprinus carpio*	Abundant	☐	☐	☐	☐	☐	
Common Shiner	*Luxilus cornutus*	Abundant	☐	☐	☑	☐	☐	
Creek Chub	*Semotilus atromaculatus*	Abundant	☐	☐	☑	☐	☐	
Eastern Sand Darter	*Ammocrypta pellucida*	Uncommon	☑	☐	☑	☐	☐	Threatened
Emerald Shiner	*Notropis atherinoides*	Common	☐	☐	☑	☑	☐	
Fantail Darter	*Etheostoma flabellare*	Abundant	☐	☐	☑	☐	☐	
Fathead Minnow	*Pimephales promelas*	Abundant	☐	☐	☑	☐	☐	
Freshwater Drum	*Aplodinotus grunniens*	Uncommon	☐	☐	☑	☑	☐	
Ghost Shiner	*Notropis buchanani*	Common	☐	☐	☑	☐	☐	
Gizzard Shad	*Dorosoma cepedianum*	Common	☐	☐	☑	☑	☐	
Golden Redhorse	*Moxostoma erythrurum*	Abundant	☐	☐	☑	☐	☐	
Golden Shiner	*Notemigonus crysoleucas*	Common	☐	☐	☑	☐	☐	
Goldfish	*Carassius auratus*	Uncommon	☐	☐	☐	☐	☐	
Gravel Chub	*Erimystax x-punctata*	Rare	☑	☐	☑	☐	☐	Extirpated
Greater Redhorse	*Moxostoma valenciennesi*	Common	☑	☐	☑	☐	☐	
Green Sunfish	*Lepomis cyanellus*	Abundant	☐	☐	☑	☐	☐	
Greenside Darter	*Etheostoma blennioides*	Abundant	☐	☐	☑	☐	☐	Special Concern
Hornyhead Chub	*Nocomis biguttatus*	Abundant	☐	☐	☑	☐	☐	
Iowa Darter	*Etheostoma exile*	Common	☐	☐	☑	☐	☐	
Johnny Darter	*Etheostoma nigrum*	Abundant	☐	☐	☑	☐	☐	
Lake Chubsucker	*Erimyzon sucetta*	Rare	☑	☐	☑	☐	☐	Threatened
Largemouth Bass	*Micropterus salmoides*	Abundant	☐	☐	☑	☐	☑	
Least Darter	*Etheostoma microperca*	Common	☐	☐	☑	☐	☐	
Logperch	*Percina caprodes*	Common	☐	☐	☑	☐	☐	
Longear Sunfish	*Lepomis megalotis*	Common	☑	☐	☑	☐	☐	
Longnose Dace	*Rhinichthys cataractae*	Common	☐	☐	☑	☐	☐	
Longnose Gar	*Lepisosteus osseus*	Uncommon	☐	☐	☑	☑	☐	
Mimic Shiner	*Notropis volucellus*	Abundant	☐	☐	☑	☐	☐	

Table 2.5.1-1: Page 1 of 3

Species (Common Name)	Species (Scientific Name)	Thames Abundance	Sensitive	Coldwater	Native	Migrant	Target	COSEWIC Status
Mooneye	*Hiodon tergisus*	Uncommon	☐	☐	☑	☑	☑	
Mottled Sculpin	*Cottus bairdi*	Uncommon	☑	☑	☑	☐	☐	
Muskellunge	*Esox masquinongy*	Rare	☑	☐	☑	☑	☑	
Northern Brook Lamprey	*Ichthyomyzon fossor*	Rare	☐	☐	☑	☐	☐	Special Concern
Northern Hog Sucker	*Hypentelium nigricans*	Abundant	☐	☐	☑	☐	☐	
Northern Madtom	*Noturus stigmosus*	Rare	☐	☐	☑	☐	☐	Endangered
Northern Pike	*Esox lucius*	Common	☑	☐	☑	☑	☑	
Northern Redbelly Dace	*Phoxinus eos*	Abundant	☐	☐	☑	☐	☐	
Pearl Dace	*Margariscus margarita*	Uncommon	☑	☑	☑	☐	☐	
Pugnose Minnow	*Opsopoeodus emiliae*	Rare	☑	☐	☑	☐	☐	Special Concern
Pumpkinseed	*Lepomis gibbosus*	Abundant	☐	☐	☑	☐	☐	
Quillback	*Carpiodes cyprinus*	Uncommon	☐	☐	☑	☑	☐	
Rainbow Darter	*Etheostoma caeruleum*	Uncommon	☐	☐	☑	☐	☐	
Rainbow Trout	*Oncorhynchus mykiss*	Common	☑	☑	☐	☑	☑	
Redfin Shiner	*Lythrurus umbratilis*	Uncommon	☐	☐	☑	☐	☐	
River Chub	*Nocomis micropogon*	Common	☐	☐	☑	☐	☐	
River Darter	*Percina shumardi*	Rare	☐	☐	☑	☐	☐	
River Redhorse	*Moxostoma carinatum*	Rare	☐	☐	☑	☑	☐	Special Concern
Rock Bass	*Ambloplites rupestris*	Abundant	☐	☐	☑	☐	☐	
Rosyface Shiner	*Notropis rubellus*	Abundant	☐	☐	☑	☐	☐	
Round Goby	*Neogobius melanostomus*	Rare	☐	☐	☐	☐	☐	
Sauger	*Sander canadensis*	Rare	☐	☐	☑	☑	☑	
Sea Lamprey	*Petromyzon marinus*	Rare	☐	☑	☐	☑	☐	
Shorthead Redhorse	*Moxostoma macrolepidotum*	Common	☐	☐	☑	☑	☐	
Silver Lamprey	*Ichthyomyzon unicuspis*	Rare	☐	☐	☑	☑	☐	
Silver Redhorse	*Moxostoma anisurum*	Common	☐	☐	☑	☑	☐	
Silver Shiner	*Notropis photogenis*	Uncommon	☐	☐	☑	☐	☐	Special Concern
Smallmouth Bass	*Micropterus dolomieu*	Abundant	☐	☐	☑	☐	☑	
Spotfin Shiner	*Cyprinella spiloptera*	Abundant	☐	☐	☑	☐	☐	
Spottail Shiner	*Notropis hudsonius*	Uncommon	☐	☑	☑	☑	☐	
Spotted Sucker	*Minytrema melanops*	Rare	☑	☐	☑	☐	☐	Special Concern
Stonecat	*Noturus flavus*	Abundant	☐	☐	☑	☐	☐	
Striped Shiner	*Luxilus chrysocephalus*	Abundant	☐	☐	☑	☐	☐	
Tadpole Madtom	*Noturus gyrinus*	Uncommon	☐	☐	☑	☐	☐	
Trout-perch	*Percopsis omiscomaycus*	Uncommon	☐	☑	☑	☐	☐	
Walleye	*Sander vitreus*	Uncommon	☑	☐	☑	☑	☑	
White Bass	*Morone chrysops*	Uncommon	☐	☐	☑	☑	☑	
White Crappie	*Pomoxis annularis*	Common	☐	☐	☑	☐	☑	
White Perch	*Morone americana*	Uncommon	☐	☐	☐	☑	☑	
White Sucker	*Catostomus commersoni*	Abundant	☐	☐	☑	☑	☐	
Yellow Bullhead	*Ameiurus natalis*	Common	☐	☐	☑	☐	☐	
Yellow Perch	*Perca flavescens*	Common	☐	☐	☑	☑	☑	

With respect to the preceeding table, the terms are described as:
Abundance: Refers to the relative abundance or common occurrence of the species found within the waters of the Thames River watershed based on sampling results. Consideration was given to accurately reflect the species presence within the watershed due to the sampling capture method, effort, and biases, difficulty in capturing certain species and

Abundant: Greater than 50 sample records in the database
Common: Between 15 and 50 sample records in the database
Historical: species that have been previously recorded in the Thames.
Rare: Less than 5 sample records in database
Uncommon: Between 5 and 15 sample records in database

Table 2.5.1-1: Page 2 of 3

Sensitive: In 2005, Coker and Portt identified sensitive species in the draft "Sensitive Species List for Agricultural Municipal Drain Clean Outs". Sensitive species have specific habitat requirements, and any alterations to their habitat could prove to be detrimental to the species.
Coldwater: Life history information was reviewed in "Morphological and Ecological Characteristics of Canadian Freshwater Fishes" to identify species habitat, including thermal 'preferences'. These species are found in coldwater habitats, defined as having water temperatures of less than 19°C.
Native: A species indigenous to a particular region or area.
Migrant: A species that moves to a riverine area from a lake in order to carry out one of its life history requirements such as spawning.
Target: Indicates if the species is a sportfish and considered a top level predator. Generally speaking, any species that is targeted for angling purposes would be a sportfish. Most sportfish feed on smaller fish, and baitfish can be used when angling for sportfish.
COSEWIC Status: Status assigned by the Committee on the Status of Endangered Wildlife in Canada for the Species at Risk Act (SARA).

- **Extinct:** A species that no longer exists.
- **Extirpated:** A species no longer existing in the wild in Canada, but occurring elsewhere in the wild.
- **Endangered:** A species facing imminent extirpation or extinction.
- **Threatened:** A species likely to become endangered if limiting factors are not reversed.
- **Special Concern:** A species that may become threatened or endangered species because of a combination of biological characteristics and identified threats.

Table 2.5.1-1: Page 3 of 3

Table 2.5.1-2: LTVCA Lake Erie Tributaries Fish Species Summary

Table 2.5.1-2: LTVCA Lake Erie Tributaries Fish Species Summary

Species (Common Name)	Species (Scientific Name)	Sensitive	Coldwater	Native	Migrant	Target	COSEWIC Status
Alewife	*Alosa pseudoharengus*	☐	☑	☐	☑	☐	
Black Bullhead	*Ameiurus melas*	☐	☑	☑	☐	☐	
Black Crappie	*Pomoxis nigromaculatus*	☐	☐	☑	☐	☑	
Blackchin Shiner	*Notropis heterodon*	☑	☐	☑	☐	☐	
Blacknose Dace	*Rhinichthys atratulus*	☐	☐	☑	☐	☐	
Blacknose Shiner	*Notropis heterolepis*	☑	☐	☑	☐	☐	
Blackside Darter	*Percina maculata*	☐	☐	☑	☐	☐	
Bluegill	*Lepomis macrochirus*	☐	☐	☑	☐	☐	
Bluntnose Minnow	*Pimephales notatus*	☐	☐	☑	☐	☐	
Brassy Minnow	*Hybognathus hankinsoni*	☐	☐	☑	☐	☐	
Brook Silverside	*Labidesthes sicculus*	☐	☐	☑	☐	☐	
Brook Stickleback	*Culaea inconstans*	☐	☐	☑	☐	☐	
Brown Bullhead	*Ameiurus nebulosus*	☐	☐	☑	☐	☐	
Burbot	*Lota Lota*	☐	☑	☑	☑	☐	
Central Mudminnow	*Umbra limi*	☐	☐	☑	☐	☐	
Channel Catfish	*Ictalurus punctatus*	☐	☐	☑	☑	☑	
Common Carp	*Cyprinus carpio*	☐	☐	☐	☐	☐	
Common Shiner	*Luxilus cornutus*	☐	☐	☑	☐	☐	
Creek Chub	*Semotilus atromaculatus*	☐	☐	☑	☐	☐	
Emerald Shiner	*Notropis atherinoides*	☐	☐	☑	☑	☐	
Fantail Darter	*Etheostoma flabellare*	☐	☐	☑	☐	☐	
Fathead Minnow	*Pimephales promelas*	☐	☐	☑	☐	☐	
Freshwater Drum	*Aplodinotus grunniens*	☐	☐	☑	☑	☐	
Gizzard Shad	*Dorosoma cepedianum*	☐	☐	☑	☑	☐	
Golden Redhorse	*Moxostoma erythrurum*	☐	☐	☑	☐	☐	
Golden Shiner	*Notemigonus crysoleucas*	☐	☐	☑	☐	☐	
Goldfish	*Carassius auratus*	☐	☐	☐	☐	☐	
Green Sunfish	*Lepomis cyanellus*	☐	☐	☑	☐	☐	
Johnny Darter	*Etheostoma nigrum*	☐	☐	☑	☐	☐	
Lake Chubsucker	*Erimyzon sucetta*	☑	☐	☑	☐	☐	Threatened
Largemouth Bass	*Micropterus salmoides*	☐	☐	☑	☐	☑	
Logperch	*Percina caprodes*	☐	☐	☑	☐	☐	
Longnose Gar	*Lepisosteus osseus*	☐	☐	☑	☑	☐	
Mimic Shiner	*Notropis volucellus*	☐	☐	☑	☐	☐	
Mooneye	*Hiodon tergisus*	☐	☐	☑	☑	☑	
Mottled Sculpin	*Cottus bairdi*	☑	☑	☑	☐	☐	
Northern Pike	*Esox lucius*	☑	☐	☑	☑	☑	
Pugnose Minnow	*Opsopoeodus emiliae*	☑	☐	☑	☐	☐	Special Concern
Pumpkinseed	*Lepomis gibbosus*	☐	☐	☑	☐	☐	
Quillback	*Carpiodes cyprinus*	☐	☐	☑	☑	☐	
Rock Bass	*Ambloplites rupestris*	☐	☐	☑	☐	☐	
Sand Shiner	*Notropis stramineus*	☐	☐	☑	☑	☑	
Sea Lamprey	*Petromyzon marinus*	☐	☑	☐	☑	☐	
Shorthead Redhorse	*Moxostoma macrolepidotum*	☐	☐	☑	☑	☐	
Silver Lamprey	*Ichthyomyzon unicuspis*	☐	☐	☑	☑	☐	
Slimy Sculpin	*Cottus cognatus*	☐	☑	☑	☐	☐	
Smallmouth Bass	*Micropterus dolomieu*	☐	☐	☑	☐	☑	
Spotfin Shiner	*Cyprinella spiloptera*	☐	☐	☑	☐	☐	
Spottail Shiner	*Notropis hudsonius*	☐	☑	☑	☑	☐	
Spotted Gar	*Lepisosteus oculatus*	☐	☐	☑	☐	☐	Threatened
Tadpole Madtom	*Noturus gyrinus*	☐	☐	☑	☐	☐	

Table 2.5.1-2: Page 1 of 2

Species (Common Name)	Species (Scientific Name)	Sensitive	Coldwater	Native	Migrant	Target	COSEWIC Status
Trout-perch	*Percopsis omiscomaycus*	☐	☑	☑	☐	☐	
White Bass	*Morone chrysops*	☐	☐	☑	☑	☑	
White Crappie	*Pomoxis annularis*	☐	☐	☑	☐	☑	
White Perch	*Morone americana*	☐	☐	☐	☑	☑	
White Sucker	*Catostomus commersoni*	☐	☐	☑	☑	☐	
Yellow Bullhead	*Ameiurus natalis*	☐	☐	☑	☐	☐	
Yellow Perch	*Perca flavescens*	☐	☐	☑	☑	☑	

With respect to the preceeding table, the terms are described as:

Sensitive: In 2005, Coker and Portt identified sensitive species in the draft "Sensitive Species List for Agricultural Municipal Drain Clean Outs". Sensitive species have specific habitat requirements, and any alterations to their habitat could prove to be detrimental to the species.

Coldwater: Life history information was reviewed in "Morphological and Ecological Characteristics of Canadian Freshwater Fishes" to identify species habitat, including thermal 'preferences'. These species are found in coldwater habitats, defined as having water temperatures of less than 19°C.

Native: A species indigenous to a particular region or area.

Migrant: A species that moves to a riverine area from a lake in order to carry out one of its life history requirements such as spawning.

Target: Indicates if the species is a sportfish and considered a top level predator. Generally speaking, any species that is targeted for angling purposes would be a sportfish. Most sportfish feed on smaller fish, and baitfish can be used when angling for sportfish.

COSEWIC Status: Status assigned by the Committee on the Status of Endangered Wildlife in Canada for the Species at Risk Act (SARA).

Extinct: A species that no longer exists.

Extirpated: A species no longer existing in the wild in Canada, but occurring elsewhere in the wild.

Endangered: A species facing imminent extirpation or extinction.

Threatened: A species likely to become endangered if limiting factors are not reversed.

Special Concern: A species that may become threatened or endangered species because of a combination of biological characteristics and identified threats.

Table 2.5.1-2: Page 2 of 2

Table 2.5.1-3: LTVCA Lake St. Clair Tributaries Fish Species Summary

Table 2.5.1-3: LTVCA Lake St Clair Tributaries Fish Species Summary

Species (Common Name)	Species (Scientific Name)	Sensitive	Coldwater	Native	Migrant	Target	COSEWIC Status
Alewife	*Alosa pseudoharengus*	☐	✓	☐	✓	☐	
Black Bullhead	*Ameiurus melas*	☐	✓	✓	☐	☐	
Black Crappie	*Pomoxis nigromaculatus*	☐	☐	✓	☐	✓	
Bluegill	*Lepomis macrochirus*	☐	☐	✓	☐	☐	
Bluntnose Minnow	*Pimephales notatus*	☐	☐	✓	☐	☐	
Brindled Madtom	*Noturus miurus*	☐	☐	✓	☐	☐	
Brook Silverside	*Labidesthes sicculus*	☐	☐	✓	☐	☐	
Channel Catfish	*Ictalurus punctatus*	☐	☐	✓	✓	✓	
Common Carp	*Cyprinus carpio*	☐	☐	☐	☐	☐	
Emerald Shiner	*Notropis atherinoides*	☐	☐	✓	✓	☐	
Freshwater Drum	*Aplodinotus grunniens*	☐	☐	✓	✓	☐	
Gizzard Shad	*Dorosoma cepedianum*	☐	☐	✓	✓	☐	
Golden Shiner	*Notemigonus crysoleucas*	☐	☐	✓	☐	☐	
Grass Pickerel	*Esox americanus vermiculatu*	✓	☐	✓	☐	☐	
Green Sunfish	*Lepomis cyanellus*	☐	☐	✓	☐	☐	
Largemouth Bass	*Micropterus salmoides*	☐	☐	✓	☐	✓	
Logperch	*Percina caprodes*	☐	☐	✓	☐	☐	
Longnose Gar	*Lepisosteus osseus*	☐	☐	✓	✓	☐	
Mimic Shiner	*Notropis volucellus*	☐	☐	✓	☐	☐	
Northern Pike	*Esox lucius*	✓	☐	✓	✓	✓	
Pugnose Minnow	*Opsopoeodus emiliae*	✓	☐	✓	☐	☐	Special Concern
Pumpkinseed	*Lepomis gibbosus*	☐	☐	✓	☐	☐	
Quillback	*Carpiodes cyprinus*	☐	☐	✓	✓	☐	
River Darter	*Percina shumardi*	☐	☐	✓	☐	☐	
Rock Bass	*Ambloplites rupestris*	☐	☐	✓	☐	☐	
Shorthead Redhorse	*Moxostoma macrolepidotum*	☐	☐	✓	✓	☐	
Smallmouth Bass	*Micropterus dolomieu*	☐	☐	✓	☐	✓	
Spotfin Shiner	*Cyprinella spiloptera*	☐	☐	✓	☐	☐	
Spottail Shiner	*Notropis hudsonius*	☐	✓	✓	✓	☐	
Spotted Gar	*Lepisosteus oculatus*	☐	☐	✓	☐	✓	Threatened
Spotted Sucker	*Minytrema melanops*	✓	☐	✓	☐	☐	Special Concern
Walleye	*Sander vitreus*	✓	☐	✓	✓	✓	
White Bass	*Morone chrysops*	☐	☐	✓	✓	✓	
White Crappie	*Pomoxis annularis*	☐	☐	✓	☐	✓	
White Perch	*Morone americana*	☐	☐	☐	✓	✓	
Yellow Bullhead	*Ameiurus natalis*	☐	☐	✓	☐	☐	
Yellow Perch	*Perca flavescens*	☐	☐	✓	✓	✓	

With respect to the preceeding table, the terms are described as:

Sensitive: In 2005, Coker and Portt identified sensitive species in the draft "Sensitive Species List for Agricultural Municipal Drain Clean Outs". Sensitive species have specific habitat requirements, and any alterations to their habitat could prove to be detrimental to the species.

Coldwater: Life history information was reviewed in "Morphological and Ecological Characteristics of Canadian Freshwater Fishes" to identify species habitat, including thermal 'preferences'. These species are found in coldwater habitats, defined as having water temperatures of less than 19°C.

Native: A species indigenous to a particular region or area.

Migrant: A species that moves to a riverine area from a lake in order to carry out one of its life history requirements such as spawning.

Target: Indicates if the species is a sportfish and considered a top level predator. Generally speaking, any species that is targeted for angling purposes would be a sportfish. Most sportfish feed on smaller fish, and baitfish can be used when angling for sportfish.

COSEWIC Status: Status assigned by the Committee on the Status of Endangered Wildlife in Canada for the Species at Risk Act (SARA).

Extinct: A species that no longer exists.
Extirpated: A species no longer existing in the wild in Canada, but occurring elsewhere in the wild.
Endangered: A species facing imminent extirpation or extinction.
Threatened: A species likely to become endangered if limiting factors are not reversed.
Special Concern: A species that may become threatened or endangered species because of a combination of biological characteristics and identified threats.

In 1986, Holm and Crossman completed a study comparing current (1985) information to historic surveys from the 1920s and 1940s. They identified water quality and fish habitat as conditions that had deteriorated significantly in the Thames River. They noted that turbidity and siltation had increased, and that stream flow rates had changed as a result of habitat disruptions such as impoundments. They also indicated a decline of species with a preference for clear, fast water and an increase in abundance of species more tolerant of turbidity. In general, the changes pose a distinct disadvantage to most freshwater fishes in the watershed[118].

More recently, two projects, the Species at Risk (SAR) Recovery Plan, and the Municipal Drain Classification Project (MDC) have been responsible for the most recent monitoring of fish communities. Over 500 fish community samples have been collected by UTRCA sampling crews throughout the Thames River watershed. Fisheries and Oceans Canada (DFO) crews have been active in the Thames in recent years, with their main focus being the Thames and its tributaries downstream of London to Lake St. Clair. Seine netting, gill netting, trawling, minnow trapping and electro-fishing were techniques used to collect fish data in the Thames Watershed.

Map 26: Fish Sampling Locations illustrates locations of the recent (1997- 2004) work. This map also includes historic fish sampling efforts recorded in the Royal Ontario Museum (ROM) database from various sources.

The recent fish sampling efforts as part of the Municipal Drain Classification (MDC) work have identified over two dozen streams that support resident populations of cold water indicator species such as trout, sculpins and brook lamprey, mostly in the Upper Thames watershed. The cold water communities in the Thames watershed are evenly divided between small, relatively undisturbed headwater streams and larger second and third order streams. Many of the headwater streams are associated with areas of extensive forest cover and may or may not rely on groundwater discharges, while all of the larger streams are in areas of significant groundwater discharge.

Other high quality fish communities in the Thames are indicated by the large diversity of fish species present. These usually include one or more of the SAR that require good water and habitat quality. The SAR sampling conducted in recent years indicates that Black Redhorse, Silver Shiner, and Greenside Darter are present in much of the North Thames, parts of the Middle and South Thames, and several of their larger tributaries. Other species requiring clean substrate for their survival include the Eastern Sand Darter and the Northern Madtom, which are found in the Thames downstream of London.

Other information relevant to fisheries management has been collected in recent years through the MDC. Stoneman's protocol[121] was used to evaluate the thermal regime of the municipal drains targeting the identification of cold water habitats. Also, drains with intermittent or permanent flow were identified, and habitat evaluations were completed throughout the Thames watershed.

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[121] Stoneman, C.L. and M.L Jones. 1996. A Simple Methodology to Evaluate the Thermal Stability of Trout Streams. In North American Journal of Fisheries Management. 16:728-737.

Other sources of information include the Ontario Ministry of Natural Resources (OMNR), the Royal Ontario Museum (ROM) and the Ontario Ministry of the Environment (OMOE). Fish sampling data has also been obtained from DFO and the OMNR Lake Erie Management Unit. Fish are also used as biomonitors and the OMOE monitors fish through their Sport fish Contaminant Monitoring Program. This program informs the public of the amount of fish that can safely be consumed throughout Ontario. Other data include observations made conducting other aquatic sampling activities, and information from local anglers or bait operators. Although this information is useful, this data has not been incorporated due to the anecdotal nature.

The OMNR Fish and Wildlife Branch has prepared a Watershed Based Fisheries Management Plan Guideline. Fisheries management planning has a significant impact on the management of fish, their habitat and use. The guideline document discusses the need for fisheries management plans (FMP) to be based on watershed divides and how to prepare such a plan.[122] Prior to this initiative from OMNR, other watershed based fisheries management plans were prepared and a plan for the Thames River Watershed was in the initial stages. It is anticipated with the required funding to support the plan, it will be completed in 2007.[123]

Throughout the Thames River Fisheries Management Plan (TRFMP) planning process, many fish habitat, fish community and fishery development projects have been identified as underway in the watershed based on several outdated FMPs for the watershed (based on political boundaries). A current TRFMP based on the watershed boundary would help guide and integrate fisheries-related initiatives to optimize societal benefits from use of fisheries resources. The TRFMP will complement other watershed plans and will recognize other planning efforts. The purpose of the plan is to articulate and enable a vision for the fisheries of the Thames River Watershed in a way that is most likely to maintain and improve benefits for those living in the watershed and those utilizing the resource. The plan will form a document and will be developed in collaboration with stakeholders. The needs of the human and fish and wildlife communities will be articulated in order for the human population to implement the plan[123].

Some of the information gleaned from MNR's fisheries management plans circa 1986-1990 relevant to habitat disturbance and water quality issues are provided in the Aylmer District Fisheries Management Plan, Wingham District Fisheries Management Plan and Chatham District Fisheries Management Plan.

Aylmer District Fisheries Management Plan (ADFMP)[124]

- Agencies such as the City of London should be advised to regulate the timing of low water flow augmentation for sewage dilution to prevent/avoid the interruption of critical fish spawning and hatching periods.
- Urban and rural land and water use changes related to agricultural land changes, industrialization and urbanization influenced every district watershed by altering their cold and warm water streams through soil erosion, ditching and discharging of waste. Ultimately, these alterations degraded and reduced fishery habitats and their related community structures.
- To reverse the declining fisheries, OMNR initiated its present management direction – a cooperative public and ministry approach towards fishery and habitat rehabilitation.[125]
- Degraded habitats are defined as watercourses with sedimentation, poor shade, unstable banks, water quality problems and periodic change in the quality and quantity of habitat. Twenty-eight degraded streams are identified in the Thames River.

[122] OMNR. 2004. Watershed-based Fisheries Management Plan Guideline Terms of Reference. 10p.
[123] Thames River Fisheries Management Plan. 2004. TRFMP – Terms of Reference. 14p (may be downloaded at www.thamesfishplan.ca/Terms_of_Reference.pdf)
[124] OMNR. 1990. Aylmer District Fisheries Management Plan 1987-2000. 49p.
[125] OMNR. 1990. Background Information and Optional Management Strategies and Tactics, Aylmer District Fisheries Management Plan 1987-2000 A Summary. 40p.

- Inadequate knowledge exists to define critical fish habitat such as spawning grounds, nursery areas and adult habitat in the Thames River.
- Fish production cannot be fully utilized due to impoundments that act as barriers by restricting the upstream migration of desired fish species to acceptable habitats – North, Middle and South Thames.
- "The general public often is not familiar with the basic fisheries concepts and how the concepts relate to wise land management practices across the district. This may result in unrealistic public demands about the resource's capability to produce fish for angling success as well as a misunderstanding among user groups of the impact each group has on the resource."

Wingham District Fisheries Management Plan (WDFMP) [126]

- Production of fish is limited by poor water quality, impoundments and degraded habitat among other factors in the Thames. Rehabilitation efforts would be required to improve the fishery.
- The wholesomeness of fish products are impaired by high levels of contaminants. Contaminant sampling programs have identified high levels of contaminants in fish in several watercourses. Restrictions on the use of these fish for food have been recommended in the Guide to Eating Ontario Sport fish produced by the Ontario Ministry of the Environment (OMOE).
- To protect existing habitat the following tactic was proposed – restrict in-stream habitat alteration and protect wetlands and recharge areas on all cold water streams. Protecting existing habitat is more effective and efficient than rehabilitating degraded habitat. This strategy has major implications to agricultural land use operations especially with regards to drainage.
- Maintain contaminant monitoring and information programs. Reduce levels of contaminants in fish by detecting and controlling sources of contaminants and encourage agencies to take measures to reduce toxic chemicals entering water supplies.

The Chatham District Fisheries Management Plan (CDFMP) [127]

- Pollution sources, whether agricultural, municipal or industrial, can impair water quality and/or fish habitat and result in reduced potential fish yields.
- In Chatham district, habitat degradation occurs in a number of ways. High intensity agricultural land use practices have severely degraded most inland fisheries habitat and water quality to a point where the cost of rehabilitation is potentially very high and involves application of soil conservation and review of drainage procedures across whole watersheds. These types of agricultural practices coupled with industrial and other municipal pollution sources along the Great Lakes waterways within the district continues to threaten water quality and fish habitat when effluent disposal is conducted contrary to existing legislation.
- Great Lakes shoreline marshes and inshore fish habitats have been reduced by the combined impacts of poor water quality, inflows from inland watersheds, high water levels, dyking and developments along shorelines.
- Water quality and fish habitat must be maintained if fish populations are to become stable and self-sustaining. Improve water quality and reduce the incidence of fish kills, and reduce contaminant levels in the aquatic environment, while continuing existing contaminant monitoring and information programs. Identify, protect and rehabilitate fish habitat.

Several of the plans required ongoing communication and monitoring programs. Due to the loss of funding past district FMPs; many of the previous recommendations were not followed through.

Ultimately, the protection of fish and fish habitat falls under the jurisdiction of the federal Fisheries Act. It is assumed that the Fisheries Act directly benefits fish and all other aquatic species including mussels.

[126] OMNR. 1986. Wingham District Fisheries Management Plan: Background Information and Optional Management Strategies 1986-2000 A Summary. 39p.
[127] OMNR. 1990. Chatham District Fisheries Management Plan 1987-2000. 85p.

Fish - Data Gap

Much of the current knowledge of cold water community locations was gathered through the Municipal Drain Classification (MDC) program that concentrated almost exclusively on municipal drains. This work needs to be extended to natural systems to seek out cold headwater streams and cold water refuges in larger streams.

GIS analysis could aid in targeting this sampling by examining the features (physiography, groundwater, land use, etc.) at the better quality known cold water sites and searching out similar conditions.

Historical evidence of cold water streams should also be investigated for areas of protection, conservation, preservation or restoration potential.

Continued sampling of SAR populations is recommended to further refine knowledge of their ranges and habitat.

Fish sampling data obtained from DFO and OMNR Lake Erie Management Unit needs to be incorporated into a database. MNR data stored in hard copies should be made available.

Application of indices such as the Index of Biological Integrity (IBI)[128][129] to existing fish data would help identify areas of high quality habitat and identify areas where further sampling may be required.

2.5.2 Mussels

At one point in time, mussel shells were harvested from the Thames River in large quantities. Permits to take clams from the Thames River were issued by the Ontario Game and Fisheries Department. One copy of a permit from 1940 contains photos with several large piles of harvested mussels on the banks of the South Thames River near Putnam. Even though they seem to no longer have an apparent economic significance, freshwater mussels are significant ecosystem monitors.

Freshwater mussels are sensitive to environmental pollution and habitat alterations. They are sedentary filter-feeders existing on algae, bacteria and organic matter in the water column. Due to their sedentary nature, their filter-feeding, and their ability to accumulate substances, mussels have a significant role as biological indicators of ecosystem health.[130]

In general, a diverse mussel community indicates a healthy ecosystem as mussels are adversely affected by environmental degradation. Mussels have been recommended for use as biomonitors for both heavy metals and organic industrial contaminants.[131] Their use as biomonitors[132] has effectively aided the implementation processes of Remedial Action Plans on the St. Clair, Detroit and Niagara Rivers.[133]

Canada is home to 55 native freshwater mussel species and 41 of those are found in Ontario. The rivers of southern Ontario, specifically those draining into Lake St. Clair and Lake Erie, have been considered,

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[128] Karr, J.R., K.D. Fausch, P.L. Angermeier, P.R. Yant, and I.J. Schlosser. 1986. Assessing biological integrity in running waters, a method and its rational. Illinois Natural History Survey, Special Publication 5.

[129] Karr, J.R. 1999. Defining and measuring river health. In Freshwater Biology, 41:221-234.

[130] Morris, T.J. 2004. National Recovery Strategy for the Round Hickorynut (*Obovaria subrotunda*, Rafinesque 1820) and the Kidneyshell (*Ptychobranchus fasciolaris*, Rafinesque 1820): 2004-2009. Prepared for the Freshwater Mussel Recovery Team. Draft – November 25, 2004. x + 36p.

[131] Metcalfe-Smith, J.L., R.H. Green and L.C. Grapentine. 1996. Influence of biological factors on concentrations of metals in the tissues of freshwater mussels (*Elliptio complanata* and *Lamsilis radiate radiate*) from the St. Lawrence River. In Can. J. Fish. Aquatic. Sci. 53:205-219.

[132] Coma, M.E., J.L. Metcalfe-Smith and K.L.E. Kaiser. 1996. Zebra mussels as biomonitors for organic contaminants in the lower Great Lakes. In Water Qual. Res. J. Canada 31(2):411-430.

[133] Species at Risk Public Registry website: Species Profile – Wavy-rayed lampmussel. www.sararegistry.gc.ca/species/speciesDetails_e.cfm?sid=583

historically, to be home to the most diverse mussel communities in Canada. To date, 33 native species and one non-native species of freshwater mussels have been recorded in the Thames River watershed. **Table 2.5.2-1: Thames River Freshwater Mussel Species Summary** provides a complete list of the mussel species found in the watershed. It should be noted that the presence of a mussel shell(s) does not necessarily confirm the presence of live animals since shells tend to persist in the environment for years after the animals themselves have died. If shells are in excellent condition then it is presumed that the shells came from live animals or animals that had only been dead a short time.

From research conducted through the 1990s, it was suggested that the biodiversity of freshwater mussels had declined across the whole lower Great Lakes drainage basin. Janice Metcalfe-Smith et al. concluded, "River systems that once supported numerous species characteristic of a wide variety of habitats are now dominated by fewer siltation and pollution tolerant species".[134] Previously, research had shown that there had been declines of 15-31% in the freshwater mussel species for the Thames River watershed.[135]

Since 2004, the mussel monitoring network was expanded to incorporate the whole Thames River in order to provide updated information for this system. Over the past two years, the whole Thames was surveyed by Fisheries and Oceans Canada (DFO), with the assistance of staff from LTVCA and UTRCA. **Map 27: Mussel Sampling Locations** shows the locations of recent (1990-2004) and historic (prior to 1990) sampling throughout the watershed.

The recent monitoring efforts indicate that the Thames River can still be characterized as a good mussel river. The lower Thames River watershed, essentially downstream of London to Chatham, has a high diversity of mussels with abundant numbers. Unfortunately, researchers have confirmed that there are five species of mussels that are believed to no longer occur within the Thames River watershed.[136] Mussel SAR are virtually absent in this part of the watershed.

Historically, from Chatham downstream to Lake St. Clair, the Thames River has had many mussel species. Sampling conditions are less favourable in the deeper waters of the lower Thames River; therefore, it is difficult to confirm the current status of mussels in this area.

Five of the main factors that could significantly affect mussels are:

- mussels are sensitive to pollutants,
- mussels are restricted by their habitat requirements,
- mussels rely on a host during their larval stage (called glochicial) to complete their life cycle,
- mussels are susceptible to habitat alterations such as sedimentation and siltation,
- mussel populations are decimated by the non-native invasive zebra mussel.[137]

As stated, a diverse community of mussels aids in characterizing a healthy aquatic environment. Mussel species that have disappeared, or mussel species that are extremely hard to find, tend to indicate that aquatic conditions are deteriorating. Seven Species At Risk mussel species have been identified in the Thames River and will be discussed in Section 2.5.4 of this report.

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[134] Metcalfe-Smith, J.L., S.K. Stanton, G.L. Mackie, and N.M. Lane. 1998. Changes in the Biodiversity of Freshwater Mussels in the Canadian Waters of the Lower Great Lakes Drainage Basin Over the Past 140 years. In J.Great Lakes Res. 24(4):845-858.

[135] West, E.L., J.L. Metcalfe-Smith, and S.K. Stanton. 2000. Status of the Rayed Bean, *Villosa fabalis* (Bivalvia: Unionidae), in Ontario and Canada. In Canadian Field-Naturalist 114(2): 248-258.

[136] Morris, Todd J. 2005. Great Lakes Laboratory for Fisheries and Aquatic Sciences, Fisheries and Oceans Canada.

[137] Thames River Recovery Team. 2004. Recovery strategy for the Thames River Aquatic Ecosystem: 2005-2010. December 2004 Draft. 145 pp.
www.thamesriver.on.ca/Species_at_Risk/synthesis_report/Thames_River_Synthesis_report.pdf
Morris, T.J. 2004. National Recovery Strategy for the Wavy-Rayed Lampmussel (*Lampsilis fasciola*, Rafineseque 1820): 2004-2009. Prepared for the Freshwater Mussel Recovery Team. Draft – November 25, 2004. viii + 33p.
Metcalfe-Smith, J. L., S. K. Stanton, and E. L. West. 2000. Status of the wavy-rayed lampmussel, *Lampsilis fasciola* (Bivalvia: Unionidae), in Ontario and Canada. In The Canadian Field Naturalist 114: 457-470.

Table 2.5.2-1: Thames River Freshwater Mussel Species Summary

Table 2.5.2-1: Thames River Freshwater Mussel Species Summary

Common Name	Scientific Name	Thames	COSEWIC Status	Native
Black Sandshell	*Ligumia recta*	Live		✓
Creek Heelsplitter	*Lasmigona compressa*	Live		✓
Creeper	*Strophitus undulatus*	Live		✓
Cylindrical Floater (papershell)	*Anodontoides ferussacianus*	Live		✓
Deertoe	*Truncilla truncata*	Live		✓
Elktoe	*Alasmidonta marginata*	Live		✓
Fat Mucket	*Lampsilis siliquoidea*	Live		✓
Fawnsfoot	*Truncilla donaciformis*	Live		✓
Fluted Shell	*Lasmigona costata*	Live		✓
Fragile Papershell	*Leptodea fragilis*	Live		✓
Giant Floater	*Pyganodon grandis*	Live		✓
Hickorynut	*Obovaria olivaria*	Live		✓
Kidneyshell	*Ptychobranchus fasciolaris*	Live	Endangered	✓
Lilliput Mussel	*Toxolasma parvus*	Live		✓
Mapleleaf	*Quadrula quadrula*	Live	Threatened	✓
Mucket	*Actinonaias ligamentina*	Live		✓
Mudpuppy Mussel	*Simpsonaias ambigua*	Shells only	Endangered	✓
Pimpleback	*Quadrula pustulosa*	Live		✓
Pink Heelsplitter	*Potamilus alatus*	Live		✓
Plain Pocketbook	*Lampsilis cardium*	Live		✓
Purple Wartyback	*Cyclonaias tuberculata*	Live		✓
Rainbow	*Villosa iris*	Live	Endangered	✓
Rayed Bean	*Villosa fabalis*	Live	Endangered	✓
Round Hickorynut	*Obovaria subrotunda*	Shells only	Endangered	✓
Round Pigtoe	*Pleurobema sintoxia*	Live	Endangered	✓
Slippershell Mussel	*Alasmidonta viridis*	Shells only		✓
Snuffbox	*Epioblasma triquetra*	Shells only	Endangered	✓
Spike	*Elliptio dilatata*	Live		✓
Threehorned Wartyback	*Obliquaria reflexa*	Live		✓
Threeridge	*Amblema plicata*	Live		✓
Wabash Pigtoe	*Fusconaia flava*	Live		✓
Wavy-rayed Lampmussel	*Lampsilis fasciola*	Live	Endangered	✓
White Heelsplitter	*Lasmigona complanata*	Live		✓
Zebra Mussel	*Dreissena polymorpha*	Live		☐

With respect to the above table, the terms are described as:

Thames: Indicates wether live specimens have been located or relict shells only located.

COSEWIC Status: Status assigned by the Committee on the Status of Endangered Wildlife in Canada for the Species at Risk Act (SARA).

- **Extinct:** A species that no longer exists.
- **Extirpated:** A species no longer existing in the wild in Canada, but occurring elsewhere in the wild.
- **Endangered:** A species facing imminent extirpation or extinction.
- **Threatened:** A species likely to become endangered if limiting factors are not reversed.
- **Special Concern:** A species that may become threatened or endangered species because of a combination of biological characteristics and identified threats.

Native: A species indigenous to a particular region or area.

2.5.3 Aquatic Macroinvertebrates

Aquatic invertebrates, especially the benthic macroinvertebrates (BMI) that inhabit watercourse substrates, are abundant in all Thames reaches and tributaries. BMI communities consist of insect larvae, aquatic worms, crustaceans, and many other species. Most have fairly well known tolerances to pollution and disturbance. They are relatively easy to sample and can reliably be identified to taxonomic levels suitable for monitoring purposes. Since they are comparatively sedentary, spend all or most of their lives in the aquatic environment and have life spans that last most of the year (or more), they can provide a relatively long-term assessment of water and habitat quality.

For example, a sample dominated by pollution-sensitive caddisflies and mayflies indicates good water quality with no major disturbances in recent years. A sample that is dominated by pollution-tolerant aquatic worms and midge larvae indicates that poor water quality such as chronic contamination, a spill or major habitat disturbance has removed the sensitive species. Additional sampling is usually required to determine the specific cause of the water quality problem.

UTRCA has been monitoring the BMI community and conducting habitat assessments since 1994 at over 300 sites throughout the upper Thames watershed to capture data on the diverse habitat and water quality conditions. This monitoring program has been a cooperative venture between the UTRCA and the Biology Department of the University of Western Ontario (UWO).

In recent years, about 50 benthic samples have also been conducted at 40 sites on wadeable portions of the lower Thames River and its tributaries. The Canada Ontario Agreement Respecting the Great Lakes Basin Ecosystem (COA) and the Lake Erie COA partners (Lake Erie Management Unit, Aylmer District, and Guelph District – OMNR Offices) have supported this initiative through a three year Thames River Habitat Assessment and Monitoring Program. **Map 28: Benthic Monitoring Sampling Sites** shows the locations.

A list of the benthic macroinvertebrates (BMI) that are more commonly encountered in the Thames River sampling is provided in **Table 2.5.3-1: Benthic Taxa of the Thames River and Tributaries**. **Table 2.5.3-2: Benthic Taxa of the Thames River and Tributaries** includes the level of taxonomic resolution to which the BMI are identified, their biotic index (BI), which is a regionally adapted indicator of their pollution tolerance and sensitivity[138][139], and their sensitivity class based on the assigned BI. The Family Biotic Index (FBI) [115], a weighted average of the BI's of the BMI in a sample, can be used to assign a water quality/ecosystem health designation to each site.

Table 2.5.3-3: Family Biotic Index Values for all Benthic Samples in the UTRCA Watershed clearly indicates that the aquatic ecosystem health of the Thames and its tributaries is impaired, as can be expected in an intensively developed watershed. Of the BMI sampled, 72% are considered tolerant, 25% mid-tolerant and only 3% sensitive. A preliminary evaluation of the raw benthic data indicated that a correlation likely exists between groundwater discharge and the proportion of a site's sample that consists of sensitive BMI. Many of the sites with higher numbers of sensitive taxa (species) are cold headwater streams or larger streams known to support trout populations. A similar correlation seemed to be evident for those sites having a relatively high proportion of mid-tolerant BMI (and usually at least some sensitive taxa). These tended to be sites having reasonably clean and diverse substrates, well developed riffle/pool morphology, and may indicate that flow is occurring between surface and subsurface hyporheic waters. These are likely important groundwater-surface water interface areas and are important for cycling and metabolizing nutrients.

Table 2.5.3-4: Family Biotic Index Values for the Lower Thames River provides a summary for the benthic monitoring results of the lower Thames River and tributary samples.

Benthic sampling results are incorporated into the UTRCA's watershed report cards, which are scheduled for production every five years.[140] Benthic sampling is conducted at or near the mouth of each of the UTRCA's 28 subwatersheds. The results are combined with certain surface water parameter sample results and pooled for a five year period to assign a water quality score to each subwatershed. This allows a comparison of subwatersheds, helps to identify changes in particular subwatersheds over time, and is

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[138] Bode, R.W., M.A. Novak and L.E. Abele. 1996. Quality Assurance Work Plan for Biological Stream Monitoring in New York State. NYS Department of Environmental Conservation. 89p.
[139] Mandaville, S.M. 2002. Benthic Macroinvertebrates in Freshwaters - Taxa Tolerance Values, Metrics, and Protocols. Project H-1, Soil & Water Conservation Society of Metro Halifax. xviii, 48p., Appendices A-B. 120p.
[140] Maaskant, K., C. Quinlan and I. Taylor. 2001. The Upper Thames River Watershed Report Cards. UTRCA.

useful for targeting UTRCA programs and activities. A summary of the subwatershed benthic data is provided in **Table 2.5.3-5: FBI Averages and Stream Health Classifications**. **Table 2.5.3-6: Averaged Benthic Macroinvertebrates** contains more detailed benthic monitoring results for the UTRCA watershed.

Table 2.5.3-1: Benthic Taxa of the Thames River and Tributaries

Table 2.5.3-1. Benthic Taxa of the Thames River and Tributaries: All benthic macroinvertebrate (BMI) taxa from 1997-2006 benthic sampling that made up over .03% of the total of over 280,000 organisms examined are displayed by taxonomic level.

Phylum	Class	Order	Family	Common Name
Annelida	Hirudinea	Arhynchobdellida	Erpobdellidae	Leech
		Rhynchobdellida	Glossiphoniidae	Leech
	Oligochaeta	Class ID only	Class ID only	Aquatic Worm
Arthropoda	Arachnida	Acari	Class ID only	Water Mite
	Crustacea	Amphipoda	Gammaridae	Sideswimmer
			Talitridae	Sideswimmer
		Cladocera	Daphnidae	Water Flea
		Cyclopoida	Order ID only	Fish Lice
		Decapoda	Cambaridae	Crayfish
		Isopoda	Asellidae	Sow Bug
		Ostracoda	Order ID only	Seed Shrimp
	Insecta	Coleoptera	Chrysomelidae	Leaf Beetle
			Dytiscidae	Predacious Diving Beetle
			Elmidae	Riffle Beetle
			Haliplidae	Crawling Water Beetle
			Hydrophilidae	Water Scavenger Beetle
			Psephenidae	Water Penny Beetle
		Diptera	Chaoboridae	Fantom Midge
			Ceratopagonidae	Biting Midge
			Chironomidae	Midge
			Empididae	Dance Fly
			Ephydridae	Shore Fly
			Muscidae	Muscid Fly
			Psychodidae	Sand Fly
			Simuliidae	Black Fly
			Stratiomyidae	Soldier Fly
			Tabanidae	Horse Fly
			Tipulidae	Crane Fly
		Ephemeroptera	Baetidae	Small Mayfly
			Caenidae	Crawling Mayfly
			Ephemerellidae	Mayfly
			Heptageniidae	Stream Mayfly
			Leptophlebiidae	Mayfly
			Oligoneuridae	Torpedo Mayfly
			Tricorythidae	Crawling Mayfly
		Hemiptera	Corixidae	Water Boatmen
			Veliidae	Ripple Bug
		Lepidoptera	Pyralidae	Pyralid Moth
		Megeloptera	Sialidae	Alderfly
		Odonata	Calopterygidae	Broad-winged Damselfly
			Coenagrionidae	Narrow-winged Damselfly
		Plecoptera	Capniidae	Stonefly
			Leuctridae	Stonefly
			Nemouridae	Stonefly
			Perlodidae	Stonefly
			Perlidae	Stonefly
			Taeniopterygidae	Stonefly
		Tricoptera	Brachycentridae	Brachycentrid Caddisfly
			Glossosomatidae	Caddisfly
			Helicopsychidae	Snail-case Caddisfly
			Hydroptilidae	Micro-caddisfly
			Hydropsychidae	Net-spinning Caddisfly
			Leptoceridae	Long-horned Caddisfly
			Limnephilidae	Northern Caddisfly
			Lepidostomatidae	Lepistomatid Caddisfly
			Phryganeidae	Large Caddisfly
			Philopotamatidae	Finger-net Caddisfly
			Polycentropodidae	Caddisfly
			Rhyacophilidae	Primative Caddisfly
Cnidaria	Hydrozoa	Class ID only	Class ID only	Hydra
Mollusca	Gastrapoda	Prosobranchia	Hydrobiidae	Snail
			Valvatidae	Round-mouthed Snail
		Pulmonata	Ancylidae	Limpet
			Lymnaeidae	Pond Snail
			Physidae	Pouch Snail
			Planorbidae	Orb Snail
	Bivalvia	Veneroida	Sphaeriidae	Fingernail Clam
Nematoda	Phylum only	Phylum only	Phylum only	Thread Worm
Platyhelminthes	Turbellaria	Class ID only	Class ID only	Flatworm

Table 2.5.3-2: Benthic Taxa of the Thames River and Tributaries

Table 2.5.3-2: Benthic Taxa of the Thames River and Tributaries: Benthic macroinvertebrates (BMI) that constituted >.05% of the 280,000 organisms sampled during 1997-2006 are displayed by the taxonomic level to which they were identified. Also provided are common name, number of samples they occurred in (count), total (sum), % of the total sample, the biotic index (BI, with 10 being most tolerant and 0 least tolerant to pollution), and pollution sensitivity.

Taxonomic Level	Taxon Name	Common Name	Count	Sum	% of total	BI	Pollution Sensitivity
Family	Glossiphoniidae	Leech	103	195	0.07	8	Tolerant
Class	Oligochaeta	Aquatic Worm	1194	46774	16.70	8	Tolerant
Order	Acariformes	Water Mite	970	5949	2.12	4	Mid-tolerant
Family	Gammaridae	Sideswimmer	253	2313	0.83	4	Mid-tolerant
Family	Talitridae	Sideswimmer	259	1574	0.56	8	Tolerant
Family	Daphnidae	Water Flea	128	1997	0.71	8	Tolerant
Order	Cyclopoida	Fish Lice	413	3856	1.38	8	Tolerant
Family	Asellidae	Sow Bug	480	5206	1.86	8	Tolerant
Order	Ostracoda	Seed Shrimp	341	2555	0.91	8	Tolerant
Family	Dytiscidae	Predacious Diving Beetle	321	1623	0.58	5	Mid-tolerant
Family	Elmidae	Riffle Beetle	1881	19433	6.94	4	Mid-tolerant
Family	Haliplidae	Crawling Water Beetle	130	250	0.09	5	Mid-tolerant
Family	Hydrophilidae	Water Scavenger Beetle	195	415	0.15	5	Mid-tolerant
Family	Psephenidae	Water Penny Beetle	151	333	0.12	4	Mid-tolerant
Family	Ceratopagonidae	Biting Midge	516	2259	0.81	6	Tolerant
Family	Chironomidae	Midge	2327	102660	36.66	6	Tolerant
Family	Empididae	Dance Fly	512	1449	0.52	6	Tolerant
Family	Simuliidae	Black Fly	779	5501	1.96	6	Tolerant
Family	Tabanidae	Horse Fly	117	280	0.10	6	Tolerant
Family	Tipulidae	Crane Fly	356	1319	0.47	3	Mid-tolerant
Family	Baetidae	Small Mayfly	767	11803	4.21	4	Mid-tolerant
Family	Caenidae	Crawling Mayfly	569	5037	1.80	7	Tolerant
Family	Ephemerellidae	Mayfly	143	1551	0.55	1	Sensitive
Family	Heptageniidae	Stream Mayfly	360	2895	1.03	4	Mid-tolerant
Family	Leptophlebiidae	Mayfly	65	295	0.11	2	Sensitive
Family	Oligoneuridae	Torpedo Mayfly	37	142	0.05	2	Sensitive
Family	Tricorythidae	Crawling Mayfly	259	3109	1.11	4	Mid-tolerant
Family	Corixidae	Water Boatmen	302	2495	0.89	5	Mid-tolerant
Family	Coenagrionidae	Narrow-winged Damselfly	137	374	0.13	9	Tolerant
Family	Leuctridae	Stonefly	33	271	0.10	0	Sensitive
Family	Nemouridae	Stonefly	127	1708	0.61	2	Sensitive
Family	Perlidae	Stonefly	127	589	0.21	1	Sensitive
Family	Helicopsychidae	Snail-case Caddisfly	85	386	0.14	3	Mid-tolerant
Family	Hydroptilidae	Micro-caddisfly	361	1402	0.50	4	Mid-tolerant
Family	Hydropsychidae	Net-spinning Caddisfly	833	11656	4.16	4	Mid-tolerant
Family	Leptoceridae	Long-horned Caddisfly	227	596	0.21	4	Mid-tolerant
Family	Lepidostomatidae	Lepistomatid Caddisfly	47	196	0.07	1	Sensitive
Family	Philopotamatidae	Finger-net Caddisfly	143	753	0.27	3	Mid-tolerant
Family	Sphaeriidae	Fingernail Clam	889	9781	3.49	8	Tolerant
Family	Valvatidae	Round-mouthed Snail	19	258	0.09	8	Tolerant
Family	Lymnaeidae	Pond Snail	219	1844	0.66	6	Tolerant
Family	Physidae	Pouch Snail	398	2844	1.02	8	Tolerant
Family	Planorbidae	Orb Snail	214	2177	0.78	7	Tolerant
Phylum	Nematoda	Thread Worm	568	2069	0.74	-1	Not classified
Class	Planaria	Flatworm	447	3434	1.23	4	Mid-tolerant
Family	Limnephilidae	Northern Caddisfly	142	635	0.23	4	Mid-tolerant
Class	Hydrozoa	Hydra	132	867	0.31	5	Mid-tolerant
Family	Taeniopterygidae	Stonefly	66	227	0.08	2	Sensitive
Family	Capniidae	Stonefly	124	1806	0.64	1	Sensitive

Table 2.5.3-3: Family Biotic Index Values for all Benthic Samples in the UTRCA Watershed

Table 2.5.3-3: Family Biotic Index Values for all Benthic Samples in the UTRCA Watershed

Subwatershed	Site Code	Stream Name	1997 Spring	1998 Spring	1999 Spring	2000 Spring	2000 Fall	2001 Spring	2001 Fall	2002 Spring	2002 Fall	2003 Spring	2003 Fall	2004 Spring	2004 Fall
Avon River	AV01	Avon River	6.48	5.29	6.04	6.22	4.78	5.41		7.19		5.94		6.13	
	AV02	Avon River	7.07												
	AV03	Avon River		6.52	7.12	7.43		7.22		7.53		6.48		7.55	
	AV04	Avon River	6.09												6.32
	AV05	Avon River		5.56											
	AV06	Avon River				7.47									
	AV07	Avon River									5.69				
	AV08	Avon River									5.97				
	AV09	Avon River													6.22
	AV20	Roadhouse Drain			7.25				6.54				5.47		
	AV21	Roadhouse Drain			6.77				6.55				7.11		
	AV22	Court Drain		5.57	6.90	6.94						6.82			
	AV23	Court Drain		5.52	6.29	7.33			5.22			7.10			
	AV24	Court Drain Tributary				6.99						6.82			
	AV25	Bannerman Drain			7.05	6.81						6.49			
	AV26	CS Drain	5.97	6.22	6.06				5.69		5.28	5.51	6.09	5.65	5.60
	AV27	CS Drain	6.33												
	AV28	CS Drain	6.03	6.26	6.71				7.82						
	AV29	Avon Tributary			6.08										
	AV30	Kuhne Drain							5.31		4.77				
Black Creek	BL01	Black Creek				5.14		4.81		4.71	4.82	5.36		4.33	
	BL02	Black Creek		6.09	5.58										
	BL03	Black Creek		5.88											
	BL04	Black Creek	6.57		6.19										
	BL21	Black Creek Tributary				6.86				6.83	6.70				
	BL22	Black Creek Tributary				7.25				6.85	6.84				
	BL23	Black Creek Tributary								6.98			6.47		
	BL30	Doell Drain										5.83	6.36		
	BL31	Hartang Drain										5.98	5.48		
Cedar Creek	CE01	Cedar Creek	7.52	5.75	7.21	7.44		7.61		7.57		6.71		7.33	
	CE02	Cedar Creek							7.12		7.20		6.74		5.19
	CE03	Cedar Creek	5.57	5.62	7.09						6.49		6.17		
	CE04	Cedar Creek			6.08	7.78				7.60	4.09	6.65		6.10	
	CE05	Cedar Creek			6.06										
	CE21	Mud Creek			7.09						7.17		6.10		
	CE22	Sweaburg Drain			5.80										
	CE23	Cedar Creek Tributary			7.27										
	CE24	Cedar Creek Tributary			5.52										
	CE25	Cedar Creek Tributary	5.49	6.10											
	CE26	Cedar Creek	5.70	5.91	6.34										
Dingman Creek	DI01	Dingman Creek						4.64		5.45					
	DI02	Dingman Creek		6.70	6.71	6.23	4.18	4.93	4.11	5.71		6.44		4.74	
	DI03	Dingman Creek	7.02												
	DI04	Dingman Creek			6.52	7.05		5.93			6.23	6.02		5.78	5.76
	DI05	Dingman Creek		7.06								7.42		5.41	
	DI06	Dingman Creek						6.40							
	DI07	Dingman Creek				7.49									
	DI08	Dingman Creek						5.81							
	DI09	Dingman Creek		6.24				6.85							
	DI10	Dingman Creek			5.97	6.57		5.15				5.60		5.34	5.43
	DI11	Dingman Creek						6.72							
	DI12	Dingman Creek												6.45	
	DI13	Dingman Creek													5.80
	DI14	Dingman Creek													6.21
	DI20	Anguish Creek				6.18			6.27		6.86		6.45		
	DI21	Dingman Creek Tributary	6.24	7.11											
	DI22	Hampton-Scott Drain			7.33										
	DI23	Hampton-Scott Drain				7.81									7.50
	DI24	Dingman Tributary									4.95		4.75		

Table 2.5.3-3: Page 1 of 6

Subwatershed	Site Code	Stream Name	1997 Spring	1998 Spring	1999 Spring	2000 Spring	2000 Fall	2001 Spring	2001 Fall	2002 Spring	2002 Fall	2003 Spring	2003 Fall	2004 Spring	2004 Fall
	DI30	Cedar Branch										6.05	7.00		
	DI31	Unknown										6.67	7.42		
Dorchester	DO01	South Thames River		5.48		6.36	4.73	6.05		6.70		6.60		6.32	
	DO02	South Thames River	5.82		4.69										
	DO03	South Thames River	4.81	5.48											
	DO20	South Thames Tributary	6.49												
	DO21	South Thames Tributary	5.05	5.08	5.95	6.13	5.70	5.72	5.11	7.37	4.21	5.89	2.78	5.19	5.48
	DO22	Dorchester Conservation Area Drain				5.84									
	DO23	Dorchester Swamp Creek Tributary			6.52	7.08		6.34		6.90		6.47			
	DO24	Dorchester Swamp Creek	5.55	6.17	5.97	5.85		5.23		6.10		5.17		5.83	
	DO25	Caddy Creek	5.54	5.81	5.03	5.42	5.12	5.44	5.24	4.71	4.35	5.46	4.21	3.88	
	DO26	Caddy Creek	6.03												
	DO29	Dorchester Swamp Creek									7.00				
	DO30	Dorchester Swamp Creek									5.60				5.47
	DO31	South Thames Tributary													5.10
	DO32	South Thames Tributary													5.58
Fish Creek	FI01	Fish Creek		6.07											
	FI02	Fish Creek			6.26	6.78		5.56		7.39		5.57		5.44	
	FI03	Fish Creek		5.52	5.66	6.33	6.08	5.72	5.04	6.89	5.82	6.57	5.69	6.11	4.92
	FI20	Nineteen Creek	5.44	5.41	5.86	7.11	4.97	5.67	4.22	7.28	4.32		5.38	6.08	5.52
	FI21	Nineteen Creek			6.66	6.26					4.83				
	FI22	Fish Creek Tributary	6.72												
	FI30	Youngson Creek Drain										6.48	6.04		
	FI31	Watson Drain										6.25	6.65		
	FI32	Fish Creek tributary											5.45		
Flat Creek	FL01	Flat Creek		5.71	6.05	5.55	6.18	5.57		5.59		6.00		6.10	
	FL02	Flat Creek				6.80									
	FL03	Flat Creek		5.90											
	FL04	Flat Creek			6.05										
	FL30	Unknown Drain										5.21	4.90		
	FL31	Harris Drain										5.68	6.28		
	FL32	Unknown Drain										7.25	7.11		
	FL33	Parson Drain										5.79	5.07		
The Forks	TF01	Thames River			7.35	6.54		6.01		6.76				5.59	
	TF02	Thames River			6.13	6.33		5.49		7.22		7.06			
	TF03	Thames River	6.02												
	TF07	South Thames River	5.16	5.00	5.13	7.21		6.60	4.70	4.81	7.20				5.69
	TF08	South Thames River	5.76												
	TF11	North Thames River	5.73	5.99	6.59	6.04									
	TF12	North Thames River		5.96	6.49					7.50					
	TF13	North Thames River	5.57				5.71							5.28	
	TF14	North Thames River													5.33
	TF20	McNay Drain			6.54	7.61					5.66				
	TF21	McNay Drain			6.99										
	TF22	McNay Drain							6.55		4.75				
	TF23	The Coves								7.49					
	TF24	The Coves													7.40
	TF25	The Coves													6.21
	TF26	The Coves													7.65
	TF27	The Coves													7.10
Glengowan	GL01	North Thames River				6.47		5.20		5.62		5.72		5.64	5.09
	GL02	North Thames River	6.04	5.82	5.98										
	GL03	North Thames River	6.10	5.46											
	GL04	North Thames River	6.03	5.44											
	GL20	Fullarton Pond Creek		7.20											

Table 2.5.3-3: Page 2 of 6

Subwatershed	Site Code	Stream Name	1997 Spring	1998 Spring	1999 Spring	2000 Spring	2000 Fall	2001 Spring	2001 Fall	2002 Spring	2002 Fall	2003 Spring	2003 Fall	2004 Spring	2004 Fall
	GL21	North Thames Tributary	6.73												
	GL30	North Thames Tributary										5.54	4.88		
Gregory Creek	GR01	Gregory Creek	5.19	4.96	5.76	6.29	5.11	4.59	5.17	5.81	5.06				
	GR02	Gregory Creek	5.84												
	GR03	Gregory Creek	5.77	5.81											
	GR04	Gregory Creek Tributary			6.24	5.80									
	GR05	Gregory Creek										4.23	5.13	4.63	5.46
Komoka Creek	KO01	Komoka Creek		4.86	5.06	5.36	3.61	4.73	3.30	4.99	3.41	5.83	4.31	4.82	3.69
	KO02	Komoka Creek	4.93		4.74										
Medway Creek	ME01	Medway Creek	5.05	5.45	5.74	5.52		5.61		6.12		6.24		5.96	
	ME02	Medway Creek	6.12	6.02	5.84		5.02	5.16	5.12	6.62	5.60	5.96	5.41	5.49	4.79
	ME03	Medway Creek			6.38										
	ME04	Medway Creek										4.81			
	ME05	Medway Creek													5.27
	ME20	Snake Creek			6.34	6.44					4.86				
	ME21	Medway Creek			7.43	6.86			7.56						
	ME22	Medway Creek Tributary			6.79										
	ME23	Medway Creek Tributary		5.96				5.47							
	ME24	WF Drain	6.47	6.67	6.68										
	ME25	WF Drain	5.91	6.51	6.31										
	ME26	WF Drain			7.88										
	ME27	Elginfield Drain				6.78									
	ME30	Mills Drain										7.15	7.61		
	ME32	McClary Dr										5.87	5.71		
	ME33	Elginfield Dr										6.63	6.84		
	ME34	Unknown Drain										6.06	7.04		
Middle Thames	MI01	Middle Thames River				6.50		5.49							
	MI02	Middle Thames River		5.52	5.85							6.03		6.09	
	MI03	Middle Thames River	4.99			5.87	4.96	5.88		5.76					
	MI04	Middle Thames River	6.31												
	MI05	Middle Thames River	6.50	5.33											
	MI06	Middle Thames River	6.20												
	MI20	Kintore Creek		6.05	6.68	6.43	4.71	5.13		6.89		5.62			
	MI21	Kintore Creek Tributary				6.84		6.08		6.59		5.36		4.54	
	MI22	Kintore Creek Tributary				6.00									
	MI23	Nissouri Creek		5.99	6.27	6.76		6.05		6.33		5.85		7.43	5.50
	MI24	Murray Drain		5.67	5.99	6.70		6.19		6.97		6.60			
	MI30	Graham-Steele Drain										5.67	4.85		
North Branch / Mud Creek	MI07	Middle Thames River				6.31		5.86		6.57		5.34		6.31	
	MU01	Mud Creek		6.09	7.34	6.87		6.38		7.27					
	MU02	Mud Creek				7.23									
	MU03	Mud Creek	6.68	6.30											
	MU20	North Branch Creek	6.00	5.47	5.68	6.97	5.03	6.33		7.35					
	MU21	North Branch Creek	6.88	5.92											
	MU22	North Branch Creek Trib	6.29												
	MU23	North Branch Creek Tributary				7.71									
	MU24	Youngsville Drain											6.34		
	MU30	Hollock Drain										5.67	6.30		
	MU31	North Branch Creek										5.66	6.85		
North Mitchell	GL05	North Thames River	6.66	5.91	5.90	5.82	5.49	5.40		7.22		6.27		5.35	
	NM00	North Thames River							6.69						5.89
	NM01	North Thames River			5.93			6.60		7.63	5.33	6.86			
	NM02	North Thames River		6.76											
	NM20	North Thames Tributary		5.54	5.86	5.95	6.53								
	NM21	North Thames Tributary				7.70									
	NM22	North Thames Tributary	6.65	6.87											
	NM23	North Thames Tributary			7.42										

Table 2.5.3-3: Page 3 of 6

Subwatershed	Site Code	Stream Name	1997 Spring	1998 Spring	1999 Spring	2000 Spring	2000 Fall	2001 Spring	2001 Fall	2002 Spring	2002 Fall	2003 Spring	2003 Fall	2004 Spring	2004 Fall
	NM24	North Thames River	6.61												
	NM30	Logan Road Drain										6.48			4.80
	NM31	Branch Drain										7.59	7.38		
North Woodstock	NW01	South Thames River	6.07	5.11	5.62	6.43	5.06	4.65		6.93	5.32	5.24	4.37	5.53	
	NW02	South Thames River - Thames River Improvement Drain		5.99	7.01	7.22		5.95		6.92		6.54		6.62	
	NW20	Phelan Creek		6.37	6.78	7.37	6.06	5.91		7.04		6.97			
	NW21	Phelan Creek	5.85												
	NW22	Phelan Creek Tributary	5.87												
	NW23	South Thames River Tributary	5.50	5.85											
	NW24	Lockhart Pond							7.19						
	NW25	South Thames Tributary - Hohner Drain									7.68		7.33		
	NW26	South Thames Tributary - Hohner Drain									6.55				
	NW30	Lampman-Lock Drain										6.02	6.65		
	NW31	Unknown										4.79	4.61		
	SO06	South Thames River	6.00												
Otter Creek	OT01	Otter Creek	6.97	4.71	5.22	6.24	4.70	5.26	5.42	6.51	5.52	6.11	4.72	5.59	4.90
	OT02	Otter Creek								7.00					
	OT03	Otter Creek								6.68					
Oxbow Creek	OX01	Oxbow Creek		5.55	4.94	5.36	3.96	5.08		5.63	3.81	4.81		4.85	3.64
	OX02	Oxbow Creek	6.11												
	OX03	Oxbow Creek							5.33			5.81			
	OX04	Oxbow Creek			6.45				6.28						
	OX05	Oxbow Creek		6.07					6.07						
	OX06	Oxbow Creek										6.22			
	OX07	Oxbow Creek										6.23			
	OX08	Oxbow Creek										6.45			
	OX09	Oxbow Creek										5.42			
	OX10	Oxbow Creek										6.04			
	OX21	Oxbow Creek Tributary										5.91			
Plover Mills Corridor	PL01	North Thames River		4.90	4.98	5.57	4.34	4.39	4.03	5.96	3.77	5.60	3.85	4.84	4.73
	PL02	North Thames River	5.33												
	PL03	North Thames River		5.73		5.88		5.48							
	PL04	North Thames River		5.96	5.42	6.72	5.32	5.29		6.26		6.25			
	PL05	North Thames River	5.89												
	PL20	North Thames Tributary		5.83	5.80										
	PL21	North Thames Tributary	5.97												
	PL22	Stormwater Drain													7.12
	PL30	Summerville Drain										5.75	5.39		
	PL31	Needham-Moir Drain										6.23	4.88		
Pottersburg Creek	PO01	Pottersburg Creek		6.10	6.17	7.84	5.57	6.51		7.27		7.92		6.73	
	PO02	Pottersburg Creek													5.81
Reynolds Creek	RE01	Reynolds Creek		5.70	5.53	7.60	4.95	5.74		7.23		6.14		5.75	
	RE02	Reynolds Creek		6.15	7.05										
	RE03	Reynolds Creek				7.89									
	RE20	Five Point Creek				6.16	6.24								
	RE21	Five Point Creek	4.68	5.63	5.73										
	RE30	Warren Drain										6.40	7.24		
River Bend	RI01	Thames River	5.14	4.87	6.15	6.40		5.66		5.29					4.34
	RI02	Thames River	5.35	5.14	5.77	5.84						7.27		6.19	
	RI03	Thames River	5.95	5.03	5.50	5.88		4.84		6.17				5.97	
	RI20	Unknown Drain			7.01	7.63				7.40					

Table 2.5.3-3: Page 4 of 6

Subwatershed	Site Code	Stream Name	1997 Spring	1998 Spring	1999 Spring	2000 Spring	2000 Fall	2001 Spring	2001 Fall	2002 Spring	2002 Fall	2003 Spring	2003 Fall	2004 Spring	2004 Fall
	RI21	Stanton Drain			6.46	7.38			7.19		7.55		6.56		6.45
	RI22	Kelly Drain				6.38									
	RI23	Thames Tributary			5.78						4.33				
	RI24	Thames Tributary			5.37	4.45					3.83				
	RI25	Stanton Drain									2.14		3.60		4.98
South Thames	SO01	South Thames River		5.59	6.68	6.53	5.70	7.08		7.13		6.75		6.31	
	SO02	South Thames River	6.39						4.95						
	SO03	South Thames River		5.77											
	SO04	South Thames River		5.79											
	SO05	South Thames River		5.64								7.22		7.53	
	SO20	Whiting Creek				7.25									
	SO21	Halls Creek			6.30			6.92	5.40						
	SO22	Halls Creek	6.64	6.04	6.12	6.91									
	SO23	Halls Creek	5.97												
	SO24	Halls Creek			7.15										
	SO25	Halls Creek			5.76										
	SO26	Halls Creek			5.39	6.39									
	SO27	Halls Creek				7.63									
	SO28	Foldens Creek	6.11									6.21			
	SO29	Foldens Creek		6.01	6.03	6.25		6.07		6.05				6.48	
	SO30	Sally's Creek	6.07	5.87	6.36	6.59	5.38								
	SO31	Sally's Creek tributary	4.96	4.89	5.44	5.78	4.40	5.25		5.97		5.32	4.69	5.50	5.10
	SO32	Halls Creek							5.38						
	SO34	Sally's Creek							5.32		5.17	5.56		6.21	4.90
	SO35	Patterson-Robbins Drain											5.92		
	SO36	Armstrong Park Creek			7.31	7.34		7.61	6.85		7.17		6.99		
	SO37	Whiting Creek							6.02						
Stoney Creek	ST01	Stoney Creek							6.59		7.11		6.39		5.88
	ST02	Stoney Creek		6.05	6.95	6.24	5.56	5.99	6.27	6.32	5.57				
	ST03	Stoney Creek				6.91									
	ST04	Stoney Creek			5.72										
	ST05	Stoney Creek										5.74		5.66	
	ST20	Powell Drain			5.53				5.66		7.10		6.38		6.33
	ST21	Stoney Creek Northdale Tributary			5.89	6.14			5.78		2.56	5.82	4.26	5.42	5.41
	ST22	Stoney Creek East Tributary	5.95												
Trout Creek / Wildwood	TR01	Trout Creek	6.78												
	TR02	Trout Creek		6.92	6.88	6.44				7.43		6.65		7.53	
	TR03	Trout Creek	6.76												
	TR04	Trout Creek				6.72		6.32		6.81					
	TR05	Trout Creek	6.07	6.29	6.00	7.42	6.03	6.69		7.68					
	TR06	Trout Creek				7.46									
	TR07	Trout Creek										6.19		5.85	
	TR20	Wildwood CA Creek								5.28	6.74	4.52	2.13	3.71	
	TR21	Harrington Creek	5.54	5.21	5.12	4.84	5.30	4.22		4.27		4.17		4.79	
	TR22	Trout Creek Tributary	5.50	5.48											
	TR23	Trout Creek Tributary		6.07	5.84			5.92							
	TR24	Trout Creek Tributary				6.27									
	TR25	Kerr-Lupton Drain			6.10										
	TR26	Trout Creek Tributary			5.61										
	TR27	Trout Creek Tributary	6.37	5.35											
	TR28	Rolston Drain											4.22		
	TR30	Kerr-Lupman Drain Branch D										6.18	6.60		
	TR31	John Green Drain										6.29	7.14		
Waubuno Creek	WA01	Waubuno Creek		5.77								5.06		5.60	
	WA02	Waubuno Creek	5.22		5.62	7.16	5.37	5.50		7.08					
	WA03	Waubuno Creek			6.42										
	WA04	Waubuno Creek	4.86	4.97											

Table 2.5.3-3: Page 5 of 6

Subwatershed	Site Code	Stream Name	1997 Spring	1998 Spring	1999 Spring	2000 Spring	2000 Fall	2001 Spring	2001 Fall	2002 Spring	2002 Fall	2003 Spring	2003 Fall	2004 Spring	2004 Fall
	WA05	Waubuno Creek													5.16
	WA06	Waubuno Creek				5.85		5.48						4.94	
	WA20	Waubuno Creek			5.87										
	WA21	Waubuno Creek Tributary												5.20	
	WA22	Waubuno Creek												7.08	
Whirl Creek	WH01	Whirl Creek		5.75	6.57	6.58	5.44	5.19		6.85		5.56		5.39	
	WH02	Whirl Creek		6.22	6.38	6.76									
	WH03	Whirl Creek									7.09		5.81		
	WH30	Michiel's Drain										6.41	2.89		
	WH31	Whirl Cr Drain										6.99	6.95		
Wye Creek	WY01	Wye Creek		5.97	6.13	6.30	4.58	4.69		6.76		5.71		5.85	
	WY02	Wye Creek			6.71										
	WY30	Elliot Drain										6.27	5.88		
	WY31	Wye Creek West Tributary										5.77	6.21		
	WY32	Wye Creek East Tributary										5.72	6.19		

With respect to the preceeding table, the FBI Values are explained in the following: Biotic indices are values assigned to benthic invertebrate taxa indicating their pollution sensitivity and tolerance on a scale from 0 to 10. Lower numbers indicate pollution sensitivity and high numbers indicate pollution tolerance. The Family Biotic Index (FBI) value is the weighted average of the biotic index and number of bugs within each taxa found in the sample. The water quality ranges for the FBI

Table 2.5.3-3: Page 6 of 6

Table 2.5.3-4: Aquatic Ecosystem Health of the Lower Thames River and Tributaries

Table 2.5.3-4: Aquatic Ecosystem Health of the Lower Thames River and Tributaries: Benthic macroinvertebrates (BMI) were sampled and tabulated using Hilsenhoff's Family Biotic Index (FBI) to assess stream health/surface water quality throughout the Lower Thames watershed.

Stream Name	Location	Year	FBI	Stream Health
Talbot Creek	Southwest of Iona, Erin Line	2004	6.80	Poor
Thames River	Littlejohn Road	2003	4.55	Good
Thames River	Littlejohn Road	2005	4.56	Good
Thames River	Between Wardsville and Bothwell	2004	4.97	Good
Thames River	1 km Downstream of Wardsville STP	2004	4.96	Good
Thames River	Big Bend C. A.	2003	4.84	Good
Thames River	Big Bend C. A.	2004	4.65	Good
Thames River	Simpsons Road	2004	5.45	Fair
Thames River	Thames Road	2003	4.40	Good
Thames River	2 km Downstream of Middlemiss bridge	2004	4.97	Good
Thames River	Middlemiss Bridge - Melbourne Road	2005	5.32	Fair
Thames River	Hazel Road	2003	4.90	Good
Thames River	Off Cook road	2004	4.38	Good
Thames River	Downstream of Delawae	2003	4.72	Good
Big Munday Creek	Near outlet to Thames	2003	5.29	Fair
Fleming Creek	Gibb Line West of Morrison Road	2003	5.63	Fair
Fleming Creek	Gibb Line West of Morrison Road	2004	5.47	Fair
Fleming Creek	Gibb Line West of Morrison Road	2005	6.17	Fairly Poor
Fleming Creek	Kintyre Road	2004	5.01	Fair
Fleming Creek	Kintyre Road	2005	4.60	Good
Fleming Creek	McLean Line	2004	6.12	Fairly Poor
Gentleman Creek	Gentleman Road	2003	5.97	Fairly Poor
Government Drain #2	Drake Road South Hwy 2	2004	6.38	Fairly Poor
Hunt Drain	Townline Road	2005	6.68	Poor
McDougall Drain	McDougall Road North of Hwy 2	2004	7.38	Very Poor
McGregor Creek	At Creek and Maynard Road	2004	6.21	Fairly Poor
McGregor Creek	At Creek and Maynard Road	2005	6.10	Fairly Poor
McGregor Creek Tributary	McLarty Line	2004	6.26	Fairly Poor
Mill Creek	Longwoods Road	2003	5.98	Fairly Poor
Oneida Creek	Ballpark Road	2005	10.00	Very Poor
Raleigh Plains Drain		2004	7.11	Poor
Sharon Creek	Near outlet to Thames	2003	5.22	Fair
Sharon Creek	Upstream of Sharon Creek Reservoir	2004	5.84	Fairly Poor
Thames River	Near Tecumseh Monument	2004	5.19	Fair
Thames River Tributary		2004	5.73	Fair
Thames River Tributary	Trillium Line	2004	6.79	Poor
Thames River Tributary	Hwy 2 East of Glencoe	2004	6.27	Fairly Poor
Thames River Tributary	Corner of McCarthur and Hyndman Roads	2004	7.17	Poor
Thames River Tributary	Celtic Line	2004	5.65	Fair
Thames River Tributary		2003	5.83	Fairly Poor
Thames River Tributary	Fifth Range near Thames River	2005	6.70	Poor
Thames River Tributary	Jubilee Road	2005	5.95	Fairly Poor
Thames River Tributary	Near Dump Site	2003	7.19	Poor
Turkey Creek	River Road	2005	4.02	Excellent
Turkey Creek	Ballpark Road	2003	6.28	Fairly Poor

Table 2.5.3-5: FBI Averages and Stream Health Classifications for 28 UTRCA Subwatersheds

Table 2.5.3-5: FBI Averages and Stream Health Clasifications for 28 UTRCA Subwatersheds for the two report card groupings - 1997-2000 and 2001-2005

Subwatershed	1997-1999		2000-2004	
	FBI	Stream Health	FBI	Stream Health
Avon River	6.01	Fairly Poor	6.22	Fairly Poor
Black Creek	5.60	Fair	4.80	Good
Cedar Creek	7.03	Poor	7.26	Very Poor
Dingman Creek	6.55	Poor	5.54	Fair
Dorchester	5.57	Fair	6.34	Fairly Poor
Fish Creek	6.37	Fairly Poor	5.96	Fairly Poor
Flat Creek	5.77	Fairly Poor	5.81	Fairly Poor
Forks	6.10	Fairly Poor	6.28	Fairly Poor
Glengowan	6.03	Fairly Poor	5.54	Fair
Gregory Creek	5.55	Fair	4.90	Good
Komoka Creek	4.97	Good	5.26	Fair
Medway Creek	5.49	Fair	5.98	Fairly Poor
Middle Thames	5.56	Fair	5.91	Fairly Poor
North Branch / Mud Creek	6.34	Fairly Poor	6.46	Fairly Poor
North Mitchell	6.04	Fairly Poor	6.42	Fairly Poor
North Woodstock	5.77	Fairly Poor	5.57	Fair
Otter Creek	5.79	Fairly Poor	5.80	Fairly Poor
Oxbow Creek	5.28	Fair	5.12	Fair
Plover Mills Corridor	5.15	Fair	5.12	Fair
Pottersburg Creek	6.70	Poor	7.32	Very Poor
Reynolds Creek	6.27	Fairly Poor	6.18	Fairly Poor
River Bend	5.62	Fair	5.98	Fairly Poor
South Thames	6.27	Fairly Poor	6.93	Poor
Stoney Creek	6.41	Fairly Poor	5.91	Fairly Poor
Trout Creek / Wildwood	6.57	Poor	6.78	Poor
Waubuno Creek	5.94	Fairly Poor	5.66	Fair
Whirl Creek	6.30	Fairly Poor	5.62	Fair
Wye Creek	6.13	Fairly Poor	5.77	Fairly Poor

With respect to the preceeding table, the FBI Values are explained in the following: Biotic indices are values assigned to benthic invertebrate taxa indicating their pollution sensitivity and tolerance on a scale from 0 to 10. Lower numbers indicate pollution sensitivity and high numbers indicate pollution tolerance. The Family Biotic Index (FBI) value is the weighted average of the biotic index and number of bugs within each taxa found in the sample. The water quality ranges for the FBI values are as follows: < 4.25 = Excellent; 4.25 - 5.00 = Good; 5.00 - 5.75 = Fair; 5.75 - 6.50 = Fairly Poor; 6.50 - 7.25 = Poor; and > 7.25 = Very Poor.

Table 2.5.3-6: Averaged Benthic Macroinvertebrate Family Biotic Index Values for the UTRCA Subwatersheds

SiteCode	STREAM NAME	LOCATION	Number of Samples	FBIs and Water Quality Categories					
				Average		Best		Worst	
AV01	AVON R	11 KM DOWNSTREAM OF STRATFORD	11	5.72	Fair	4.80	Good	7.19	Poor
AV02	AVON R	APPROX. 10 KM WEST OF STRATFORD	1	6.89	Poor	6.89	Poor	6.89	Poor
AV03	AVON R	2 KM DOWNSTREAM OF STRATFORD	7	7.01	Poor	6.14	Fairly Poor	7.49	Very Poor
AV04	AVON R	FIRST ROAD EAST OF STRATFORD	2	5.83	Fairly Poor	5.73	Fair	5.94	Fairly Poor
AV05	AVON R	4 KM EAST OF STRATFORD	1	5.63	Fair	5.63	Fair	5.63	Fair
AV06	AVON R	8 KM U/S OF STRATFORD	1	7.44	Very Poor	7.44	Very Poor	7.44	Very Poor
AV07	AVON RIVER	DOWNSTREAM OF DAM	1	5.97	Fairly Poor	5.97	Fairly Poor	5.97	Fairly Poor
AV08	AVON RIVER	UPSTREAM OF DAM	1	5.73	Fair	5.73	Fair	5.73	Fair
AV09	AVON R	UPSTREAM OF WEIR	1	5.88	Fairly Poor	5.88	Fairly Poor	5.88	Fairly Poor
AV20	ROADHOUSE DR	LOWER SITE	3	6.29	Fairly Poor	5.42	Fair	7.05	Poor
AV21	ROADHOUSE DR	UPSTREAM SITE	3	6.76	Poor	6.43	Fairly Poor	7.26	Very Poor
AV22	COURT DR	NORTH OF STRATFORD	4	6.49	Fairly Poor	5.56	Fair	6.96	Poor
AV23	COURT DR	EAST END OF STRATFORD	5	6.33	Fairly Poor	5.42	Fair	7.57	Very Poor
AV24	COURT DR TRIB	UPSTREAM, SOUTH OF ROAD	2	6.89	Poor	6.73	Poor	7.04	Poor
AV25	BANNERMAN DR	COURT DR TRIB JUST E OF HWY 19	3	6.67	Poor	6.49	Fairly Poor	6.92	Poor
AV26	CS DRAIN	UPSTREAM SITE - LINE 40	9	5.66	Fair	5.38	Fair	6.02	Fairly Poor
AV27	CS DRAIN	MIDDLE SITE	1	5.87	Fairly Poor	5.87	Fairly Poor	5.87	Fairly Poor
AV28	CS DRAIN	DOWNSTREAM SITE - LINE 37	4	6.51	Poor	5.52	Fair	7.84	Very Poor
AV29	AVON TRIB	MCTAVISH PROPERTY	1	5.41	Fair	5.41	Fair	5.41	Fair
AV30	AVON R TRIB	NEAR CS DRAIN	2	5.14	Fair	4.96	Good	5.33	Fair
BL01	BLACK CR	COUNTY RD NEAR OUTLET	7	4.85	Good	4.43	Good	5.24	Fair
BL02	BLACK CR	FULLARTON/DOWNIE TWP LINE	3	5.51	Fair	5.27	Fair	5.84	Fairly Poor
BL03	BLACK CR	NORTHWEST OF STRATFORD	1	5.67	Fair	5.67	Fair	5.67	Fair
BL04	BLACK CR	NORTH OF STRATFORD	2	5.70	Fair	5.45	Fair	5.96	Fairly Poor
BL21	BLACK CR	W TRIB	3	6.57	Poor	6.37	Fairly Poor	6.67	Poor
BL22	BLACK CR TRIB	E TRIB	3	7.01	Poor	6.70	Poor	7.49	Very Poor
BL23	BLACK CR TRIB	E TRIB U/S SITE	2	6.43	Fairly Poor	6.19	Fairly Poor	6.66	Poor
BL30	Doell Dr	d/s RD 140	2	5.75	Fair	5.56	Fair	5.94	Fairly Poor
BL31	Hartang Drain	u/s Line 36, East crossing of Bk Cr Dr.	2	5.44	Fair	5.17	Fair	5.70	Fair
CE01	CEDAR CR	WESTEND PARK, WOODSTOCK	9	7.07	Poor	5.66	Fair	7.55	Very Poor
CE02	CEDAR CR	WOODSTOCK SOUTHSIDE PARK	4	6.60	Poor	5.46	Fair	7.17	Poor
CE03	CEDAR CR	BUTLER PROPERTY	5	5.92	Fairly Poor	5.25	Fair	6.83	Poor
CE04	CEDAR CR	ABOVE HODGES POND	7	6.04	Fairly Poor	3.71	Excellent	7.77	Very Poor
CE05	CEDAR CR	4 KM ABOVE HODGES POND	1	5.77	Fairly Poor	5.77	Fairly Poor	5.77	Fairly Poor
CE21	MUD CR	BUTLER PROPERTY	3	6.43	Fairly Poor	5.71	Fair	7.29	Very Poor
CE22	SWEABURG DR		1	5.40	Fair	5.40	Fair	5.40	Fair
CE23	CEDAR CR TRIB	UNNAMED SPRING CREEK	1	5.23	Fair	5.23	Fair	5.23	Fair
CE24	CEDAR CR TRIB	AT HWY 59	1	5.32	Fair	5.32	Fair	5.32	Fair
CE25	CEDAR CR TRIB	WORKMAN PROPERTY	2	5.40	Fair	5.23	Fair	5.57	Fair
CE26	CEDAR CR	GARFAT PROPERTY	4	5.60	Fair	5.29	Fair	6.06	Fairly Poor
DI01	DINGMAN CR	NEAR OUTLET	2	5.14	Fair	4.82	Good	5.46	Fair
DI02	DINGMAN CR	AT BRIGHAM RD	9	5.56	Fair	4.39	Good	6.67	Poor
DI03	DINGMAN CR	CORNER OF SOUTHDALE RD AND WESTDEL BOURNE	1	6.79	Poor	6.79	Poor	6.79	Poor

Table 2.5.3-6: Page 1 of 7

SiteCode	STREAM NAME	LOCATION	Number of Samples	FBIs and Water Quality Categories					
				Average		Best		Worst	
DI04	DINGMAN CR	AT CONSERVATION AREA	7	6.05	Fairly Poor	5.50	Fair	6.98	Poor
DI05	DINGMAN CR	NORTHWEST OF LAMBETH	3	6.61	Poor	5.38	Fair	7.38	Very Poor
DI06	DINGMAN CR	NEAR 401 CROSSING	1	6.00	Fairly Poor	6.00	Fairly Poor	6.00	Fairly Poor
DI07	DINGMAN CR	WONDERLAND RD	1	7.45	Very Poor	7.45	Very Poor	7.45	Very Poor
DI08	DINGMAN CR	COLONEL TALBOT RD	1	5.60	Fair	5.60	Fair	5.60	Fair
DI09	DINGMAN CR	EAST OF LAMBETH	2	6.47	Fairly Poor	6.09	Fairly Poor	6.86	Poor
DI10	DINGMAN CR	AT OLD VICTORIA RD	6	5.53	Fair	5.10	Fair	6.34	Fairly Poor
DI11	DINGMAN CR	HWY 74	1	6.66	Poor	6.66	Poor	6.66	Poor
DI12	DINGMAN CR	DOWNSTREAM OF PACK ROAD	1	6.51	Poor	6.51	Poor	6.51	Poor
DI13	DINGMAN CR	DINGMAN RD	1	5.74	Fair	5.74	Fair	5.74	Fair
DI14	DINGMAN CR	D/S OF 401- MCNIECE PROPERTY	1	6.43	Fairly Poor	6.43	Fairly Poor	6.43	Fairly Poor
DI20	ANGUISH CR	NORTH OF LAMBETH	4	6.14	Fairly Poor	5.61	Fair	6.59	Poor
DI21	DINGMAN CR TRIBUTARY	WHITE OAKS RD SOUTH OF EXETER RD	3	6.73	Poor	5.94	Fairly Poor	7.29	Very Poor
DI22	HAMPTON-SCOTT DR	AT JACKSON RD	1	6.94	Poor	6.94	Poor	6.94	Poor
DI23	HAMPTON-SCOTT DR	AT BRADLEY AVE	2	7.40	Very Poor	7.04	Poor	7.76	Very Poor
DI24	DINGMAN TRIB	PACK RD	2	4.78	Good	4.71	Good	4.84	Good
DI30	Cedar Branch	North of Thompson Road	2	5.90	Fairly Poor	5.55	Fair	6.25	Fairly Poor
DI31	Unknown	Westchester and Crampton Roads	2	6.76	Poor	6.24	Fairly Poor	7.28	Very Poor
DO01	S THAMES R	LONDON, HAMILTON AND CLARKE RD	9	5.81	Fairly Poor	4.64	Good	6.53	Poor
DO02	S THAMES R	NORTH OF NILESTOWN	2	4.99	Good	4.55	Good	5.42	Fair
DO03	S THAMES R	EAST OF DORCHESTER	2	5.00	Good	4.87	Good	5.12	Fair
DO20	S THAMES R TRIB	RIVER RD IN SOUTHEAST LONDON	1	5.68	Fair	5.68	Fair	5.68	Fair
DO21	S THAMES R TRIB	IN DORCHESTER C.A.	14	5.32	Fair	2.82	Excellent	7.30	Very Poor
DO22	DORCHESTER CA DRAIN	AT ROAD UPSTREAM OF CAMP	1	5.93	Fairly Poor	5.93	Fairly Poor	5.93	Fairly Poor
DO23	DORCHESTER SWAMP CR TRIB	CULVERT S OF MAIN CHANNEL, UPSTREAM OF POND	5	6.44	Fairly Poor	6.05	Fairly Poor	6.85	Poor
DO24	DORCHESTER SWAMP CR	OFF SLO PITCH RD	8	5.38	Fair	4.93	Good	5.70	Fair
DO25	CADDY CR	EAST OF DORCHESTER	13	4.85	Good	3.85	Excellent	5.34	Fair
DO26	CADDY CR	WEST OF THAMESFORD - 15TH LINE	1	5.59	Fair	5.59	Fair	5.59	Fair
DO29	DORCHESTER SWAMP CR	DOWNSTREAM OF DAM	1	7.23	Poor	7.23	Poor	7.23	Poor
DO30	DORCHESTER SWAMP CR	UPSTREAM OF DAM	2	5.53	Fair	5.39	Fair	5.68	Fair
DO31	S THAMES TRIB	OFF HAMILTON RD	1	5.02	Fair	5.02	Fair	5.02	Fair
DO32	S THAMES TRIB	TOPSOIL PLACE	1	5.36	Fair	5.36	Fair	5.36	Fair
FI01	FISH CR	AT OUTLET WEST OF ST MARY'S	1	5.62	Fair	5.62	Fair	5.62	Fair
FI02	FISH CR	DOWNSTREAM OF PROSPECT HILL RD	6	5.96	Fairly Poor	5.23	Fair	7.38	Very Poor
FI03	FISH CR	SOUTHEAST OF WOODHAM	13	5.69	Fair	4.98	Good	6.75	Poor
FI20	NINETEEN CR	JUST UPSTREAM OF FISH CR	14	5.55	Fair	4.40	Good	7.23	Poor
FI21	NINETEEN CR	UPSTREAM OF COLDSTREAM FARM	3	5.57	Fair	4.57	Good	6.23	Fairly Poor
FI22	FISH CR TRIB	NORTH OF HWY 83	1	5.93	Fairly Poor	5.93	Fairly Poor	5.93	Fairly Poor
FI30	Youngson Creek Drain	Line 2	2	6.25	Fairly Poor	6.03	Fairly Poor	6.47	Fairly Poor
FI31	Watson Drain	Road 164	2	6.31	Fairly Poor	5.68	Fair	6.95	Poor
FL01	FLAT CR	AT OUTLET NEAR SCIENCE HILL	8	5.57	Fair	5.16	Fair	6.04	Fairly Poor
FL02	FLAT CR	AT HWY 23	1	6.58	Poor	6.58	Poor	6.58	Poor
FL03	FLAT CR	SOUTH OF THAMES RD (HWY 83)	1	5.78	Fairly Poor	5.78	Fairly Poor	5.78	Fairly Poor

Table 2.5.3-6: Page 2 of 7

SiteCode	STREAM NAME	LOCATION	Number of Samples	FBIs and Water Quality Categories					
				Average		Best		Worst	
FL04	FLAT CR	UPSTREAM OF THAMES RD	1	5.56	Fair	5.56	Fair	5.56	Fair
FL30	Unknown Drain	W. of Perth Road 163	2	5.12	Fair	5.09	Fair	5.15	Fair
FL31	Harris Drain	At Line 20	2	5.77	Fairly Poor	5.39	Fair	6.15	Fairly Poor
FL32	Unknown Drain	N. of Perth Line 24	2	7.21	Poor	7.20	Poor	7.21	Poor
FL33	Parson Drain	N. of Perth Line 24	2	5.50	Fair	5.25	Fair	5.74	Fair
GL01	N THAMES	S OF SCIENCE HILL	6	5.42	Fair	4.92	Good	6.18	Fairly Poor
GL02	N THAMES R	NEAR SCIENCE HILL	4	5.28	Fair	4.75	Good	5.74	Fair
GL03	N THAMES R	AT MOTHERWELL	2	5.49	Fair	5.13	Fair	5.85	Fairly Poor
GL04	N THAMES R	6 KM SOUTH OF MITCHELL	2	5.45	Fair	5.02	Fair	5.88	Fairly Poor
GL05	N THAMES R	2 KM SOUTH OF MITCHELL	9	5.80	Fairly Poor	5.15	Fair	7.20	Poor
GL20	FULLARTON POND CR	SOUTH OF FULLARTON	1	6.38	Fairly Poor	6.38	Fairly Poor	6.38	Fairly Poor
GL21	NORTH THAMES TRIB	4 KM NORTH OF ST MARYS	1	6.48	Fairly Poor	6.48	Fairly Poor	6.48	Fairly Poor
GL30	N Thames Trib	MB Site	2	4.77	Good	4.24	Excellent	5.30	Fair
GR01	GREGORY CR	AT CHERRY GROVE, NEAR N THAMES OUTLET	10	5.14	Fair	4.52	Good	6.06	Fairly Poor
GR02	GREGORY CR	SOUTHWEST OF ST MARYS	1	5.65	Fair	5.65	Fair	5.65	Fair
GR03	GREGORY CR	AT UNIONDALE	2	5.37	Fair	5.31	Fair	5.43	Fair
GR04	GREGORY TRIB	2KM EAST OF UNIONDALE	2	5.51	Fair	5.33	Fair	5.70	Fair
GR05	GREGORY CR	NEAR OUTLET	4	4.66	Good	4.00	Excellent	5.37	Fair
KO01	KOMOKA CR.	OFF COUNTY RD 14 WEST OF KOMOKA	15	4.56	Good	3.34	Excellent	5.69	Fair
KO02	KOMOKA CR.	OFF COUNTY RD 14 WEST OF KOMOKA	2	4.77	Good	4.74	Good	4.80	Good
ME01	MEDWAY CR	MEDWAY CR AT WINDERMERE RD	13	5.53	Fair	4.96	Good	6.28	Fairly Poor
ME02	MEDWAY CR	4KM N OF ARVA	14	5.38	Fair	4.82	Good	6.30	Fairly Poor
ME03	MEDWAY CR	AT MALLOY PLANT	1	5.81	Fairly Poor	5.81	Fairly Poor	5.81	Fairly Poor
ME04	MEDWAY CR	NEAR OUTLET - UWO	1	4.90	Good	4.90	Good	4.90	Good
ME05	MEDWAY CR	MEDWAY RD- N OF FANSHAWE PK RD	2	5.08	Fair	4.89	Good	5.28	Fair
ME20	SNAKE CR	FOX HOLLOW	3	5.74	Fair	5.28	Fair	6.05	Fairly Poor
ME21	MEDWAY TRIB	FOX HOLLOW	3	7.19	Poor	6.73	Poor	7.51	Very Poor
ME22	MEDWAY TRIB	OFF SUNNINGDALE	1	6.60	Poor	6.60	Poor	6.60	Poor
ME23	MEDWAY CR	EAST TRIB AT ADELAIDE ST	2	5.37	Fair	5.28	Fair	5.46	Fair
ME24	WF DRAIN	ADELAIDE ST E OF BIRR	3	6.33	Fairly Poor	6.23	Fairly Poor	6.41	Fairly Poor
ME25	WF DRAIN	ADELAIDE ST E OF BIRR	3	5.81	Fairly Poor	5.41	Fair	6.42	Fairly Poor
ME26	WF DRAIN	OFF PROSPECT HILL RD	1	7.80	Very Poor	7.80	Very Poor	7.80	Very Poor
ME27	ELGINFIELD DRAIN	BIDDULPH	1	6.73	Poor	6.73	Poor	6.73	Poor
ME30	Mills Drain	Highbury Road	2	7.42	Very Poor	7.26	Very Poor	7.58	Very Poor
ME31	Fish Creek	Road 164	1	5.53	Fair	5.53	Fair	5.53	Fair
ME32	McClary Dr	Medway Rd, roadside	2	5.66	Fair	5.43	Fair	5.89	Fairly Poor
ME33	Elginfield Dr	u/s Stonehouse Rd	2	6.46	Fairly Poor	6.34	Fairly Poor	6.57	Poor
ME34	Unknown Drain	u/s Eight Mile Road, W of Hyde Park Road	3	6.08	Fairly Poor	5.54	Fair	7.13	Poor
MI01	M THAMES R	NEAR OUTLET	2	5.77	Fairly Poor	5.19	Fair	6.35	Fairly Poor
MI02	M THAMES R	3 KM SOUTH OF THAMESFORD	4	5.63	Fair	5.24	Fair	5.84	Fairly Poor
MI03	M THAMES R	2 KM SOUTH OF THAMESFORD	5	5.25	Fair	4.69	Good	5.66	Fair
MI04	M THAMES R	AT THAMESFORD	1	5.84	Fairly Poor	5.84	Fairly Poor	5.84	Fairly Poor
MI05	M THAMES R	NORTHEAST OF THAMESFORD	2	5.18	Fair	5.18	Fair	5.18	Fair

Table 2.5.3-6: Page 3 of 7

SiteCode	STREAM NAME	LOCATION	Number of Samples	FBIs and Water Quality Categories					
				Average		Best		Worst	
MI06	M THAMES R	NORTH OF THAMESFORD	1	6.14	Fairly Poor	6.14	Fairly Poor	6.14	Fairly Poor
MI07	M THAMES R	CTY RD 6 S OF EMBRO	5	5.89	Fairly Poor	5.09	Fair	6.59	Poor
MI20	KINTORE CR	SOUTHEAST OF KINTORE	9	5.71	Fair	4.80	Good	7.10	Poor
MI21	KINTORE CR TRIB	W TRIB, NW OF KINTORE	5	5.73	Fair	4.27	Good	6.85	Poor
MI22	KINTORE CR TRIB	E TRIB E OF KINTORE	2	5.95	Fairly Poor	5.84	Fairly Poor	6.05	Fairly Poor
MI23	NISSOURI CR	WEST OF EMBRO	9	6.03	Fairly Poor	5.26	Fair	7.41	Very Poor
MI24	MURRAY DRAIN	ROAD 74	7	6.52	Poor	5.77	Fairly Poor	7.13	Poor
MI30	Graham-Steele Drain	Road 78	2	5.11	Fair	4.91	Good	5.30	Fair
MU01	MUD CR	SOUTHEAST OF EMBRO	5	6.50	Poor	5.61	Fair	7.21	Poor
MU02	MUD CR	UPSTREAM SITE	1	7.09	Poor	7.09	Poor	7.09	Poor
MU03	MUD CR	AT ZORRA TWP LINE	2	6.15	Fairly Poor	5.93	Fairly Poor	6.38	Fairly Poor
MU20	NORTH BRANCH CR	SOUTH OF EMBRO	8	5.90	Fairly Poor	5.03	Fair	7.30	Very Poor
MU21	NORTH BRANCH CR	NORTH OF EMBRO	2	6.05	Fairly Poor	5.49	Fair	6.60	Poor
MU22	NORTH BRANCH CR. TRIB	BROOKSIDE	1	5.74	Fair	5.74	Fair	5.74	Fair
MU23	NORTH BRANCH CR TRIB		1	7.64	Very Poor	7.64	Very Poor	7.64	Very Poor
MU24	YOUNGSVILLE DR	35TH LINE	1	6.26	Fairly Poor	6.26	Fairly Poor	6.26	Fairly Poor
MU30	Hollock Drain	10th Line	2	5.80	Fairly Poor	5.50	Fair	6.11	Fairly Poor
MU31	North Branch Creek	41st Line	2	6.12	Fairly Poor	5.55	Fair	6.69	Poor
NM00	N THAMES R	BELOW MITCHELL DAM	2	6.52	Poor	5.47	Fair	7.57	Very Poor
NM01	NORTH THAMES	4 KM ABOVE MITCHELL	5	6.26	Fairly Poor	5.40	Fair	7.56	Very Poor
NM02	N THAMES R	NORTHWEST OF MITCHELL	1	6.39	Fairly Poor	6.39	Fairly Poor	6.39	Fairly Poor
NM20	N THAMES TRIB	HWY 23 NORTH OF MITCHELL	5	5.72	Fair	5.40	Fair	6.46	Fairly Poor
NM21	N THAMES	WEST TRIB	1	7.65	Very Poor	7.65	Very Poor	7.65	Very Poor
NM22	N THAMES TRIB	SOUTHWEST OF MONKTON	3	5.72	Fair	5.34	Fair	6.25	Fairly Poor
NM23	NORTH THAMES TRIB	W OF BORNHOLM	1	6.68	Poor	6.68	Poor	6.68	Poor
NM24	N THAMES R	NORTH OF BROADHAGEN	1	6.26	Fairly Poor	6.26	Fairly Poor	6.26	Fairly Poor
NM30	Logan Road Drain	S.W. Line 42	2	5.52	Fair	4.76	Good	6.27	Fairly Poor
NM31	Branch D	N. Line 46, W. Road 155	2	7.51	Very Poor	7.32	Very Poor	7.70	Very Poor
NW01	S THAMES R	AT INNERKIP	14	5.26	Fair	4.17	Excellent	6.75	Poor
NW02	S THAMES R DRAIN	SOUTH OF TAVISTOCK	8	6.34	Fairly Poor	5.50	Fair	7.03	Poor
NW20	PHELAN CR	2ND ROAD WEST OF OUTLET	8	6.32	Fairly Poor	5.24	Fair	7.31	Very Poor
NW21	PHELAN CR	NORTHWEST OF INNERKIP	1	5.34	Fair	5.34	Fair	5.34	Fair
NW22	PHELAN CR TRIB	NORTHWEST OF INNERKIP	1	5.60	Fair	5.60	Fair	5.60	Fair
NW23	S THAMES R TRIB	OXFORD/PERTH LINE WEST OF TAVISTOCK	2	5.33	Fair	5.26	Fair	5.41	Fair
NW24	LOCKHART POND	EAST OF WOODSTOCK	1	7.09	Poor	7.09	Poor	7.09	Poor
NW25	S THAMES TRIB - Hohner Dr	D/S OF FISH KILL	2	7.59	Very Poor	7.31	Very Poor	7.88	Very Poor
NW26	S THAMES TRIB - Hohner Dr	U/S OF FISH KILL	1	7.84	Very Poor	7.84	Very Poor	7.84	Very Poor
NW30	Lampman-Lock Drain	E of Oxford Road 4, N of Township Road :	2	6.14	Fairly Poor	5.67	Fair	6.62	Poor
NW31	Unknown	Other CA	2	4.83	Good	4.62	Good	5.03	Fair
OT01	OTTER CR	2 KM NORTH OF ST MARYS	14	5.49	Fair	4.80	Good	6.79	Poor
OT02	OTTER CR	DOWNIE RD	1	6.88	Poor	6.88	Poor	6.88	Poor
OT03	OTTER CR	ST PAULS RD & HWY 7	1	6.53	Poor	6.53	Poor	6.53	Poor
OX01	OXBOW CR.	NEAR THAMES OUTLET	13	4.75	Good	3.90	Excellent	5.45	Fair

Table 2.5.3-6: Page 4 of 7

SiteCode	STREAM NAME	LOCATION	Number of Samples	FBIs and Water Quality Categories					
				Average		Best		Worst	
OX02	OXBOW CR.	E OF KOMOKA	1	5.81	Fairly Poor	5.81	Fairly Poor	5.81	Fairly Poor
OX03	OXBOW CR	DENFIELD RD	2	5.41	Fair	5.35	Fair	5.47	Fair
OX04	OXBOW CR	8 MILE RD	2	6.13	Fairly Poor	6.06	Fairly Poor	6.21	Fairly Poor
OX05	OXBOW CR	HYDE PARK RD	2	5.88	Fairly Poor	5.63	Fair	6.13	Fairly Poor
OX06	OXBOW CR	VANNECK RD, KILWORTH	1	5.97	Fairly Poor	5.97	Fairly Poor	5.97	Fairly Poor
OX07	OXBOW CR	12 MILE RD	1	5.78	Fairly Poor	5.78	Fairly Poor	5.78	Fairly Poor
OX08	OXBOW CR	10 MILE RD	1	6.08	Fairly Poor	6.08	Fairly Poor	6.08	Fairly Poor
OX09	OXBOW CR	U/S OF EGREMONT RD	1	5.21	Fair	5.21	Fair	5.21	Fair
OX10	OXBOW CR	OXBOW RD - E CROSSING	1	5.89	Fairly Poor	5.89	Fairly Poor	5.89	Fairly Poor
OX21	OXBOW CR TRIB	12 MILE RD	1	5.39	Fair	5.39	Fair	5.39	Fair
PL01	N THAMES R	WEST OF THORNDALE	13	4.72	Good	3.76	Excellent	5.84	Fairly Poor
PL02	N THAMES R	NEAR PLOVER MILLS	1	5.13	Fair	5.13	Fair	5.13	Fair
PL03	N THAMES R	AT HWY 7	3	5.42	Fair	5.17	Fair	5.66	Fair
PL04	N THAMES R	DOWNSTREAM OF ST. MARYS	8	5.70	Fair	5.07	Fair	6.54	Poor
PL05	N THAMES R	AT ST. MARYS PARK ST BRIDGE	1	5.60	Fair	5.60	Fair	5.60	Fair
PL20	NORTH THAMES TRIB	SOUTH OF RANNOCH	2	5.49	Fair	5.44	Fair	5.54	Fair
PL21	NORTH THAMES TRIB	WEST OF RANNOCH	1	5.43	Fair	5.43	Fair	5.43	Fair
PL22	STORMWATER DR	OFF FANSHAWE CA ADMIN PARKING LOT	1	6.11	Fairly Poor	6.11	Fairly Poor	6.11	Fairly Poor
PL30	Summerville Drain	Perth Road 139	2	5.39	Fair	5.18	Fair	5.59	Fair
PL31	Needham-Moir Drain	Plover Mills Road	2	5.42	Fair	4.68	Good	6.15	Fairly Poor
PO01	POTTERSBURG CR	AT HAMILTON RD	8	6.60	Poor	5.63	Fair	7.91	Very Poor
PO02	POTTERSBURG CR	RELOCATION SITE	2	5.37	Fair	5.35	Fair	5.40	Fair
RE01	REYNOLDS CREEK	SOUTH OF PUTNAM	8	6.05	Fairly Poor	5.26	Fair	7.56	Very Poor
RE02	REYNOLDS CR	WEST OF MT ELGIN	2	6.50	Poor	5.78	Fairly Poor	7.23	Poor
RE03	REYNOLDS CR	EBENEZER RD - MIDDLE CROSSING	1	7.86	Very Poor	7.86	Very Poor	7.86	Very Poor
RE20	FIVE POINT CR	BETWEEN FORKS IN ROAD	2	5.96	Fairly Poor	5.76	Fairly Poor	6.17	Fairly Poor
RE21	FIVE POINT CR	EAST OF PUTNAM	3	4.91	Good	4.39	Good	5.27	Fair
RE30	Warren Drain	Ebenezer Road	2	6.67	Poor	5.84	Fairly Poor	7.50	Very Poor
RI01	THAMES R	AT DELAWARE	8	5.36	Fair	4.29	Good	6.34	Fairly Poor
RI02	THAMES R	AT KOMOKA	8	5.67	Fair	5.02	Fair	7.07	Poor
RI03	THAMES R	AT KILWORTH	8	5.42	Fair	4.84	Good	6.12	Fairly Poor
RI20	UNKNOWN DR	NEAR OUTLET	3	7.23	Poor	6.79	Poor	7.65	Very Poor
RI21	STANTON DR	OFF GAINSBOROUGH - EAST TRIB	7	6.51	Poor	6.07	Fairly Poor	7.28	Very Poor
RI22	KELLY DR	AT GAINSBOROUGH	1	5.64	Fair	5.64	Fair	5.64	Fair
RI23	THAMES TRIB	AT EASTER CAMP	3	5.10	Fair	4.59	Good	5.38	Fair
RI24	THAMES TRIB	COMMISSIONERS RD	3	4.33	Good	3.83	Excellent	4.84	Good
RI25	STANTON DR	DOWNSTREAM SITE	3	3.51	Excellent	1.81	Excellent	5.09	Fair
SO01	S THAMES R	DOWNSTREAM OF INGERSOLL	8	6.35	Fairly Poor	5.32	Fair	7.11	Poor
SO02	S THAMES R	IN INGERSOL	2	5.57	Fair	4.98	Good	6.16	Fairly Poor
SO03	S THAMES R	EAST SIDE OF INGERSOLL	1	5.42	Fair	5.42	Fair	5.42	Fair
SO04	S THAMES R	AT BEACHVILLE	1	5.62	Fair	5.62	Fair	5.62	Fair
SO05	S THAMES R	DOWNSTREAM OF WOODSTOCK	3	6.65	Poor	5.43	Fair	7.51	Very Poor
SO06	S THAMES R	AT WOODSTOCK	1	5.64	Fair	5.64	Fair	5.64	Fair

Table 2.5.3-6: Page 5 of 7

SiteCode	STREAM NAME	LOCATION	Number of Samples	FBIs and Water Quality Categories: Average		Best		Worst	
SO20	WHITING CREEK	NEAR OUTLET	2	6.75	Poor	6.46	Fairly Poor	7.04	Poor
SO21	HALLS CR	AT HWY 19 AND WATER ST	2	6.45	Fairly Poor	6.22	Fairly Poor	6.67	Poor
SO22	HALLS CR	BEHIND ELMHURST INN	4	6.10	Fairly Poor	5.59	Fair	6.74	Poor
SO23	HALLS CR	AT MAYBERRY FARM	1	5.69	Fair	5.69	Fair	5.69	Fair
SO24	HALLS CR	1ST BRIDGE UPSTREAM OF MAYBERRY FARM	1	7.07	Poor	7.07	Poor	7.07	Poor
SO25	HALLS CR	DOWNSTREAM OF ABATTOIR	1	5.45	Fair	5.45	Fair	5.45	Fair
SO26	HALLS CR	UPSTREAM OF ABATTOIR	2	5.67	Fair	5.28	Fair	6.07	Fairly Poor
SO27	HALLS CR	DOWNSTREAM OF ABATTOIR	1	7.56	Very Poor	7.56	Very Poor	7.56	Very Poor
SO28	FOLDENS CR	NORTH END OF CENTREVILLE	2	5.93	Fairly Poor	5.90	Fairly Poor	5.97	Fairly Poor
SO29	FOLDENS CREEK	SOUTH OF HWY 401	6	5.73	Fair	5.40	Fair	6.23	Fairly Poor
SO30	SALLY'S CR	NORTHWEST OF WOODSTOCK	5	5.79	Fairly Poor	5.24	Fair	6.33	Fairly Poor
SO31	SALLY'S CR TRIB	NORTHWEST OF WOODSTOCK	12	5.12	Fair	4.62	Good	5.67	Fair
SO32	HALLS CR	HWY 19	1	5.41	Fair	5.41	Fair	5.41	Fair
SO33	HALLS CR	INGERSOLL	1	5.31	Fair	5.31	Fair	5.31	Fair
SO34	SALLYS CR	NEAR OUTLET	5	5.41	Fair	4.95	Good	6.20	Fairly Poor
SO35	PATTERSON-ROBBINS DR	E OF INGERSOLL	1	5.49	Fair	5.49	Fair	5.49	Fair
SO36	ARMSTRONG PARK CR	WOODSTOCK - NEW CREEK	6	7.09	Poor	6.74	Poor	7.56	Very Poor
ST01	STONEY CR	NEAR ELMDALE FOOTBRIDGE	4	6.13	Fairly Poor	5.68	Fair	6.57	Poor
ST02	STONEY CR	D/S OF TROSSACKS AVE	8	5.89	Fairly Poor	5.36	Fair	6.72	Poor
ST03	STONEY CR	SOUTH CROSSING OF HIGHBURY	1	6.07	Fairly Poor	6.07	Fairly Poor	6.07	Fairly Poor
ST04	STONEY CR	WEST OF HIGHBURY - BAPTIST CHURCH SITE	1	5.43	Fair	5.43	Fair	5.43	Fair
ST05	STONEY CR	AT WINDERMERE RD	2	5.57	Fair	5.45	Fair	5.68	Fair
ST20	POWELL DR	DOWNSTREAM OF BRIDGE AT ADELAIDE	5	6.11	Fairly Poor	5.17	Fair	7.03	Poor
ST21	FORAN-GOUGH DR	STONEY CR TRIB	8	4.85	Good	1.54	Excellent	5.84	Fairly Poor
ST22	STONEY CR	EAST BRANCH AT SUNNINGDALE RD	1	5.72	Fair	5.72	Fair	5.72	Fair
TF01	THAMES R	WEST END OF OXFORD ST - D/S OF STP	5	6.20	Fairly Poor	5.21	Fair	7.19	Poor
TF02	THAMES R	WEST END OF OXFORD ST	5	6.24	Fairly Poor	5.32	Fair	7.04	Poor
TF03	THAMES R	IN SPRINGBANK PARK	1	5.63	Fair	5.63	Fair	5.63	Fair
TF07	S THAMES R	OFF WATSON ST.	10	5.62	Fair	4.82	Good	7.16	Poor
TF08	S THAMES R	SOUTHEAST OF CORNER OF HIGHBURY & HAMILTON	1	5.30	Fair	5.30	Fair	5.30	Fair
TF11	N THAMES R	LONDON AT EAST END OF WINDERMERE RD	4	5.74	Fair	5.35	Fair	6.29	Fairly Poor
TF12	N THAMES R	AT CLARKE RD	3	6.11	Fairly Poor	5.77	Fairly Poor	6.57	Poor
TF13	N THAMES R	BELOW FANSHAWE RESERVOIR	3	5.58	Fair	5.17	Fair	6.17	Fairly Poor
TF14	N THAMES	D/S BLACKFRIARS	2	5.18	Fair	5.05	Fair	5.31	Fair
TF20	MCNAY DR	NEAR OUTLET	3	6.38	Fairly Poor	5.59	Fair	7.51	Very Poor
TF21	MCNAY DR	UPSTREAM OF GABIONS	1	6.73	Poor	6.73	Poor	6.73	Poor
TF22	MCNAY DR	U/S SITE IN SCHOOLYARD	2	7.32	Very Poor	7.08	Poor	7.56	Very Poor
TF23	THE COVES	W BRANCH N OF SPRINGBANK DR	1	7.37	Very Poor	7.37	Very Poor	7.37	Very Poor
TF24	THE COVES	MAIN RAVINE	1	7.23	Poor	7.23	Poor	7.23	Poor
TF25	THE COVES	SOUTH RAVINE	1	5.66	Fair	5.66	Fair	5.66	Fair
TF26	THE COVES	STREAM - UPSTREAM SITE	1	7.61	Very Poor	7.61	Very Poor	7.61	Very Poor
TF27	THE COVES	STREAM DOWNSTREAM SITE	1	6.92	Poor	6.92	Poor	6.92	Poor
TR01	TROUT CR	BETWEEN WILDWOOD AND ST MARYS	1	6.51	Poor	6.51	Poor	6.51	Poor

Table 2.5.3-6: Page 6 of 7

SiteCode	STREAM NAME	LOCATION	Number of Samples	FBIs and Water Quality Categories: Average		Best		Worst	
TR02	TROUT CR	PERTH CNTY RD 9	6	6.96	Poor	6.30	Fairly Poor	7.72	Very Poor
TR03	TROUT CR	BELOW WILDWOOD RESERVOIR	1	6.34	Fairly Poor	6.34	Fairly Poor	6.34	Fairly Poor
TR04	TROUT CR	TOWNSHIP LINE UPSTREAM OF RESERVOIR	3	6.43	Fairly Poor	6.05	Fairly Poor	6.63	Poor
TR05	TROUT CR	AT COUNTY RD. 20	8	6.22	Fairly Poor	5.47	Fair	7.64	Very Poor
TR06	TROUT CR	AT DUMP RD	1	7.39	Very Poor	7.39	Very Poor	7.39	Very Poor
TR07	TROUT CR	BELOW JUNCTION OF MAIN TRIBS	2	6.01	Fairly Poor	5.91	Fairly Poor	6.11	Fairly Poor
TR20	WILDWOOD CA CREEK	WILDWOOD CA	6	4.16	Excellent	1.96	Excellent	5.85	Fairly Poor
TR21	HARRINGTON CR	NEAR HARRINGTON	10	4.63	Good	4.06	Excellent	5.40	Fair
TR22	TROUT CR TRIB	EAST OF HARRINGTON	2	5.20	Fair	5.15	Fair	5.25	Fair
TR23	TROUT CR TRIB	UPSTREAM OF WILDWOOD	3	5.61	Fair	5.51	Fair	5.74	Fair
TR24	TROUT CR TRIB	T JACKSON PROPERTY	1	5.71	Fair	5.71	Fair	5.71	Fair
TR25	KERR-LUPTON DR	WEST OF TAVISTOCK	1	5.66	Fair	5.66	Fair	5.66	Fair
TR26	TROUT CR TRIB	E OF WILDWOOD	1	5.27	Fair	5.27	Fair	5.27	Fair
TR27	HARMONY CR	EAST OF HARMONY	2	5.53	Fair	5.11	Fair	5.96	Fairly Poor
TR28	ROLSTON DR	ST MARYS	1	3.70	Excellent	3.70	Excellent	3.70	Excellent
TR30	Kerr-Lupman Drain Branch D	45th Line	2	6.25	Fairly Poor	5.70	Fair	6.80	Poor
TR31	John Green Drain	u/s Road 96	2	6.54	Poor	6.01	Fairly Poor	7.06	Poor
WA01	WAUBUNO CR	GORE RD EAST OF LONDON	3	5.22	Fair	4.94	Good	5.36	Fair
WA02	WAUBUNO CR	EAST OF LONDON AT TRAFALGAR RD	7	5.74	Fair	5.02	Fair	7.00	Poor
WA03	WAUBUNO CR	SOUTHEAST OF THORNDALE	1	6.14	Fairly Poor	6.14	Fairly Poor	6.14	Fairly Poor
WA04	WAUBUNO CR	SOUTHEAST OF THORNDALE	2	4.96	Good	4.90	Good	5.01	Fair
WA05	WAUBUNO CR	UKRAINE CLUB	1	4.95	Good	4.95	Good	4.95	Good
WA06	WAUBUNO CR	U/S OF R16	3	5.34	Fair	5.03	Fair	5.68	Fair
WA20	WAUBUNO CR	UPSTREAM AT 15TH LINE	1	5.81	Fairly Poor	5.81	Fairly Poor	5.81	Fairly Poor
WA21	WAUBUNO CR	WHYTON RD (E TRIB)	1	5.09	Fair	5.09	Fair	5.09	Fair
WA22	WAUBUNO CR	OLIVER RD	1	6.86	Poor	6.86	Poor	6.86	Poor
WH01	WHIRL CR	EAST OF MITCHELL	9	5.66	Fair	4.91	Good	6.82	Poor
WH02	WHIRL CR	NORTHEAST OF MITCHELL	3	6.07	Fairly Poor	5.71	Fair	6.54	Poor
WH03	WHIRL CR	HWY 8 - D. FISHER SITE	2	5.98	Fairly Poor	5.52	Fair	6.44	Fairly Poor
WH30	Michiel's Drain	u/s Rd 145	2	4.32	Good	2.78	Excellent	5.86	Fairly Poor
WH31	Whirl Cr Drain	u/s Line 39	2	6.95	Poor	6.95	Poor	6.96	Poor
WY01	WYE CR	NEAR FANSHAWE RESERVOIR	10	5.45	Fair	4.27	Good	6.70	Poor
WY02	WYE CR	AT OLIVER DR	1	6.67	Poor	6.67	Poor	6.67	Poor
WY30	Elliot Drain	Heritage Road	2	5.76	Fairly Poor	5.70	Fair	5.83	Fairly Poor
WY31	Wye Creek W. Trib	Fairview Road	2	5.77	Fairly Poor	5.67	Fair	5.86	Fairly Poor
WY32	Wye Creek E. Trib	Fairview Road	2	5.74	Fair	5.26	Fair	6.22	Fairly Poor

With respect to the preceeding table, the Family Biotic Index Values are explained in the following:

Biotic indices are values assigned to benthic invertebrate taxa indicating their pollution sensitivity and tolerance on a scale from 0 to 10. Lower numbers indicate pollution sensitivity and high numbers indicate pollution tolerance. The Family Biotic Index (FBI) value is the weighted average of the biotic index and number of bugs within each taxa found in the sample. The water quality ranges for the FBI values are as follows: < 4.25 = Excellent; 4.25 - 5.00 = Good; 5.00 - 5.75 = Fair; 5.75 - 6.50 = Fairly Poor; 6.50 - 7.25 = Poor; > 7.25 = Very Poor.

Table 2.5.3-6: Page 7 of 7

These tables indicate a moderate level of water quality impairment throughout the upper Thames watershed with most sites occurring in the "fair" or "fairly poor" categories. Major improvements such as were evident on Dingman Creek and Black Creek may indicate positive land use changes, the removal of a pollution point-source, effective application of remedial activities, or a combination of these. Negative changes evident in the Pottersburg and Meadowlily/Dorchester subwatersheds may have resulted from spills, new pollution sources, extensive development or negative land use changes. Most of the other changes between the two time periods (2000-2005) are relatively minor and could likely be attributed to land use changes or environmental conditions. The latter could include low flow (drought) conditions or atypical flows (i.e. lack of a spring runoff event, summer flooding).

In addition to annual sampling of the subwatershed sites, a representative set of reference or "least impacted" sites is sampled twice annually. Other samples monitor the effects of stream rehabilitation projects, gather baseline data for developing areas, or monitor the impacts of development or other potential stressors. Approximately 100 samples are collected annually from about 80 sites in the UTRCA watershed. Sampling is conducted in both the spring and the fall, and analyzed at the UWO benthic lab, usually the subsequent winter. This program allows for comparisons between similar watercourses and habitat types, provides baseline information and monitors long-term trends.

The UTRCA's benthic monitoring program is also associated with the Ontario Benthos Biomonitoring Network (OBBN)[141]. This provincial program provides consistent monitoring protocols to assess aquatic ecosystems. OBBN protocol development was led by the Ontario Ministry of the Environment, with federal, provincial, conservation authority, and academic input and partnership. As the OBBN develops, comparisons with other streams and rivers throughout Ontario will be possible and more detailed analysis of the samples facilitated.[142]

Other sampling programs

The City of London also conducts benthic monitoring within the municipal boundaries of the city. This information is available in a report that is prepared each year. However, the City utilizes a protocol that differs from the UTRCA's protocol and the provincial protocol. Regardless of the differing methodology and analysis the information helps to provide historical and baseline information.

The OMNR historically collected benthic samples throughout the Thames River watershed. Unfortunately, these samples have not been analyzed to provide an indication of water quality.

The OMOE has recently sampled two upper Thames sites as part of a provincial nutrient handling monitoring initiative.

Data Gap - Aquatic Macroinvertebrates

An analysis of the physiography and land use at cold headwater streams and in their upstream catchment areas may allow identification of other potential cold water communities. Similar areas that do not support cold water communities could be investigated for groundwater quality or quantity stressors and impacts.

There are several other indices that could be utilized to further indicate habitat conditions and water quality. The Simpson's Diversity index is one example to consider for further benthic analysis.

2.5.4 Species At Risk (SAR)

The Thames River & Region is rich in aquatic life and has a number of aquatic species that are listed as Extirpated, Endangered, Threatened or Special Concern. The Committee on the Status of Endangered

[141] UTRCA. 2004. UTRCA Water Report.
[142] UTRCA. 2004. UTRCA Water Report.

Wildlife in Canada (COSEWIC) assigns status to species according to the Species at Risk Act (SARA) of Canada.

COSEWIC wildlife species definition and status categories[143] are defined as follows:

- **Wildlife Species** – A species, subspecies, variety or geographically or genetically distinct population of animal, plant or other organism, other than a bacterium or virus, that is wild by nature and is either native to Canada or has extended its range into Canada without human intervention and has been present in Canada for at least 50 years.
- **Extinct (X)** – A wildlife species that no longer exists.
- **Extirpated (XT)** – A wildlife species no longer existing in the wild in Canada, but occurring elsewhere.
- **Endangered (E)** –A wildlife species facing imminent extirpation or extinction.
- **Threatened (T)** – A wildlife species likely to become endangered if limiting factors are not reversed.
- **Special Concern (SC)** – A wildlife species that may become a threatened or an endangered species because of a combination of biological characteristics and identified threats.
- **Data Deficient (DD)** – Category that applies when the available information is insufficient (a) to resolve a wildlife species' eligibility for assessment or (b) to permit an assessment of the wildlife species' risk of extinction.

In the Thames River watershed, 27 aquatic species found have been identified as having Species at Risk (SAR) status. Lake Erie, and the many tributaries that flow into it, also have approximately 19 species of fish, six species of freshwater mussels and 13 species of reptiles and amphibians listed. **Table 2.5.4.1: Aquatic SAR in the Thames River Watershed** and **Table 2.5.4-2: Aquatic SAR in the Lake Erie Tributary Watershed** provide summaries of the Species At Risk for these areas. Some of the species that historically were found in Thames River or Lake Erie have not been found there for many years. **Map 29: Species At Risk** provides an overview of the number of species in the local subwatersheds. A brief outline of SAR studies for the Thames River and Lake Erie is provided below. Most of the discussion in this report will focus on the Thames River since it has received the most intensive examination.

[143] Committee on the Status of Endangered Wildlife in Canada website. www.cosewic.gc.ca

Table 2.5.4-1: Aquatic SAR in the Thames River Watershed

Common Name	Scientific Name	COSEWIC Status	Provincial Rank	Global Rank	Status in Watershed
Reptiles					
Spiny Softshell	*Apalone spinifera*	Threatened	S3	G5	Reduced range, may be declining
Northern Map Turtle	*Graptemys geographica*	Special Concern	S3	G5	Locally common, under pressure
Northern Ribbonsnake	*Thamnophis sauritus septentrionalis*	Special Concern	S3	G5	Rare
Queen Snake	*Regina septemvitatta*	Threatened	S2	G5	Reduced Range, declining population
Blanding's Turtle	*Emys (Emydoidea) blandingii*	Threatened	S3	G4	Rare
Spotted Turtle	*Clemmys guttata*	Endangered	S3	G5	May be extirpated or very rare
Stinkpot Turtle	*Sternotherus odoratus*	Threatened	S3	G5	May be extirpated
Fish					
Bigmouth Buffalo	*Ictiobus cyprinellus*	Special Concern	SU	G5	Rare, may be expanding range
Black Buffalo	*Ictiobus niger*	Special Concern	SU	G5	Recent unconfirmed record
Black Redhorse	*Moxostoma duquesnei*	Threatened	S2	G5	Rare, localised
Eastern Sand Darter	*Ammocrypta pellucida*	Threatened	S2	G3	Uncommon, localized
Gravel Chub	*Ermystax x-punctatus*	Extirpated	SX	G4	Presumed extirpated
Greenside Darter	*Etheostoma blennioides*	Special Concern	S4	G5	Common, widespread
Lake Chubsucker	*Erimyzon sucetta*	Threatened	S2	G5	Rare, localized
Northern Brook Lamprey	*Icthyomyzon fossor*	Special Concern	S3	G4	Rare, localized
Northern Madtom	*Noturus stigmosus*	Endangered	S1S2	G3	Rare, localized
Pugnose Minnow	*Opsopoeodus emiliae*	Special Concern	S2	G5	Rare, localized, may be extirpated
River Redhorse	*Moxostoma carinatum*	Special Concern	S2	G4	One recent record only
Silver Shiner	*Notropis photogenis*	Special Concern	S2S3	G5	Locally common
Spotted Sucker	*Minytrema melanops*	Special Concern	S2	G5	Uncommon, localized, may be expanding in range
Mussels					
Kidneyshell	*Ptychobranchus fasciolaris*	Endangered	S1	G4G5	Very rare
Mudpuppy Mussel	*Simpsonaias ambigua*	Endangered	S1	G3	Presumed extirpated
Rayed Bean	*Villosa fabalis*	Endangered	S1	G1G2	Very rare
Round Hickorynut	*Obovaria subrotunda*	Endangered	S1	G4	Presumed extirpated
Round Pigtoe	*Pleurobema sintoxia*	Endangered	S2	G4	Rare
Snuffbox	*Epioblasma triquetra*	Endangered	S1	G3	Presumed extirpated
Wavy-rayed lampmussel	*Lampsilis fasciola*	Endangered	S1	G4	Stable

With respect to Table 2.5.4-1 and Table 2.5.4-2, the terms are described as:

COSEWIC Status: Status assigned by the Committee on the Status of Endangered Wildlife in Canada for the Species at Risk Act (SARA).

- **Extinct (X)** – A wildlife species that no longer exists.
- **Extirpated (XT)** – A wildlife species no longer existing in the wild in Canada, but occurring elsewhere.
- **Endangered (E)** – A wildlife species facing imminent extirpation or extinction
- **Threatened (T)** – A wildlife species likely to become endangered if limiting factors are not reversed
- **Special Concern (SC)** – A wildlife species that may become a threatened or an endangered species because of a combination of biological characteristics and identified threats.

Provincial Rank (SRANK): Provincial (or Subnational) ranks are used by the Natural Heritage Information Centre to set protection priorities for rare species and natural communities. These ranks are not legal designations. Provincial ranks are assigned in a manner similar to that described for global ranks, but consider only those factors within the political boundaries of Ontario. By comparing the global and provincial ranks, the status, rarity, and the urgency of conservation needs can be ascertained. The NHIC evaluates provincial ranks on a continual basis and produces updated lists at least annually. The NHIC welcomes information that will assist in assigning accurate provincial ranks.

S1 Extremely rare in Ontario; usually 5 or fewer occurrences in the province or very few remaining individuals; often especially vulnerable to extirpation.

S2 Very rare in Ontario; usually between 5 and 20 occurrences in the province or with many individuals in fewer occurrences; often susceptible to extirpation.

S3 Rare to uncommon in Ontario; usually between 20 and 100 occurrences in the province; may have fewer occurrences, but with a large number of individuals in some populations; may be susceptible to large-scale disturbances. Most species with an S3 rank are assigned to the watch list, unless they have a relatively high global rank.

S4 Common and apparently secure in Ontario; usually with more than 100 occurrences in the province.

S5 Very common and demonstrably secure in Ontario.

SE Exotic; not believed to be a native component of Ontario's flora.

S? Unranked, or, if following a ranking, rank uncertain (e.g. S3?). S? species are thought to be rare in Ontario, but there is insufficient information available to assign a more accurate rank.

Global Rank (GRANK): Global ranks are assigned by a consensus of the network of natural heritage programs (conservation data centres), scientific experts, and The Nature Conservancy to designate a rarity rank based on the range-wide status of a species, subspecies or variety. The most important factors considered in assigning global (and provincial) ranks are the total number of known, extant sites world-wide, and the degree to which they are potentially or actively threatened with destruction. Other criteria include the number of known populations considered to be securely protected, the size of the various populations, and the ability of the taxon to persist at its known sites. The taxonomic distinctness of each taxon has also been considered. Hybrids, introduced species, and taxonomically dubious species, subspecies and varieties have not been included.

G1 Extremely rare; usually 5 or fewer occurrences in the overall range or very few remaining individuals; or because of some factor(s) making it especially vulnerable to extinction.

G2 Very rare; usually between 5 and 20 occurrences in the overall range or with many individuals in fewer occurrences; or because of some factor(s) making it vulnerable to extinction.

G3 Rare to uncommon; usually between 20 and 100 occurrences; may have fewer occurrences, but with a large number of individuals in some populations; may be susceptible to large-scale disturbances.

G4 Common; usually more than 100 occurrences; usually not susceptible to immediate threats.

G5 Very common; demonstrably secure under present conditions.

Table 2.5.4-2: Aquatic SAR in the Lake Erie Tributary Watershed

Common Name	Scientific Name	COSEWIC Status	Provincial Rank	Global Rank	Status in Watershed
Reptiles					
Eastern Spiny Softshell	*Apalone spinifera*	Threatened			Reduced range, may be declining
Northern Map Turtle	*Graptemys geographica*	Special Concern			Locally common, under pressure
Blanding's Turtle	*Emydoidea blandingii*	Threatened			Unknown
Spotted Turtle	*Clemmys guttata*	Endangered			May be extirpated or very rare
Stinkpot Turtle	*Sternotherus odoratus*	Threatened			May be extirpated
Fowler's Toad	*Bufo fowleri*	Threatened			Sustainable population at Rondeau
Northern Cricket Frog	*Acris crepitans*	Endangered			Extirpated
Queen Snake	*Regina septemvittata*	Threatened			Reduced range, declining population
Tiger Salamander	*Ambystoma tigrinum*	Extirpated			Extirpated
Jefferson Salamander	*Ambystoma jeffersonianum*	Threatened			Rare
Eastern Foxsnake	*Elaphe gloydi*	Threatened			Discontinuous distribution along the Lake Erie - Lake Huron waterway shoreline, including tributaries and several islands
Massassauga	*Sistrurus catenatus*	Threatened			
Eastern Ribbonsnake	*Thamnophis sauritus*	Special Concern			Localized, may be extirpated
Fish					
Bigmouth Buffalo	*Ictiobus cyprinellus*	Special Concern			Disjunct
Black Buffalo	*Ictiobus niger*	Special Concern			Rare
Black Redhorse	*Moxostoma duquesnei*	Threatened			Rare, localized
Eastern Sand Darter	*Ammocrypta pellucida*	Threatened			Uncommon, localized
Greenside Darter	*Etheostoma blennioides*	Special Concern			Common, Widespread
Lake Chubsucker	*Erimyzon sucetta*	Threatened			Rare, localized
Northern Brook Lamprey	*Icthyomyzon fossor*	Special Concern			Rare, localized
Northern Madtom	*Noturus stigmosus*	Endangered			
Pugnose Minnow	*Opsopoeodus emiliae*	Special Concern			Rare, may be extirpated

Common Name	Scientific Name	COSEWIC Status	Provincial Rank	Global Rank	Status in Watershed
River Redhorse	*Moxostoma carinatum*	Special Concern			Unknown
Pugnose Shiner	*Notropis anogenus*	Endangered			Restricted to the Great Lakes
Spotted Gar	*Lepisosteus oculatus*	Threatened			Rare, localized
Channel Darter	*Percina copelandi*	Threatened			Rare to unknown
Warmouth	*Lepomis gulosus*	Special Concern			Extant, localized
Orangespotted Sunfish	*Lepomis humilis*	Special Concern			Unknown
Silver Chub	*Macrhybopsis storeriana*	Special Concern			Localized
Grass Pickerel	*Esox americanus vermiculatus*	Special Concern			Unknown
Lake Sturgeon	*Acipenser fulvescens*	Special Concern			Unknown
Spotted Sucker	*Minytrema melanops*	Special Concern			Uncommon, localized, may be expanding
Mussels					
Northern Riffleshell	*Epioblasma torulosa rangiana*	Endangered			May be extirpated or very rare
Wavy-rayed Lampmussel	*Lampsilis fasciola*	Endangered			Extirpated
Rayed Bean	*Villosa fabalis*	Endangered			Presumed extirpated
Round Hickorynut	*Obovaria subrotunda*	Endangered			Presumed extirpated
Round Pigtoe	*Pleurobema sintoxia*	Endangered			Rare
Snuffbox	*Epioblasma triquetra*	Endangered			Presumed extirpated

Lake Erie

Five Conservation Authorities (ERCA, LTVCA, KCCA, CCCA and LPRCA) together with provincial and federal agencies are participating in a multi-partner north shore Lake Erie Recovery Team for aquatic SAR. At present, the document is in draft stages only as the area of interest was recently expanded to take in the Long Point Region Conservation Authority.

Species data has been obtained from several sources, including Ministry of Natural Resources, Department of Fisheries & Oceans, universities and the Royal Ontario Museum. Historical and current information from these sources has been used to learn more about the SAR distribution, abundance and life history in the western basin of Lake Erie's watershed. As these species utilize the lake for the majority of their life stages, they are an important environmental indicator on the state of the lake.

A recovery strategy will be prepared in order to guide activities within the northwestern basin of the Lake Erie watershed in order to stabilize and improve species at risk populations, if possible, and to reduce or eliminate the threats to these species and their associated habitats.

Thames River

Both the UTRCA and LTVCA have participated in the multi-partner Thames River Recovery Team for aquatic SAR within the watershed. This team has been involved with producing the following documents: Thames River Watershed Synthesis Report[144], Aquatic Species at Risk in the Thames River Watershed, Ontario[118], and the Recovery Strategy for the Thames River Aquatic Ecosystem: 2005-2010[137].

The UTRCA has been monitoring and researching aquatic species at risk (fish and reptiles) to a limited extent within the Thames River to learn more about their distribution, abundance and life history. Species at risk are an important part of a monitoring program because these species are sensitive to environmental change and give warning signs of overall environmental health.

The Recovery Strategy for the Thames River Aquatic Ecosystem has been prepared to guide activities within the Thames watershed in order to stabilize and improve species at risk populations and to reduce or eliminate the threats to these species and their associated habitats.

2.5.4.1 Reptile SAR

There are 13 reptile species at risk within the northwestern basin of the Lake Erie watershed. The Northern Cricket Frog **(Figure 2.5.4.1-1)** and Tiger Salamander **(Figure 2.5.4.1-2)** have been extirpated from the area. Spotted Turtle and Stinkpot Turtle are thought to be rare or extirpated.

Figure 2.5.4.1-1: Northern Cricket Frog

Figure 2.5.4.1-2: Tiger Salamander

In the Thames River watershed, there are 12 SAR reptiles and seven of these species depend on aquatic habitats for survival. Of these, the stinkpot turtle is considered possibly extirpated, the spiny softshell and northern map turtles occur in pockets, the Blanding's turtle is rare and the spotted turtle, queen snake and northern ribbonsnake are very rare.

The wary and elusive nature of snakes and turtles has made accurate population estimates and trends difficult to obtain. Historical and current distributions were estimated from historic records and ongoing

[144] Taylor, I., B. Cudmore, C. MacKinnon, S. Madzia and S. Hohn. 2004. The Thames River Watershed Synthesis Report. Prepared for The Thames River Ecosystem Recovery Team. www.thamesriver.on.ca/Species_at_Risk/synthesis_report/Thames_River_Synthesis_report.pdf

field monitoring efforts[137]. Recent sampling efforts have been concentrated in the upper Thames; thus, the distribution and abundance of the reptiles in the lower Thames is not currently known.

Because reptiles (especially turtles) are generally long-lived, late-maturing and produce relatively few offspring, they are particularly vulnerable to decline. Any increase in adult mortality could have a severe impact on the population. The primary limiting factors for adult reptiles in the Thames River watershed include habitat destruction or alteration, human interference and road mortality[118]. Alteration of sensitive nesting habitat, combined with a high level of nest predation, results in low nesting success for the spiny softshell turtle[137].

The queen snake is extremely specialized in its diet, primarily consuming freshly molted crayfishes. As a result, the health of the local crayfish population is a considerable limiting factor for the queen snake. Crayfishes are currently not specifically sampled in any of the existing monitoring programs being conducted in the watershed[137].

The stinkpot turtle has not been recorded in the watershed since the early 1980s, and the spotted turtle is considered rare in the watershed, likely due to the rarity of preferred wetland habitat. Despite the difficulties in surveying, several areas in the watershed stand out as important reptile areas. These happen to occur in the most urbanized areas of the watershed.

Recovery teams are currently drafting recovery strategies for the spiny softshell turtle[145] and the queen snake.[146] The goal of these strategies is to down-list the respective species. The UTRCA SAR reptile research team is studying the queen snake and spiny softshell in some detail along the Thames River. The spiny softshell habitat enhancement, nest protection and maintenance, mark-recapture PIT tag study and a predation study will continue to be monitored by the SAR reptile team. Queen snake surveys and monitoring (including mark-recapture PIT tag studies), micro-habitat investigations and habitat enhancements are ongoing. Future research includes investigation into prey selection and abundance. Additional surveys for all other SAR reptiles will also continue.

Data Gaps – Reptile

Biological information is necessary to evaluate long-term survival habitat and population dynamics to direct recovery efforts.

For some species, it will be necessary to collect information on the extent, abundance and population demographics of their prey items as well.

Complete lack of species information, including biology and ecology of all life stages, is a knowledge gap for most of the aquatic reptile species at risk.

Information on habitat identification and use, seasonal dispersal, population isolation, size and trends, age structure, reproductive success, survival, recruitment and mortality rates are needed. In some cases, basic biological information is completely missing.

Little is known about the past or present distribution and status of many of the aquatic reptile species at risk in the Thames River watershed; more search effort is required to confirm the presence or absence of these species within the watershed.

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[145] Fletcher, M.L., M. Obbard and M. Oldham. 1997. National Recovery Plan for the Spiny Softshell Turtle (*Apalone spinifera*) DRAFT. 55 pp.

[146] Gillingwater, S. 2005. National Recovery Strategy for the Queen Snake (*Regina septemvittata*) in Canada. Prepared for the Queen Snake Recovery Team. March 2005.

As noted in the queen snake recovery strategy, surveys conducted at appropriate intervals using consistent methodologies are needed at all present and historical sites to maintain consistent long-term data. This would apply to all the aquatic reptile species at risk in the watershed.

Recent sampling efforts have been concentrated in the UTRCA watershed. Thus, the distribution and abundance of the reptiles in the lower Thames is not currently known[137].

2.5.4.2 Fish SAR

Along the estuaries and wetlands of the northern Lake Erie shoreline, there are 19 fish Species At Risk. It is believed that the Pugnose Minnow (**Figure 2.5.4.2-1**) is rare or extirpated from the Lake Erie shoreline.

Figure 2.5.4.2-1: Pugnose Minnow

In the Thames River watershed, there are potentially 13 fish Species At Risk. The gravel chub is the only species considered to be extirpated. Only two records exist for the Thames, and Canada, with the last specimen captured in 1958. A slight chance exists that the species may persist, as it is potentially very difficult to capture with the sampling methodology that has been utilized in recent years. The northern madtom is the only species listed as endangered. The eastern sand darter, lake chubsucker, and black redhorse are threatened species. The northern brook lamprey, bigmouth buffalo, black buffalo, silver shiner, pugnose minnow, river redhorse, spotted sucker, and greenside darter are of special concern.

In recent years, fish sampling efforts primarily targeted the Thames River, the main branches and larger tributaries to update information on federally designated species at risk. Preliminary data analysis indicated that the black redhorse, silver shiner, and sand darter populations are relatively stable while the greenside darter seems to be increasing in range and numbers. One northern brook lamprey population was located. The spotted sucker may be expanding its range as it was located for the first time near the downstream extent of the upper Thames watershed. One bigmouth buffalo was recorded and additional black buffalo, river redhorse and northern madtom records are awaiting confirmation. No pugnose minnows were identified during sampling.

DFO has been leading a mark-recapture pilot project since 2003 involving eastern sand darters in the lower Thames River between London and Chatham. The aim of this study is to estimate the abundance and mortality of the eastern sand darter.

Primary threats for fish SAR have been identified by Cudmore-Vokey *et al.* (2004) as turbidity and siltation, poor water quality, habitat loss or degradation and watercourse barriers.

Data Gaps – Fish

Additional sampling is required using appropriate techniques to determine the range and numbers of most of the fish species at risk present in the Thames River. There are also sections of the watershed where very little or no sampling has occurred (especially in the lower Thames River).

Population information and data on the biology and ecology of many fish species at risk, and the threats and limiting factors they are faced with, is limited. For example, population abundance, distribution or status within the Thames River is completely unknown for both the river redhorse and spotted sucker.

Information on certain aspects of habitat and reproductive characteristics are unknown for northern madtom, eastern sand darter, silver shiner, river redhorse and spotted sucker. Even basic knowledge of species identification is lacking: some redhorse species are very difficult to identify in the field; recent work suggests that northern brook and silver lampreys may be the same species; and it is unknown if silver shiners are a reproductively-isolated (from the US) population in Canada. The impacts of realized threats and limiting factors for many species have not been well researched and, therefore, are poorly understood. In some cases (e.g. silver shiner, spotted sucker), threats and limiting factors are unknown.

2.5.4.3 Mussel SAR

Within the northern Lake Erie shoreline, there are six at risk mussel species. Almost all are believed to be extirpated with only the Round Pigtoe listed as rare. It is believed that the invasive non-native zebra mussel has out-competed the native mussel species for habitat space and food.

In the Thames River watershed, seven at risk mussel species have been recorded. All of these mussels are listed as endangered by COSEWIC. The mudpuppy mussel, round hickorynut and snuffbox are believed to be extirpated from the Thames River[137]. The rayed bean and kidneyshell were also believed to be extirpated from the Thames River; however, both species were confirmed alive from different locations in 2004[136].

Additional freshwater mussel sampling was conducted during the summers of 2003 - 2005. Field data will be compiled from these field seasons to update the freshwater mussel distribution and abundance information in the Thames River Recovery Strategy.

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

Other Species At Risk Information

The Natural Heritage Information Centre[147] (NHIC) was established in 1993 as a joint venture between the Ontario Ministry of Natural Resources (MNR) and three partners: The Nature Conservancy of Canada, Natural Heritage League and The Nature Conservancy. The NHIC mission is to acquire, maintain, update, and make available data on the province's rare species, vegetation communities, and natural areas.

Map 29: Species At Risk illustrates the number of species at risk found in each subwatershed as identified by the Natural Heritage Information Centre. These recorded SAR sightings include terrestrial and aquatic species at risk.

2.5.5 Invasive Species

Human migration has long served as a source of species introductions. People tend to bring familiar plants and animals with them to their new homes and, unintentionally, they also bring diseases and pest species.[148] Not only have human development and technological advances changed the natural ecology of the watershed, humans have been vectors for the dispersal of many invasive species. Beginning with European settlers and continuing today with worldwide transportation systems, invasive species have a significant impact on the ecology of the watershed.

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[147] Natural Heritage Information Website, www.nhic.mnr.gov.on.ca
[148] Cinura, K.A., L.A. Meyerson and A. Gutierrez. 2004. The ecological and socio-economic impacts of invasive alien species in inland water ecosystems. Report to the Conservation on Biological Diversity on behalf of the Global Invasive Species Programme. p 34. www.biodiv.org/doc/ref/alien/ias-inland-waters-en.pdf

Several of these introductions were innocent enough; however, there are consequences to most actions. Some species were brought in as they were the only natural predators of some undesirable species. Many introduced species were thought to be beneficial; however, it is now known that their introduction had far greater consequences to the natural/native environment.

In addition to imported species, many species indigenous to North America, but not the local area, have taken advantage of human transport systems such as canals and other dispersion mechanisms to expand their original range. However, it bears mentioning that not all introduced species are invasive, while there are some native species that are invasive.

Over 160 non-native species have been introduced to the Great Lakes watershed, either naturally, intentionally or accidentally, since the 1800s. Many of these plants, fish, algae, invertebrates and molluscs have naturalized and became part of the ecosystem.[149] Some exotic species are so common that many people think that they must have always been here.

Since the opening of the St. Lawrence Seaway, several aquatic exotic species were brought to the Great Lakes in ballast water. These species have naturally expanded their range and taken advantage of corridors created via canal and drainage systems. Exotic species are also introduced via pet, aquarium, pond and garden trades, bait transfer, aquaculture escape, cultural practices and recreational activities such as boating and angling.

Invasive species are known by many names such as non-native, alien, exotic, non-indigenous, or introduced species. Acronyms have been used to more accurately describe theses species. NIS is short for non-native invasive species[150], while IAS denotes invasive alien species. Invasive species have been defined as an introduced species that invades natural habitats.[151]

Alien/non-native/exotic/non-indigenous/introduced species are defined as “a species that has been transported by human activities, intentional or accidental, into a region where it does not naturally occur or a species occurring in an area outside of its historically known natural range as a result of intentional or accidental dispersal by human activities.”

For purposes of this report, invasive species shall be interchangeable with NIS and defined as “a non-native species introduced outside its natural past or present distribution whose introduction and/or spread threaten biological diversity.”

Some impacts of invasive species may not be distinguishable from other stressors such as a change in hydrology, loss of habitat, or pollution. Invasive species have had a significant negative impact on the ecosystem by out-competing native species, carrying pathogens, disrupting communities, causing extinction, altering the food chain, disturbing habitat, and impacting water quality. They can also impact industries such as fisheries, tourism, water production and water removal.

Not all introduced species are invasive; some do co-exist with native species. Each introduction has likely influenced its new host ecosystem in some manner; however, initially most influences are thought to be relatively insignificant or undetectable. Some NIS may not cause ecological damage and many (especially fish) provide economic benefits. Other NIS do cause ecological harm due to their invasive behaviour, and yet still produce substantial social, economic and cultural benefits. There is a challenge of balancing the benefits and costs, both economic and ecological, to ensure the sustainable use of inland water ecosystems.

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[149] Central Lake Ontario Conservation Authority. 2005. www.cloca.com/lwc/streams_invasive.php
[150] Environment Canada. 2005. Aquatic Non-Native Invasive Species: Invaders Pose Major Threat to the Great Lakes. www.on.ec.gc.ca/coa/invaders-e.html
[151] European Community Biodiversity Clearing House Mechanism, Supporting the Convention on Biological Diversity. 2005. http://biodiversity-chm.eea.eu.int/glossary/I/invasive_species

A time lag can occur before an introduced species is recognized as an invasive. An introduction strategy might benefit the current generation but become detrimental to future generations. Therefore, before an introduction is made, consideration should be given to both the short-term and the long-term costs and benefits to all groups of people and the ecosystem. Preventing the introduction of NIS is the first and most cost effective measure against invasives. Once an introduced species has become established it can be extremely difficult or impossible to eradicate. Intact ecosystems are the best preventative measure against NIS as invasives often thrive in disturbed ecosystems. There is limited experience in the prevention, eradication and control of NIS in inland water ecosystems with fewer methods available than for the control of invasive species in terrestrial systems.

The Ontario Ministry of Natural Resources (OMNR) and the Ontario Federation of Anglers and Hunters (OFAH) established an Invading Species Awareness Program[152]. The objectives of this program are to educate the public, encourage participation in the Invading Species Watch Program with the use of the Invading Species Hotline, as well as monitor and conduct research on invasive species.[153]

Where aquatic non-native invasive species are concerned, control programs are generally intensive long-term efforts that are expensive. Generally, the 'high profile' invaders such as Sea Lamprey usually have funded management programs required for control. Most of the time, invasive species are left to find their own equilibrium in the environment, while some are monitored if they are to pose a greater risk or if very little is known about the species.

Although the governments of Canada and the United States, along with the Government of Ontario and state governments have had some success in managing the sea lamprey, other aquatic NIS are out of control, and new invaders continue to reach the Great Lakes Basin every year[150]. Some solutions to preventing the spread of invasive species are ballast water management, legislation, education and community involvement.

2.5.5.1 Reptiles

There are several exotic reptile species that have been found throughout the Thames watershed. Most of these were pets that were released or escaped from their captive environment. With the exception of the red-ear slider, the majority of non-native reptile species observed along the Thames River, are not known to survive Ontario winters. They only pose a minor threat of disease transmission to native reptiles and have not been considered to threaten native habitats or influence water quality.

The red-ear slider (*Trachemys scripta elegans*) turtle is native to the United States and poses a slight threat of disease transmission to native turtles. This species can now be found throughout southern Ontario; however, no records of reproduction in Ontario exist. Not all animals survive our winters but preliminary observations show that some individuals have withstood winters in southern Ontario.

2.5.5.2 Fish

Many species indigenous to North America but not the Thames River watershed have taken advantage of man-made dispersion mechanisms and canal systems to become established in the Great Lakes watershed. Species such as the sea lamprey have devastating impacts on fish populations, while species such as the alewife can be considered to be contributing to the fish community since many species forage on the alewife. Most invasive fish species threaten native fish through their ability to out-compete for food and habitat and to pass on disease. Introduced species found in the Thames include the Common Carp, Goldfish, Round Goby and Sea Lamprey. The following invasive fish have a direct impact on water quality.

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[152] Ontario Federation of Anglers and Hunters. 2005. Invading Species Awareness Program. www.invadingspecies.com
[153] OMNR. 2005. Stop the Invasion! www.mnr.gov.on.ca/fishing/threat.html

Common carp (*Cyprinus carpio*) are widespread throughout the Thames River Watershed. Members of the minnow family, carp grow to very large sizes. Carp feed on aquatic vegetation and aquatic invertebrates. They have significant impacts on aquatic habitats through their feeding and spawning behaviour. When carp feed, they suck up sediments and organisms from the bottom, uprooting and destroying vegetation. They create a very turbid environment by disturbing the sediment and allowing it to be carried downstream to settle. Carp can also severely modify near shore habitats and increase turbidity through their spawning behaviour.[154]

The round goby (*Neogobius melanstomus)* has been found in limited occurrences in tributaries of the lower Thames downstream of Chatham. The round goby reaches lengths of 25 cm (10 in) and lives for up to five years. They are aggressive fish that can spawn several times a year. Adult round gobies feed on zebra mussels, which often have high contaminant levels in their tissues. Concerns have been expressed that predators of gobies may be exposed to higher levels of contaminants by feeding on round gobies. It is assumed that round gobies have contracted botulism Type-E (*Clostridium botulinum*) from eating infected zebra mussels, which results in die-offs. Botulism also affects other fish and wildlife that feed on the gobies. These impacts are still being researched and studied by several agencies in the Great Lakes region.

2.5.5.3 Mussels

Zebra mussels (*Dreissena ploymorpha)* have been found in the Fanshawe Reservoir and have colonized the Thames River downstream of the Fanshawe Reservoir. Zebra mussels and a related species, the quagga mussel (*Dreissena bugensis*), are freshwater molluscs native to the Black and Caspian Sea region of Asia.

In the Great Lakes, zebra mussels have decimated native freshwater mussels. In addition to competing for food, zebra mussels will colonize on top of native clams preventing them from opening and closing. Respiration and feeding for native clams is difficult as a result of zebra mussel colonization on their shells. These mussels have been known to block pipes used for water intakes.

These mussels are tolerant of a wide range of environmental conditions. While they may be perceived to ‘clean up’ the water, zebras actually only improve the clarity of the water. All mussels filter the smallest particles in water, which includes nutrients, bacteria and algae. Mussels can accumulate toxins and, in the case of algae, can expel viable cells. It has been shown that a toxic form of blue-green algae is not digested by the zebra mussels and blooms of blue-green algae have increased after an infestation of zebra mussels.[155]

2.5.5.4 Plants

Most non-native invasive plant species that invade wetlands and other wet areas displace the diverse native plant populations with very dense monocultures. These species affect the aquatic communities as the plants they have displaced were taking up nutrients, essentially cleaning up or purifying the water.

Purple loosestrife (*Lythrum salicaria)* is a readily identifiable perennial that can rapidly degrade wetlands. Where loosestrife forms a dense monoculture, it replaces native plant species and the habitat where fish and wildlife feed, seek shelter, reproduce and rear young.

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[154] Gillingwater, S., and J. Schwindt. 2005. UTRCA. Personal Communications
[155] Dorworth, L.E. 2005. Water Taste and Odor. www.iisgcp.org/water/wic/taste.htm
Vanderploeg, H. 2002. The Zebra Mussel Connection: Nuisance Algal Blooms, Lake Erie Anoxia, and other Water Quality Problems in the Great Lakes. NOAA, Great Lake Environmental Research Laboratory. www.glerl.noaa.gov/pubs/brochures/mcystisflyer/mcystis.html

Common reed/giant reed (*Phragmites australis*) also forms dense monocultures[156] and displaces native fish and wildlife habitat.[157] It has been suggested that the common reed may be native to Southwestern Ontario; however, a variety from Europe has invaded many wetland habitats.

2.5.5.5 Invertebrates

Invertebrates such as the spiny and fishhook water fleas have not been recorded in the Thames watershed.

2.5.5.6 Potential Invasive Species of Concern[152]

The other species of carp found in North America that have the potential to threaten the watershed aquatic health are grass carp (*Ctenopharyngodon idella*), bighead carp (*Hypophthalmichthys nobilis*), silver carp (*Hypophthalmichthys molitrix*), and black carp (*Mylopharyngodon piceus*).

The tubenose goby (*Proterorhinus marmoratus*) is another member of the goby family that has the potential to invade the Thames River watershed.

Other fish species such as the snakehead (*Channa argus*) and the rudd (*Scardinius erythrophthalmus*) threaten to invade and decimate native species. All species of snakehead are voracious predators and with no known natural enemies they could have major impacts on native populations of fish. The rudd can hybridize with the native golden shiner, which could pose a risk to this important baitfish species. Over time, the unique genetics of the native golden shiner could be lost. Young rudd could also compete with native fish for food and habitat resources.

The quagga mussel (*Dreissena bugensis*) is similar to the zebra mussel and adversely affects the ecosystem. They have not been located in the Thames and it is optimistically anticipated that due to their preference for colder, deeper waters, the quagga will not invade the Thames.

Eurasian watermilfoil (*Myriophyllum spicatum*) is present in parts of the Thames River watershed and has the potential to seriously affect the watershed. This species is a submergent aquatic that forms a dense monoculture and decreases native plant diversity. The thick mats of this vegetation cause an increase in phosphorus and nitrogen concentrations. It can also raise the pH and temperature of the water while decreasing dissolved oxygen levels, which is hazardous to most aquatic species. Milfoil can interfere with recreational activities and it has been known to block pipes used for water and power generation intakes.

Fanwort (*Cabomba caroliniana*) is another species that has not been confirmed in the Thames watershed, but is a common aquarium plant. It is a submergent perennial native to the southeastern temperate climates of North and South America. It can form dense stands that have the same effect as milfoil. When dense mats of fanwort decay, dissolved oxygen levels can be depleted to a point where fish and other aquatic organisms die.

The spiny and fishhook water fleas have the potential to invade and have a massive effect on the aquatic food chain. [158] These species have no known impact to water quality.

Rusty crayfish (*Orconectes rusticus*) originate from streams in Ohio, Kentucky and Tennessee. They have a ravenous appetite for aquatic plants and have a devastating impact on the aquatic vegetation. Juveniles

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[156] Wilcox, K.L., and S.A Petrie. 1999. Monitoring *Phragmites australis* at Long Point, Ontario: Past, Present, and Future. Prepared for the Long Point Waterfowl and Wetlands Research Fund. www.escarpment.org/leading_edge/LE99/LE99_S1/Wilcox.pdf

[157] Marks, M., et al. 2005. Element Stewardship Abstract for *Phragmites australis*. Prepared for the Nature Conservancy. tncweeds.ucdavis.edu/esadocs/documnts/phraaus.html

[158] Yan, N. 2004. Limits to the Roles of Science in the Management of Non-indigenous Invasive Species: The example of the spiny water flea in Canadian Shield Lakes. Ref: York University. Interdisciplinary Approaches to the problems caused by invasive species: summary of workshop presentations prepared by Katherine Balpataky and Laurence Packer November 7 & 8, 2004.

feed heavily on benthic invertebrates, fish eggs and young fish. They displace native crayfish. They have not been confirmed in the Thames River watershed.

2.6 Human Characterization

The Thames Watershed & Region is the area covered by the Upper Thames River Conservation Authority (UTRCA) and the Lower Thames Valley Conservation Authority (LTVCA). It includes most of Chatham-Kent; large portions of Elgin, Middlesex, Oxford, and Perth Counties; and small parts of Essex and Huron Counties.

Information on the human characterization of the area will be presented based in large part on the Census Canada Divisions. The areas of each of these municipalities and the portions in the combined UTRCA and LTVCA area are summarized in **Table 2.6-1: Thames Watershed & Region Census Divisions**.

Table 2.6-1: Thames Watershed & Region Census Divisions

Census Division	Total Area (sq km)	Area in Thames Watershed & Region (sq km)	Proportion of Census Division In Thames Watershed & Region
Essex	1,820	185	10.2%
Chatham-Kent	2,490	1,840	73.9%
Elgin	1,884	785**	42%
Middlesex	3,333	1571*	47%
Oxford	2,039	1124	55%
Perth	2,218	1177	54%
Huron	3,407	33	1%

* Middlesex Area: LTVCA - 464 sq. km, UTRCA - 1107 sq. km
** Elgin Area: LTVCA - 781 sq. km, UTRCA - 4 sq. km

2.6.1 Population Distribution and Density

Based on the 2001 Census, the population in the Thames Watershed & Region is over 550,000. Most of the population is located in urban centres that have more concentrated housing densities as shown on **Map 30: Generalized Land Cover**.

Figure 2.6.1-1: Generalized Population Density – Thames Watershed & Region has been produced using 2006 Census information obtained from Census Canada. This figure helps to illustrate the variation in population density across the Source Protection Area.

The City of London is the largest urban centre in the region, with a population of 336,539.[159] While part of London is outside the Thames Watershed & Region area, the most densely populated part of the city is in the UTRCA watershed.

[159] Statistics Canada. Censuses of Population, 1901-2001 (all population numbers referenced in this section are from this source).

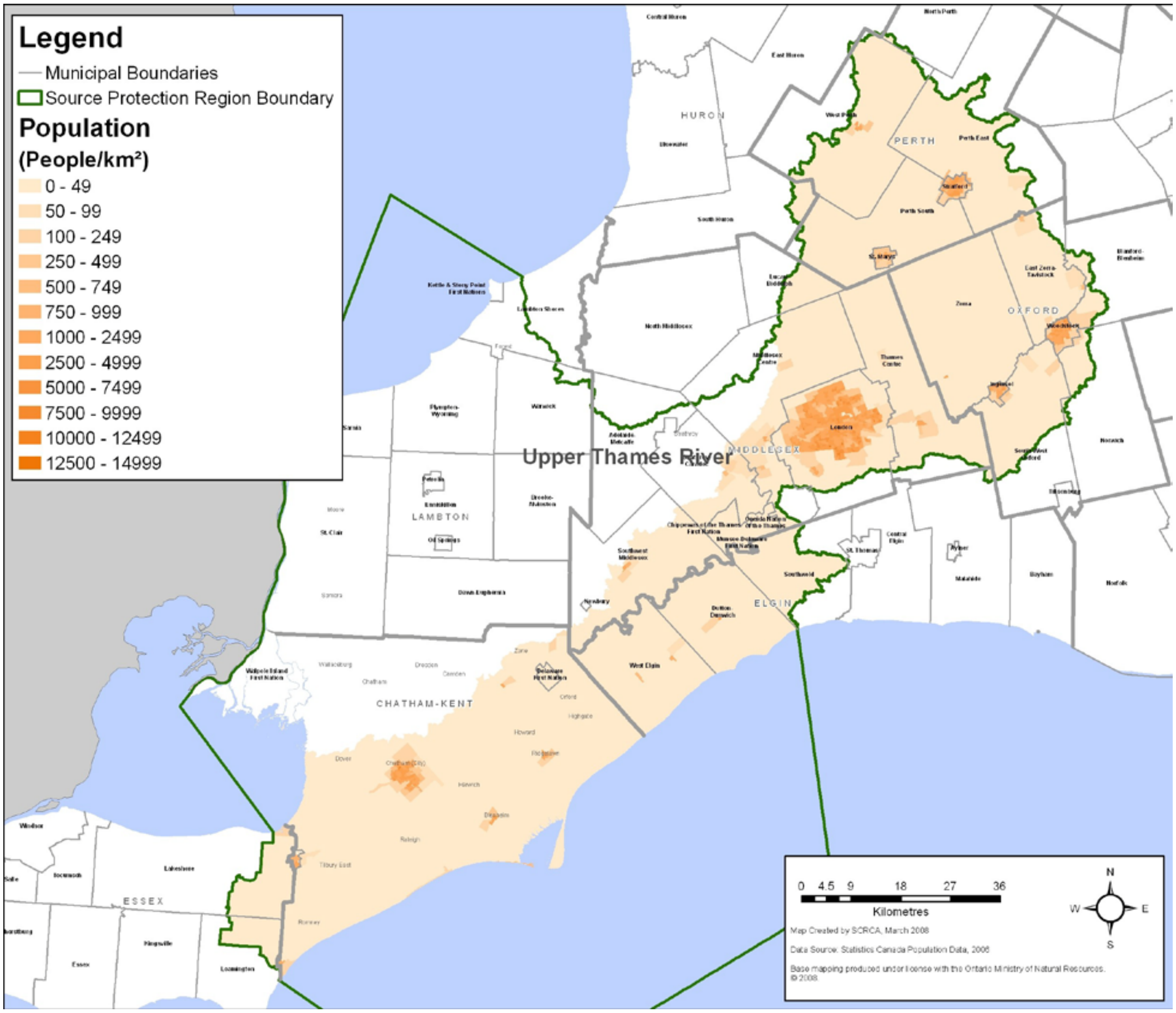

Figure 2.6.1-1: Generalized Population Density – Thames Watershed & Region

In the UTRCA area, other significant urban centres include the City of Stratford (29,676) and Town of St. Marys (6,293) in the Perth Census Division; and the City of Woodstock (33,061) and Town of Ingersoll (10,977) in the Oxford Census Division.

In the LTVCA area, the largest urban centre is the former City of Chatham (43,690) which is now part of the municipality of Chatham-Kent. Other smaller urban areas include Tilbury, Ridgetown, Blenheim, Glencoe, West Lorne and Dutton, all of which have populations under 5,000.

The Thames Watershed & Region also includes five First Nations. Oneida Nation of the Thames, Munsee-Delaware First Nation, Chippewas of the Thames First Nation, and Delaware Nation are in the Thames River part of the watershed. The Caldwell First Nation is in the Lake Erie portion of the watershed.

Over the last century[160], there has been a dramatic shift in where the majority of the population lives on both a provincial and national level. Both **Table 2.6.1-1: Population Change in Ontario – Rural to Urban Settings 1901-2001** and **Table 2.6.1-2: Population Change in Canada – Rural to Urban**

[160] Statistics Canada. Censuses of Population, 1901-2001.

Settings 1901-2001 provide evidence of this change. Fully serviced urban areas support higher density population growth. Also, as discussed later, changes in farming practices (e.g. equipment that lets one farmer cultivate a larger farm) have contributed to the lower rate growth for the rural population.

Table 2.6.1-1: Population Change in Ontario - Rural to Urban Settings 1901-2001[160]

Year	Total Ontario Population	Urban (#)	Rural (#)	Urban (%)	Rural (%)
1901	2,182,947	935,978	1,246,969	43	57
1951	4,597,542	3,251,099	1,346,443	71	29
2001	11,410,046	9,662,547	1,747,499	85	15

Table 2.6.1-2: Population Change in Canada - Rural to Urban Settings 1901-2001[160]

Year	Total Canadian Population	Urban (#)	Rural (#)	Urban (%)	Rural (%)
1901	5,418,663	2,023,364	3,395,299	37	63
1951	14,009,429	8,628,253	5,381,176	62	38
1961	18,238,247	12,700,390	5,537,857	70	30
2001	30,007,094	23,908,211	6,098,883	80	20

2.6.2 Population Projections

A review of past population growth patterns helps to explain future population projections. **Table 2.6.2-1: Historic Populations** shows the population change over a five year period from 1996 to 2001 for the seven census divisions in the Thames Watershed & Region and the adjacent Lambton Census Division.

Table 2.6.2-1: Historic Populations[160]

Census Division	2006 Population	2001 Population	1996 Population	1996 to 2001 Population Change	2001 to 2006 Population Change
Huron	59,325	59,701	60,220	-0.9 %	- 0.6%
Perth	74,344	73,675	72,106	2.2 %	0.9%
Oxford	102,756	99, 270	97,142	2.2 %	3.5%
Middlesex (incl. City of London)	422,333	403,165	389,616	3.5 %	4.7%
Elgin	85,351	81,553	79,159	3.0 %	4.7%
Chatham-Kent	108,589	107,709	109,350	-1.5 %	0.8%
Essex (incl. City of Windsor)	393,402	374,975	350,329	7.0 %	4.9%
Lambton County	128, 204	126,971	128,975	-1.6 %	1.0%

Over the 10 year period between the 2006 Census and the 1996 Census, there has been a wide variation in population growth or decline in these census divisions. In general, Essex and Middlesex, which are the census divisions with large cities (Windsor and London) had the most growth. Elgin, Perth and Oxford also had growth. Huron, Lambton and Chatham-Kent experienced an overall decline during the 10 years. However, both Lambton and Chatham-Kent had some increase in population during the last five years from 2001 to 2006.

The information on projections for Southwestern Ontario has been extracted from the Ontario Ministry of Finance website and is summarized in **Table 2.6.2-2: Population Projections**. The Ministry indicates that the population of Southwestern Ontario is projected to grow from 1,579,400 in 2006 to 1,857,700 in 2031, or by about 18%. This is lower than the projected growth rate of approximately 30% for the whole province.

Based on Ministry of Finance predictions, significant differences in the growth rates across the region are predicted over the next 25 years. The Essex (23%), Middlesex (22%) and Elgin (20%) Census Divisions are expected to exceed the provincial average while Oxford (17%) and Perth (16%) are projected to have growth close to the provincial average of 18%. Huron (11%) and Lambton (4%) will have some growth. Chatham-Kent (-1%) is expected to continue to see a population decline.

It should be noted that the Municipality of Chatham-Kent feels that the Ministry population projections do not take into account the proactive development strategy being implemented by that municipality. The Chatham-Kent Official Plan[161] projects a higher growth rate of approximately 6% and a population of 122,600 in 2021, based on a medium growth scenario.

Similarly, the Oxford County Official Plan projects a higher growth rate than the Ministry projections. Based on the Population, Household and Employment Forecasts by Hemson Consulting Ltd[162], the county projects a growth rate of about 35% between 2006 and 2031 with a population of 143,900 in the year 2031.

[161] Municipality of Chatham-Kent. Chatham-Kent Official Plan. Adopted January 2005.

[162] Hemson Consulting. April 2006. Population and Household Projections 2001-2031, www.county.oxford.on.ca

Table 2.6.2-2: Population Projections[163]

(000s)	Ontario Population Projections Update, 2006 -2031 Historical and Projected Ontario Population by Census Division, Every Fifth Year – Reference Scenario									
	Historical				Projected				
Census Division	1996	2001	2006		2011	2016	2021	2026	2031
Southwestern	**1,484.2**	**1,541.4**	**1,579.4**		**1,626.5**	**1,684.2**	**1,744.4**	**1,804.0**	**1,857.7**
Bruce	68.0	66.3	66.7		68.1	70.3	72.8	75.2	77.0
Elgin	81.4	84.7	88.8		92.1	96.1	100.1	103.8	107.0
Essex	360.3	390.5	405.3		423.1	442.1	461.7	481.3	500.0
Grey	89.9	92.5	94.7		97.5	101.5	106.1	110.7	114.9
Huron	61.8	62.0	61.4		62.2	63.6	65.2	66.9	68.4
Chatham-Kent*	112.6	111.9	110.0		108.6	108.3	108.3	108.6	108.7
Lambton	133.3	131.8	132.3		132.2	133.1	134.4	135.9	137.0
Middlesex	402.9	422.0	436.2		453.7	473.8	493.7	512.8	530.1
Oxford*	99.8	103.1	106.8		109.8	113.7	117.8	121.8	125.4
Perth	74.1	76.5	77.2		79.3	81.8	84.4	87.0	89.2
Ontario	**11,083.1**	**11,897.6**	**12,687.0**		**13,426.2**	**14,248.0**	**15,050.7**	**15,809.9**	**16,489.1**

Sources: Statistics Canada, 1996 to 2006, and projections of Ontario Ministry of Finance.
Notes:
1. Year is at July 1.
2. Figures may not add to totals due to rounding.
3. Ministry numbers include an estimate for undercounted population
* Differences between the Municipal Official Plans and Ministry of Finance Projections are discussed in accompanying text

2.6.3 Land Use and Settlement Areas

As shown on **Map 30: Generalized Land Cover**, agriculture is the dominant land use in the Thames Watershed & Region. However, a wide variety of industrial, commercial and institutional land uses provide employment for most of the population.

2.6.3.1 Existing Urban Residential Development

The largest urban centre within the LTVCA watershed is the former City of Chatham, with an approximate population of 44,000 people located in Chatham-Kent. The remaining urban centres across the watershed range in population from 4,780 (Blenheim) to 417 (Wardsville).

In the UTRCA watershed, the largest urban centre is the City of London with a population of 336,539. The Cities of Woodstock and Stratford, with populations of 33,061 and 29,676, respectively, are also located in the watershed. The Town of Ingersoll in the Oxford Census Division has a population of 10,977. The Separated Town of St. Marys in the Perth Census Division has a population of 6,293. There are numerous other urban centres on full or partial services, including, for example, the Town of Mitchell and the Villages of Thamesford and Dorchester.

[163] Ontario Ministry of Finance. Ontario Population Projections, 2006-2031. www.fin.gov.on.ca/english/economy/demographics/projections/2007/demog07t6.html.

There are also many smaller non-serviced settlement areas in the watershed area.

2.6.3.2 New and Projected Urban Residential Development

There are 24 urban centres, with another 24 smaller hamlets and villages scattered across the LTVCA part of the watershed. The smaller centres have very little, if any, lands designated for development as development pressures are not present in these communities. In these areas, the majority of expansion occurs through existing residential lot division.

For the larger urban centres, approximately 5% (more for the larger urban centres such as Chatham) of lands within the urban setting can be classified as having lots available for development under a plan of subdivision.

In the LTVCA area, there are currently few areas of urban growth within the watershed other than Tilbury and the Lighthouse Cove area in the Town of Lakeshore. Lighthouse Cove has seen an increase in development of late due to the influence of the City of Windsor and due to its proximity to Lake St. Clair. In fact, the Town of Lakeshore's population has increased 10% in the five year span from 1996 to 2001. Tilbury is also experiencing growth due to its proximity to Hwy. 401 and again the influence of industrial expansion in the City of Windsor.

Chatham-Kent is looking to increase its attractiveness to industry with the establishment of the Bloomfield industrial corridor along Hwy. 401, just south of the former City of Chatham. Also, the big box store development at the north end of the urban area provides some growth potential.

All other municipalities within the LTVCA's jurisdiction have projections of low, steady growth rates within the urban landscape over the next 20 year time span.

In the UTRCA portion of the watershed, the majority of the residential development is in the fully serviced urban cities, towns and large villages. All of these areas currently have lots available in existing subdivisions and new subdivisions are in the approval process. There is a considerable amount of urban residential growth occurring in the fully serviced urban centres. This is evidenced by record numbers of new housing starts in the City of London and a significant increase in housing starts over recent years in Woodstock and Stratford.

The City of London has a large land area available from the 1993 annexation of the Township of Westminster and smaller portions of other municipalities that are now Middlesex Centre and Thames Centre.

The City of Stratford and neighbouring municipalities have a phased annexation that is scheduled to be fully implemented on January 1, 2007. The City of Woodstock has annexed significant portions of land from Blandford–Blenheim Township and East Zorra-Tavistock Township in the past two years. The Town of Ingersoll has also annexed land for neighbouring rural municipalities in recent years. In all cases, these annexations have provided an increase in serviceable land for the interrelated uses of industrial, commercial and residential.

Residential growth in the fully serviced areas is largely occurring in new residential plans of subdivisions with a much smaller portion occurring in older approved subdivisions and as infill and brown field or downtown re-development.

Some new residential growth is also being facilitated by the extension of municipal water and sanitary services from serviced communities to nearby non-serviced communities. This is currently occurring with the City of London extending services north to the Village of Arva in Middlesex Centre. The City of Woodstock is extending sanitary sewer services to the community of Innerkip which is already serviced with municipal water. Numerous other similar arrangements have been approved or are being considered.

For example, the community of Embro, which has municipal water, should also have sanitary sewer services extended from Woodstock in the near future.

In the non-serviced or partially serviced urban centres, limited lots are available in approved subdivisions and there are limited opportunities for infill development. Residential growth in the non-serviced settlement areas is generally limited to construction on a few remaining existing lots of record and on a few infill lots created by severance.

In general, new large multiple lot subdivisions on private services are not being created as they are not consistent with the Provincial Policy Statement (2005). Smaller developments limited to five lots in prime agricultural areas are permitted in rural areas without municipal services.

2.6.3.3 Rural Residential

The population of the rural area of the watershed is experiencing a decline. Changes in farm practices are resulting in higher productivity that results in larger landholdings. Also, there seems to be a decreasing interest in farming from younger generations as this demographic segment moves toward more urban centres in search for employment.

In the LTVCA watershed, new growth in rural settings will more than likely be a result of the creation of retirement lots, or severing of surplus residences from agricultural land holdings. All municipalities realize that agriculture is the dominant land use in the region and try to limit conflicts with a rural residential population. The MMAH guidelines (Provincial Policy Statement, 2005) also reduce the likelihood of these conflicts as they heavily encourage that development take place in centres with full services as opposed to rural areas where development requires the use of groundwater and private sewage disposal systems. However, there are areas, most notably along the Thames River and Lake Erie, where farm units are too small to be economic and, therefore, some estate residential development is taking place.

Over the coming decades there will likely be more development pressure in rural areas as municipal waterlines are installed. These lines are installed in order to link urban centres, to provide water to rural areas with limited groundwater supplies and to solve water quality problems, when they arise.

In the UTRCA watershed, rural residential development is limited to construction on a few existing lots of record in the rural areas. There is also the creation of one or two lot severances for new rural residential in limited and unique situations. In most cases, the new rural residential development is being offset by losses of rural residences as farm consolidations lead to surplus existing farm houses. In some cases, these farm houses can be severed and maintained as residences. However, several municipalities have strict policies limiting the opportunity to sever these existing dwellings from the overall landholding. In cases where they cannot be severed, they may be rented. However, the market for such properties is generally not favourable for the landowner for many reasons.

2.6.3.4 Cottage Development

Within the LTVCA watershed, cottage development is not as common as it once was. Areas such as Shrewsbury, Erieau, Erie Beach and small private roads in the community of Romney still have seasonal use, but more and more cottages are being insulated and upgraded for year-round use.

Other areas of the Lake Erie shoreline, such as West Elgin, have developed seasonal trailer parks along the lake front to provide an alternative cottage type land use. The high erosion rate of the bluffs in this area results in a lack of building envelopes available for permanent residential development.

In the UTRCA watershed, there is limited private land cottage development due to the predominantly agricultural landscape and the lack of a significant recreational attraction such as Lake Erie. The community of Lakeside provides a small recreational and resort area on Lake Sunova in Oxford County. There are some seasonal or permanent individual properties associated with large natural tracts or even farm operations; however, these are not significant in terms of numbers and would be included in the rural residential category.

The UTRCA has two cottage developments on Conservation Authority owned land. In both cases, the use is required to be seasonal (i.e. nine months full time occupancy permitted from March 1 to November 30, and three months weekends only from December 1 to February 28/29). All aspects of the use of the cottages are governed by a lease between the cottage owners and the UTRCA. Fanshawe cottage development is located on the northeast shore of Fanshawe Lake and consists of 56 cottages. The cottages are serviced by a communal water system managed by the UTRCA. Sewage is treated in individual private sewage disposal systems. The Wildwood cottage development is located on the north shore of Wildwood Lake. The development consists of 24 cottages, all on private water and sewage.

There are several community campground/trailer parks located in the upper Thames watershed that provide seasonal cottage-like accommodations.

2.6.3.5 Commercial Development

Existing Commercial Development

Commercial development is located in all urban centres within the region. It can be said that most urban centres are struggling to retain vibrant downtowns while accommodating the trend to larger outlying shopping hubs with plenty of parking. An exception to this trend is Stratford which has a vibrant downtown core that is closely related to arts related tourism. The City of London is another community that is currently undertaking a program of downtown renewal.

The existing commercial development within the region services the mix of employment activities including agriculture, automotive, financial services and tourism.

All communities have the goal of retaining the spending of most of their citizens within their community. All communities have a desire to increase tourism to aid in bringing more dollars into the local community.

Major commercial hubs in the UTRCA watershed are located at London, Woodstock and, to a lesser extent, Stratford. London has several commercial shopping districts including the downtown, White Oaks Mall and Masonville Mall. In the LTVCA watershed, the Chatham urban centre is the major commercial area.

Future Commercial Development

All communities attempt to have adequate area available for future commercial development. Future commercial development normally depends on the future population of the area. As it is expected that population growth will continue to be moderate in the area it is expected that future commercial development will be moderate as well.

In relation to downtown versus suburban conflict in the placing of commercial development, it appears that the smaller the community, the less desire there is to construct suburban malls or shopping hubs. With urban areas greater than approximately 3,000 there is more incentive to create the suburban mall. For the normal planning horizon of 20 years, urban centres in the region that are larger than 3,000 will continue to be faced with this conflict, while very few urban centres less than this population will have to deal with this pressure.

Commercial development in London is shifting with the renewal of the downtown and also with the expansion of the existing commercial districts and establishment of new commercial districts. The east end commercial development area in London is currently shifting with the recent re-development of several major big box stores and the addition of new stores along the Dundas corridor east of Clarke

Road. In the north end, the Masonville area is experiencing a slight decline with the establishment of a new Hyde Park centred district that includes a number of new big box and super stores.

The City of Stratford includes a downtown district and an east end mall district. The City is currently encouraging new commercial development to locate in the under-serviced west end of the City.

Woodstock is anticipating significant additional growth in commercial development related to its proximity to the Hwy. 401/403 intersection and the projected 2008 opening of the new Toyota Manufacturing facility located east of the City. Ingersoll is emerging as a major hub due to its proximity to Hwy. 401 and neighbouring Woodstock, London and Stratford.

Trends in Commercial Development

As the LTVCA watershed is agrarian based, commercial development will more than likely supply this need. The automotive industry is also a dominant producer within this area, especially due to the connections to the Hwy. 401 corridor.

Also, due to the fact that Lake Erie, Lake St. Clair and the Thames River are dominant features of this landscape, a trend towards supplying recreational activities may be a market niche available for expansion.

In the UTRCA watershed, commercial development is continuing along a trend toward big box store development to support the growing population in the area.

2.6.3.6 Industrial Development

Existing Industrial

Due to its proximity to Highway 401 and other major urban centres in Ontario and the United States, Chatham-Kent has developed a strong industrial land base. The Municipality contains 11 industrial areas that are located either within or adjacent to its seven Primary Urban Centres:

Chatham:	Bloomfield Industrial Area
	Richmond/Park Industrial Area
	Sass Road Industrial Area
	South Industrial Park
Tilbury:	401 North
	401 South
Blenheim	
Ridgetown	
Dresden	
Wheatley	

Within Dutton/Dunwich, industrial development is situated in the northern half of Dutton, south of Hwy. 401, and is predominantly agricultural related industrial.

Industrial development within Leamington is primarily related to food processing, dominated by the H. J. Heinz Company of Canada Limited (tomato based products) and Omstead Foods Limited (fish and vegetable products). However, secondary feeder plants to the major auto industries are also becoming major employers in the area.

Industrial activity in the Township of Southwold has in the past been related primarily to the agricultural community. The exception has been the Ford Motor Co. Talbotville Assembly Plant, located adjacent to Highway 4 in the northeast sector of the Township.

Within the confines of the LTVCA border, the industrial sector in the Strathroy-Caradoc area is mostly agriculture related.

The areas of the Municipality of West Elgin considered most suited for industrial designation are those with ready and convenient access to Highway 401.

Highway 401 is a strong component in all of the municipalities within the lower Thames watershed, providing a direct link to Toronto, London, and Windsor and beyond the borders into the United States. For those urban centres located within close proximity to the 401, the industrial sector is usually located between the urban centre and the highway.

The City of London has a large, growing industrial sector that employs roughly 54,000 people between automotive and manufacturing jobs. Industry in London is anchored by major employers including Labatt Breweries and General Dynamics Land Systems. There has been an overwhelming amount of investment into industry within London supporting major new plant openings and existing plant expansion. In recent years, new investments have helped to create more than 5,000 new jobs. London has serviced industrial land available in several new business parks.

Middlesex County communities that surround London have a strong agricultural foundation and some limited industrial developments. The county and its eight member municipalities have been active in the development of their internal infrastructures and land use planning. Their cooperative efforts have resulted in the development of fully serviced industrial land supporting several existing industrial enterprises and allowing for future business development. Industrial operations range from automotive parts and recreational vehicle manufacturing to roof trusses and food production.

Since 2001, Stratford has seen an increase in new constructed industrial space. Major industrial employers include Cooper-Standard, Dresden Industrial, FAG Aerospace and Clemmer Steelcraft Tech, all which rely on the labour force from Stratford and surrounding areas. These companies supply products including carpet, industrial machinery and automotive parts. Stratford has a supply of serviced industrial land available to support new industry. The neighbouring communities of St. Marys and Mitchell support a number of industrial companies and also have serviced land available for new industrial growth.

Woodstock industries produce a range of products with automotive related industries making up approximately one third of the total. The new Toyota Manufacturing facility currently being constructed east of Woodstock is projected to employ 2,500 workers and this will increase the automotive sector component. In recent years, and in particular in the year since the Toyota announcement, the City of Woodstock has sold several industrial lots.

Industrial Trends

All communities hope to expand their current industrial base and diversify into new areas in order to diversify their economy. The current industrial base is essentially agriculture, food processing and supplying the automotive industry.

The Woodstock annexation to support the new Toyota Plant includes 400 Ha for Toyota and an additional 870 Ha of land that is the subject of a secondary plan and design study. It is anticipated that most of this land will be identified for new industrial uses. A number of parts plants have been announced or are in the site selection stage. These plants will be located in Woodstock and surrounding serviced communities. This will further intensify the industrial activity in the Oxford, Perth and Middlesex area.

To support the desire for an expanded industrial base all communities wish to have serviced land available for industrial investors. The most concerted effort to this end in the region is Chatham-Kent's creation of a new industrial area - the new Highway 401/Bloomfield Road Business Park - is being established on approximately 132 hectares of land at the Bloomfield Road interchange on Highway 401.

2.6.4 Brownfields

A "Brownfield" site is defined by the National Round Table on the Environment and the Economy as an abandoned, vacant, derelict or underused commercial or industrial property where past actions have resulted in real or perceived environmental contamination and where there is active potential for redevelopment[164].

Brownfield and Community Improvement Plans (CIP) vary from municipality to municipality. The brownfield policies that address future uses and remediation of former industrial/ commercial lands for the Municipality of Chatham Kent and the City of London are outlined below.

Chatham-Kent has the largest component of brownfield lands within the lower Thames watershed. The municipality is actively seeking alternative uses for the buildings and lands, i.e. multiple users within an existing building, until a more permanent solution can be achieved.

In Chatham-Kent, the Brownfield Strategy and CIP cover the entire Municipality, not just older industrial areas. The Strategy and CIP need to address several communities that exist within the broader community since the Municipality of Chatham-Kent was created from the amalgamation of a number of municipalities (both urban and rural). The Strategy and CIP address brownfields that result from urban activity, as do most municipal strategies, and also address brownfields that are a legacy of agriculture and agi-business.

The City of London has established a Community Improvement Plan for Brownfield Incentives[165] that applies to those lands that are within the Urban Growth Boundary identified on the Land Use Map (Schedule "A") of the Official Plan. **Figure 2.6.4-1: London Community Project Area for Brownfield Incentives** shows the area covered by this plan.

The Plan indicates that the majority of brownfield sites in the City of London are located within the Urban Growth Boundary and that most of the lands outside the Urban Growth Boundary are designated Agriculture and are not considered to be in need of remediation or redevelopment.

In the UTRCA watershed, there are brownfield areas in all of the major urban centres. Municipalities have either developed or are developing policies and incentives to encourage brownfield re-development. In the smaller urban settings, brownfields are limited in size and location.

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[164] Municipality of Chatham-Kent. Chatham-Kent Brownfield & Bluefield Community Improvement Plan. Adopted by Council April 18, 2005 as Approved by the Ministry of Municipal Affairs and Housing October 13, 2005.
[165] Municipality of Chatham-Kent. Community Improvement Plan for Brownfield Incentives. Adopted by Council February 20, 2006.

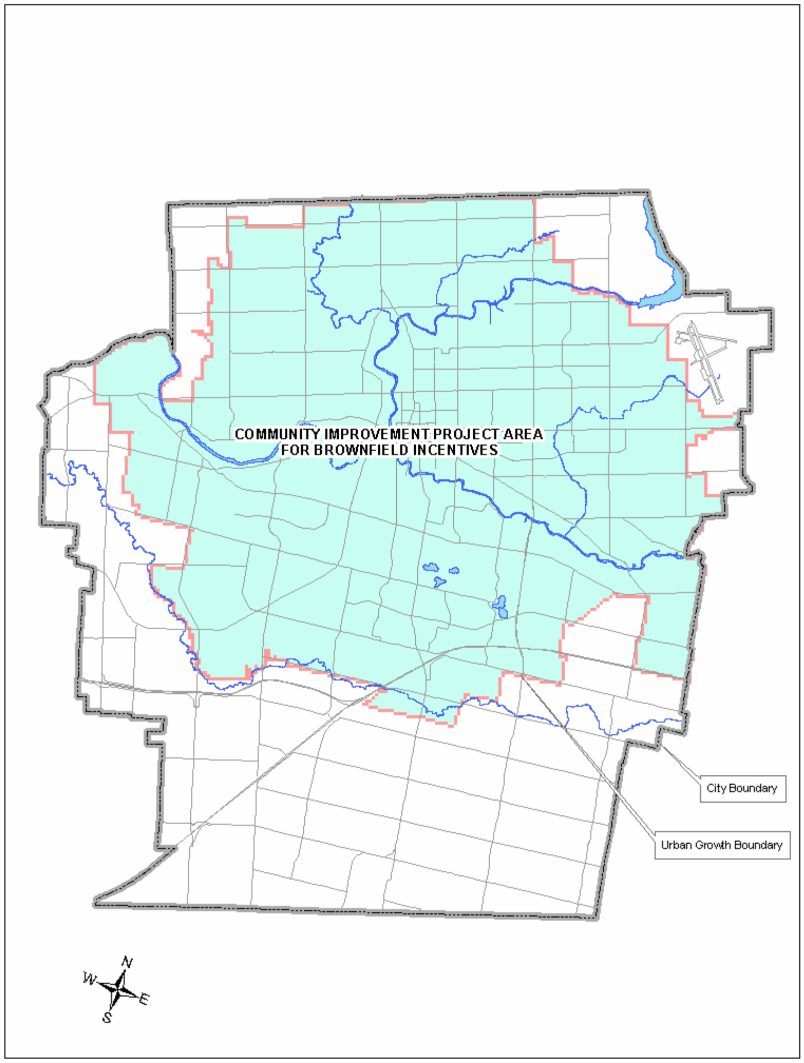

Figure 2.6.4-1: London Community Project Area for Brownfield Incentives

2.6.5 Landfills

There are number of closed and active landfills in Thames Watershed & Region.

2.6.5.1 Existing (Active) Landfills

Table 2.6.5.1-1: Active Landfills within the UTRCA Watershed shows all the active landfill sites within the UTRCA watershed. Of the 11 listed, all are relatively small local facilities for the local communities.

Table 2.6.5.1-1: Active Landfill Sites within the UTRCA Watershed[166]

Landfill Site No	Municipality	Community	Location
Huron			
162401		Usborne	Pt Lot 5, Con SE BNDR
Middlesex			
041502		Lobo	Pt Lot 6, Con 2
041305		North Dorchester	Pt Lot 14, 15,16 *
Perth			
150101		Stratford	Pt Lot 44, 4,5,7, Con 2
150401		Mitchell	Pt Lot 19, Cons 1
150601		Blanshard	Pt Lot 18, Con EMR
150701		Downie	Lot 15, Con 2
151201		Fullarton	Pt Lot 21 NE, Con 18
151202		Fullarton	Pt Lot 24, Con 2
151401		Logan	Pt Lot 20 S1/4, Con 12
Oxford			
070808	Southwest Oxford	Salford	Pt Lot 11, 12, Con 2

* Cited report only refers to Pt Lot 14. Landfill is actually located on Lot Part of Lot 15 and 16.

Table 2.6.5.1-2: Active Landfills within the LTVCA Watershed shows all the active landfill sites within the LTVCA watershed. Of the eight listed, only two, Ridge Landfill and Greenlane, are large capacity facilities, handling waste from the City of Chatham, London and the Metropolitan area of Toronto as well as smaller local urban centres. The remaining six are small, local facilities for the local communities.

Table 2.6.5.1-2: Active Landfill Sites within the LTVCA Watershed[166]

Landfill	Location	Municipality
Chatham-Kent		
Blenheim Landfill	Ridge Road	Chatham-Kent
Ridge Landfill	Erieau Road	Chatham-Kent
Middlesex		
Municipal site	Pt Lot 9, Con C	Middlesex Centre
Municipal site	Pt Lot 22, R1N(E)	Southwest Middlesex
Greenlane Landfill	N Lots 22-23, Con 3	Southwold
Municipal site	N Lot 20, Con 1	Strathroy-Caradoc
Elgin		
Municipal site	S Pt Lot B, Con 7 WD	West Elgin
Municipal site	Lot 6, Con 5 S of A	Dutton/Dunwich

[166] OMOE Waste Management Branch. June 1991.Waste Disposal Site Inventory.

2.6.5.2 Proposed Landfills

Both the Ridge Landfill in Chatham-Kent and the Greenlane Landfill in Southwold went through expansions within the last five to eight years as the existing cells were reaching their capacity. No new landfill sites have been proposed within the jurisdiction of the LTVCA. However, with increasing demands for destinations for the Toronto and Region's municipal waste, the current landfill sites may reach their capacity sooner than anticipated.

At this point in time, no new landfill sites have been proposed within the jurisdiction of the UTRCA.

2.6.5.3 Closed Landfills

Table 2.6.5.3-1: Closed Landfill Sites within the LTVCA Watershed is a list of known closed landfill sites within the LTVCA watershed. **Table 2.6.5.3-2: Closed Landfill Sites within the UTRCA Watershed** is a list of known closed landfill sites within the UTRCA watershed.

The information used to prepare these tables was taken from the Waste Disposal Site Inventory (Waste Management Branch, Ontario Ministry of the Environment, June 1991), as well as from municipal official plans and zoning bylaws. Most of the sites have been closed for many years and information is limited.

Table 2.6.5.3-1: Closed Landfill Sites within the LTVCA Watershed[166]

Landfill	Year Closed	Location	Community	Municipality
Chatham-Kent				
	unknown	E of King & Duke St	Chatham, City	Chatham-Kent
	unknown	Lot 20, Con 5	Harwich	Chatham-Kent
	unknown	Lot B, Con 2 WCR	Harwich	Chatham-Kent
	unknown	Lots 12 & 15, Con 2 RT	Harwich	Chatham-Kent
	1940	Water Street	Chatham, City	Chatham-Kent
	1949	Odette Crescent	Tilbury	Chatham-Kent
Private – Gold's	1950	E end Stanley Ave	Chatham, City	Chatham-Kent
	1952	Lot 14, Con A	Camden	Chatham-Kent
	1954	McGregor Park	Blenheim	Chatham-Kent
	1960	Lot 2, Con 2	Camden	Chatham-Kent
	1964	Lot 3, Con 5	Orford	Chatham-Kent
	1966	Merritt St & Riverview Dr	Chatham, City	Chatham-Kent
	1968	Lot 5, Con 4	Chatham	Chatham-Kent
	1968	Lot 13, Con A	Camden	Chatham-Kent
	1968	Lot 10, Con 10	Highgate	Chatham-Kent
	1969	Richmond St & Merritt St	Chatham, City	Chatham-Kent
	1969	Lot 100, STR	Howard	Chatham-Kent
	1969	Lot 10, Con 1 ECR	Harwich	Chatham-Kent
	1970	Richmond & Industrial Dr	Chatham, City	Chatham-Kent
	1972	Lot 12, Con 2	Howard	Chatham-Kent
	1974	Lots 8-9, 17-18, Plan 293	Wheatley	Chatham-Kent

Landfill	Year Closed	Location	Community	Municipality
	1974	Pt Lot 17, Con 4	Tilbury	Chatham-Kent
	1974	9-14, 16-18, Blk F; I	Wheatley	Chatham-Kent
	1974	Lot 13, Con A	Camden	Chatham-Kent
	1974	Pt Lot 1, Con 8	Dover	Chatham-Kent
	1974	Lot 13, Con 4	Raleigh	Chatham-Kent
	1975	Pt Lot 7, Con 8	Raleigh	Chatham-Kent
	1977	Byng Avenue	Chatham, City	Chatham-Kent
	1979	Lot 7, Con 3	Chatham	Chatham-Kent
	1980	SE ½ Lot 7, Con 12	Howard	Chatham-Kent
Fletcher Landfill	1981	N ½ Lot 1-2, Con 8	Tilbury East	Chatham-Kent
	1989	Pt Lot 13, Con 9	Tilbury East	Chatham-Kent
Elgin County				
	unknown	Lot 14, Con 1		Southwold
	unknown	NE ¼ Lot 10, Con 5 N of A	Dunwich	Dutton/Dunwich
	1915	Lot 10, Con BF		Southwold
	1966	Centre St & Ridout St	Rodney	West Elgin
	1971	S Pt Lot 11-12, Con 5	Rodney	West Elgin
	1973	NW ¼ Lot 15, Lot 13	Aldborough	West Elgin
	1974	Lot 17, Con 8	Aldborough	West Elgin
	1975	Lot 18, Con 4	Aldborough	West Elgin
Essex County				
	unknown	Lot 21, Con 6	Tilbury North	Lakeshore
	1971	Lot 12, Con 2	Tilbury North	Lakeshore
	1971	Ford Street (Comber)	Tilbury West	Lakeshore
Middlesex County				
	unknown	E Lot 19, Con 2	Caradoc	Strathroy-Caradoc
	unknown	Lot 20, Con 1	Caradoc	Strathroy-Caradoc
	1954	Lot 8, Con 1	Ekfrid	Southwest Middlesex
	1959	Pt Lot 8, Con 3	Ekfrid	Southwest Middlesex
	1962	Lot 18, Range 1 North	Caradoc	Strathroy-Caradoc
	1965	Lot 15, Con 1	Caradoc	Strathroy-Caradoc
	1967	Lot 21, Con 3	Mosa	Southwest Middlesex
	1971	Lot 8, Con 1	Delaware	Middlesex Centre
	1971	Lot 23, Con 2	Ekfrid	Southwest Middlesex
	1971	Lot 19, Range 1 North	Ekfrid	Southwest Middlesex
	1971	Lot 17, Range 1	Mosa	Southwest Middlesex
	1972	Pt Lot 23, Con 1	Ekfrid	Southwest Middlesex

Table 2.6.5.3-2: Closed Landfill Sites within the UTRCA Watershed[166]

Landfill Site No.	Year Closed	Municipality	Community	Location
Middlesex				
040102	1971		London	Lot 1-2, 16, Con RP29;RP
040103	1954		London	Lot 2-3, Con RP266
040104			Westminister	Pt Lot 19-22, Con 1
040105	1954		London	Pt Lot 3-4, Con A
041302	1970		Dorchester, North	Pt Lot 18 S1/2 Con 1
041501	1949		Lobo	Lot 6, Con 2
041601			London	Pt Lot 28 N1/2 Con 5
042004	1986		Nissouri, West	Pt Lot 20-21, Con 2
042101	1971		Westminister	Pt Lot 76 SE1/4, Con W.T.R
042102			Westminister	Pt Lot 18-20, Con 6
042133	1981		Westminister	Pt 69 & 70 Con W.N.B.T.R
X 5012			London	Lot 28, Con 7
X 5019	1955		Dorchester, North	Lot 22, Con 2
X 5020	1955		Dorchester, North	Lot 7, Con 5
X 5021	1970		Dorchester, North	Lot 17, Con 1-2
X 5023	1959		Nissouri, West	Lot 15, Con 2
X 5024	1949		Nissouri, West	Lot 16, Con 2
X 5045	1956		London	Thompson Rd
X 5047			London	Pond Mills Rd
X 5048	1967		London	River Road
X 5049	1971		London	The Crossway
X 5050	1961		London	Weston Street
X 5051	1972		London	Euston Street
X 5052	1961		London	Elmwood Ave
X 5053	1961		London	Forward Ave
X 5054	1946		London	Greenside Ave
X 5055	1959		London	Cove Road
X 5056	1950		London	Westown site
X 5057	1961		London	Beaufort St
X 5058	1961		London	The Parkway
X 5059			London	Victoria St.
X 5060	1960		London	Cromwell St.
X 5061			London	Logan St.

Landfill Site No.	Year Closed	Municipality	Community	Location
X 5062	1940		London	Terra Cotta Ave
X 5063	1940		London	Elliot St.
X 5064			London	Grosvenor St.
X 5065	1943		London	Mornington Ave
X 5066			London	Rectory St
X 5067	1945		London	Oak St
X 5068	1961		London	Hale St
X 5069	1970		London	Balfour Place
X 5070	1988		London	N. Pond Mills Rd
X 5071	1956		London	Emerson Ave
X 5072			London	Brookside St
X 5073			London	Bond St
X 5074	1961		London	Moore St
X 5075			London	Percy St
X 5076	1965		London	N Talbot Rd
X 5077			London	Oxford St W.
X 5078	1961		London	Terrace St
X 5079			London	Duchess Ave
X 5080			London	Lockwood Park
X 5081			London	Landsdowne & Trafalgar St
X 5082	1954		London	Wharncliffe St S.
X 5083	1930		London	Terrace St
X 5085	1968		London	Clark & Cheapside St
X 5086	1961		London	Oxford St. East
X 5107	1957		London	Nelson St
X 5249	1971		London	Lot 2-3, Con R.P 266
Oxford				
A 070101	1975		Woodstock	Parkinson Rd & Mill St
A 070201	1971		Woodstock	Lot 131-132 Plan 27
A 070501	1989		Woodstock	Pt Lot 19, Con 9
A 070502	1973		Zorra	East end of Ralph St
A 070704	1989		Norwich	Pt Lot 14 N ½, Con 7
A 070803	1979		Oxford South W	Lot 1, Con BFT
A 070808	1983		Oxford South W	Lot 11, Con 2
A 070901	1989		Zorra	Pt Lot 22 E1/2, Con 12
A 070902	1979		Zorra	Lot 22, Con 4
A 070905	1982		Zorra	Pt Lot 7 E1/2, Con 2

Landfill Site No.	Year Closed	Municipality	Community	Location
X 2001	1964		Woodstock	Ingersoll Ave
X 2002	1960		Woodstock	Phelan & Cathcart St
X 2003	1962		Woodstock	Fairgrounds
X 2004	1964		Woodstock	Park Row
X 2005	1959		Woodstock	Kintrea Park
X 2007			Ingersoll	Janes Road
X 2008	1971		Ingersoll	Victoria West
X 2009	1971		Ingersoll	Thames River & King St
X 2010	1961		Ingersoll	C.N.R & Wilson
X 2011	1971		Ingersoll	Thames River & Wonham St
X 2012	1945		Ingersoll	William & Thames St
X 2013			Ingersoll	Thomas St West
X 2026	1965		Norwich	Lot 14, Con 5
X 2029	1964		Oxford South West	Lot 21, Con 2-3
X 2030	1977		Ingersoll	County Rd # 9
X 2031	1936		Ingersoll	Pemberton St
X 2032	1971		Zorra	Lot 22, Con 4
X 2033			Zorra	Brock St
X 2034	1960		Oxford Southwest	County Rd # 9
X 2035			Zorra	Lot 1, Con 3
X 2036			Oxford Southwest	Lot 1, Con 3 (Denby)
X 2037			Oxford Southwest	County Rd # 9
X 2038	1971		Woodstock	Dundas Ave
X 2041	1920		Woodstock	Bay St
X 2042	1890		Woodstock	Burtch St
X 2043	1950		Woodstock	Hunter St
X 2044	1950		Woodstock	Main St
X 2045			Woodstock	Ingersoll Rd
Perth				
A 150201	1984		St. Mary’s	Pt Lot 24 Thames River Conc.
X 6029	1940		Stratford	Park St
X 6030	1958		Stratford	Martin St
X 6031	1966		Stratford	Romeo St
X 6043	1974		Easthope, North	Lot 18, Con 3
X 6044	1979		St. Mary’s	Huron St North
X 6045	1970		Mitchell	Eleanor St
X 6046	1945		Mitchell	Herbert St

Landfill Site No.	Year Closed	Municipality	Community	Location
X 6047	1972		Logan	Lot 30, Con 13
X 6048	1968		Ellice	Lot 1, Con 1

2.6.6 Mining/Aggregates

Aggregate removal and mining activity vary across the Thames Watershed & Region. **Map 6: Surficial Geology** provides some information on the potential aggregate (sand and gravel) resources available in the region. Diverse aggregate resources are found within the Thames Watershed & Region. Also, the proximity of bedrock to the surface has allowed the development of limestone quarrying and bedrock crushing operations.

Oxford County is characterized by significant reserves of mineral aggregates from both naturally-occurring sand and gravel deposits and bedrock-derived crushed stone. The presence of substantial, high-quality deposits has led to the establishment of significant quarrying and sand and gravel extraction industries in the County. Much of the activity is located in Zorra Township. In this Township, extensive deposits of high calcium limestone are recognized as the thickest, most uniform and purest in Ontario[167]. Similarly, many parts of Zorra contain abundant deposits of sand and gravel, many of which are currently licensed for extraction. The County of Oxford Official Plan[168] recognizes the importance of mineral aggregates as essential non-renewable natural resources and has a strategic aim of ensuring the wise management of these resources.

Several sections of Middlesex County contain abundant Quaternary deposits of sand and gravel. Portions of the City of London, including the Byron area and land surrounding Fanshawe Conservation Area, contain valuable deposits in close proximity to a large market with high demands for aggregate resources. In the Komoka area of Middlesex Centre Township, most of the aggregate resources have been extracted, although some pits are still active.

Compared to other portions of the watershed, Perth County does not have an abundance of mineral aggregate resources. Primary sand and gravel deposits are limited in terms of location and quality. Excessive overburden limits the accessibility of limestone deposits that underlay most of the county, with St. Marys being the notable exception. Here, extensive quarrying activity since the 1880s has produced a significant percentage of limestone used for the production of cement products in the Great Lakes region.

There is a significant gravel and sand deposit located in southeastern Chatham-Kent that extends into West Elgin with isolated pockets in Dutton/Dunwich and Southwold Townships. While the resource exists, extraction is dependent on nearby demand and access to a good transportation route. Therefore, actual extraction from this deposit takes place at Pinehurst in the community of Harwich, near Cedar Springs, again in the Community of Harwich and in the hamlet of Clachan. There are a few other isolated areas near the Thames River east of Thamesville in the Bothwell Sand Plain where extraction takes place.

Other smaller deposits that are not used at this time exist in the following locations:

- Dutton-Dunwich between Talbot Trail and Highway 401.
- Dutton-Dunwich near the Thames River.
- West Elgin near the Thames River and near County Road 3.
- Southwold near the Thames River and Highway 401 corridors.

[167] Oxford County. 1995. Oxford County Official Plan.
[168] Oxford County. 2005. Oxford County Official Plan 2005. www.county.oxford.on.ca

2.6.7 Oil and Gas

Southwestern Ontario has a long history related to the oil and gas industry. **Map 31: Oil and Gas Wells** shows the concentration of wells across the area.

The oil field in Bothwell was one of the earliest fields in North America. The gas field near Port Alma was so prolific that at one point it provided natural gas to the Cities of Windsor, Chatham and London. It also provided the base for the incorporation of the Union Gas Company, whose head office is still in Chatham.

Chatham-Kent remains the second largest producer of oil and gas in Ontario. Two of the largest oil pools in Ontario are located partially in the community of Romney, with other oil production taking place in the community of Dover. There is also some natural gas production in Lake Erie, with a natural gas field in Lake Erie of sufficient size to support a natural gas processing plant near Morpeth.

There is also an active oil field in West Elgin north of Rodney, and 15 active wells in Dutton-Dunwich, generally north of the Village of Dutton, extending into Middlesex County.

Middlesex, Oxford and Perth Counties are underlain by Paleozoic sedimentary rocks up to 1,000 metres in thickness. These rocks have the potential for occurrence of oil and gas resources. However, very few commercial discoveries of hydrocarbons have been made other than the Innerkip gas pool in the northwestern corner of the UTRCA watershed. The gas in the Innerkip pool occurs within porous sandstones deposited during the Cambrian Period of geologic time at a depth of approximately 900 metres. Natural gas has been produced from the Innerkip gas pool since 1961. Only non-commercial shows of oil or natural gas have been encountered in the rest of the watershed. Relatively few wells have been drilled over 100 m to explore for hydrocarbons in the area and there is potential for additional undiscovered pools.

2.6.8 Forestry

While forestry is often considered a northern Ontario operation, the high values of some hardwood species have made woodlots in southwestern Ontario very valuable. Most private land forestry in southern Ontario uses a selective logging approach[169]. Sound silvicultural practices can ensure the long-term health of the woodlot while providing a source of income for the landowner. The reforestation of marginal farmland helps prevent erosion, filters runoff and retains soil moisture.

2.6.9 Transportation, Services & Utilities

2.6.9.1 Transportation by Rail, Roads, Water and Air

Southwestern Ontario has an excellent transportation network available for travel and transportation connections across Canada, North America and the world. Much of the development, urban and industrial, can be traced to the availability of water, rail and road transportation and the availability of good transportation continues to be a major factor in industrial and commercial development activities across the region. **Map 32: Transportation** provides an overview of the transportation network for the Thames Watershed & Region.

Water

Water was initially the most important means of transportation for the municipalities along the Thames River and the shorelines of Lake St. Clair and Lake Erie. Navigation by vessels is limited to the Thames below London, but a larger extent of the river was used by early settlers for surface bulk transportation in the form of log running.

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[169] Norri, Tod. 2000. To Cut or Not to Cut. In S & W Report Winter/Spring 2000 (Volume 18).

Transportation by watercourse suffered from limitations of inland shipping capacity and a limited number of deep water harbours. While the Thames River is quite deep (approximately 6 metres) from Chatham to the river mouth, the generally shallow eastern basin of Lake St. Clair as well as the naturally formed 'sandbar' at the mouth of the river prohibits the river's use for commercial boat traffic. For this reason the Thames River itself, while it has had a long history of being used as a commercial transportation route, is no longer capable of being economic.

The only commercial shipping in the region is now based out of Erieau on Lake Erie. The primary commercial purpose of the harbour is as a fishing port and charter fishing destination. The recent past has seen the shipping of sand and gravel to the dock.

Recreational boating takes place from many centres on Lake St. Clair and Lake Erie with the primary areas being Lighthouse Cove, Chatham, Wheatley, Erieau, Rondeau Bay and Port Glasgow. The Thames, although not navigable for large craft, still provides a picturesque locale for recreational boating, canoeing, rowing, and kayaking.

Road

Early inland roads were set out to join urban centres that were historically located on either lakes or rivers. These transportation routes paralleled either these watercourses or lake shorelines. For example, one of the first surveyed roads (Dundas Street), designed originally as a military road to transport supplies to Lake St. Clair, was laid out in 1793 by widening an old Aboriginal trail that followed the course of the Thames River[170]. Similarly, the Talbot Road paralleled the Lake Erie shoreline. During the initial surveying of the area, road allowances were provided to service the yet to be settled rural area.

Today, Hwy. 401, which stretches from the Ontario-Quebec border to the Ontario-Michigan border at Windsor-Detroit, and Hwy. 402, which connects to Hwy. 401 at London to the border crossing at Sarnia-Port Huron, provide road transportation links across the region to other parts of Ontario, Canada and North America.

While road transportation has increased, the maintenance of the roads has increasingly been taken over by local governments. The only major roads that remain provincial highways are the limited access 400 route series of highways and the major connecting links to these highways, that link significant urban centres.

Rail

With the onset of the age of the railroad, new transportation routes were laid out. Again, these normally linked major urban centres and paralleled watercourses. At this transportation stage more consideration was given to linking additional centres. The City of Detroit wished to be linked with other upper New York State centres like Buffalo and Rochester. These privately owned railways could save significant funds by taking the Canadian route. Also, they found that they could save significant expenses by routing the railway through higher ground along watershed divides. The reason for this saving was that the bridges at watershed boundaries were much smaller than bridges near a major watercourse. The Chesapeake and Ohio and the Conrail routes were located generally along the watershed boundary between Lake Erie and the lower Thames River. It is interesting to note that the 401 Highway, to a large extent, follows a similar routing to reduce costs.

The usage of transportation routes is subject to the vagaries of time and economy. Transportation by railroad has less flexibility than road regarding pick-up and drop-off points. Rail has had more difficulty of late because a lot of agricultural products are being transported by truck. Recent rail lines have been abandoned, most notably being much of the C&O route from Wheatley to Blenheim.

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[170] Thames River Background Study Research Team. 1998. The Thames River Watershed, A Background Study for Nomination under the Canadian Heritage Rivers System.

Some of the more significant road and rail transportation routes are given in **Table 2.6.9.1-1 Transportation Routes-LTVCA** and **Table 2.6.9.1-2 Transportation Routes-UTRCA**.

Table 2.6.9.1-1: Transportation Routes – LTVCA

Transportation Mode	Location (related to nearby centres in the LTVCA)
Railways	
CNR	Windsor to St. Thomas through Tilbury, Blenheim, Ridgetown, West Lorne and Dutton
CNR	Windsor to London through Lighthouse Cove, Chatham, Thamesville and Glencoe
C & O	Windsor to Sarnia through Tilbury and Chatham
CPR	Windsor to London through Tilbury and Chatham
CNR	Glencoe to St. Thomas
Provincial Highways	
401	Windsor to London through Tilbury, West Lorne and Dutton
402	London to Sarnia through Delaware
40	Blenheim to Sarnia through Chatham
77	Comber to Leamington
Other Former Highways	
2	Windsor to London through Tilbury, Chatham, Thamesville and Delaware
3	Windsor to Niagara Falls through Wheatley, Blenheim, Morpeth, Eagle and Shedden
21	Ridgetown to Dresden through Thamesville
76	West Lorne to Woodgreen
80	Glencoe to Courtwright

Table 2.6.9.1-2: Transportation Routes – UTRCA

Transportation Mode	Location (related to nearby centres in the UTRCA)
Railways	
CNR	Main CN Line extends between Woodstock and London A second line runs from London, to St. Marys to Stratford and continues east A third line runs from London west to Sarnia
CPR	Innerkip west through Woodstock to Ingersoll
Goderich-Exeter Railway	Stratford to Mitchell West
Provincial Highways	
401	London to Woodstock
402	London to Delaware
403	Begins in Woodstock and continues east
Highways & Former Highways	
2	Woodstock to Thamesford to London to Delaware
7	Elginfield through St. Marys, Stratford and joins with Hwy 8 through Shakespeare to Kitchener
8	Mitchell through Sebringville, Stratford joins with Hwy 7 to Kitchener
4	Lambeth north through London, Arva, Birr and Elginfield
23	Elginfield through Kirkton, Woodham, Mitchell to Bornholm
59	Woodstock north to Tavistock
19	County Road 199 from Milverton through Stratford. Joins Hwy 7 to Wildwood then veers south through Medina, Kintore, Thamesford, Ingersoll, Salford to Mount Elgin
22	From Fanshawe Reservoir to Lobo

Airports

Three commercial airports, the London International Airport, the Chatham Airport and the Stratford Municipal Airport, are located in the region.

The London International Airport now ranks as the 12th busiest passenger airport in Canada and the 11th busiest airport as measured by aircraft take-offs and landings[171]. The Airport is home to over 40 businesses and generates an economic impact to the area in excess of $220 million. In terms of employment, the airport and associated businesses employ over 1,000 individuals and ranks in the top 10 employers in the London area. From aircraft manufacturing at Diamond Aircraft to fixed and rotary wing flight training, to jet and piston aircraft maintenance, the London International Airport is a hub for general aviation services in Southwestern Ontario.

The Stratford Municipal Airport has two asphalt runways that cater to private and corporate aircraft[172]. The airport also provides Stratford Air Service Flight Training.

[171] London International Airport website: Airport History. www.londonairport.on.ca/history.html
[172] Canadian Owners and Pilots Association website: Places to Fly. www.copanational.org/PlacesToFly

The Chatham Airport is located approximately 14 km southeast of Chatham. The commercial aspects of this airport are cargo delivery, passenger charter, specialized parcel delivery, refuelling and flight school.

2.6.9.2 Services & Utilities

Water

Most of the urban population in the Thames Watershed & Region is supplied with piped potable water from municipal systems. Expansion of the water pipeline system throughout the rural area is continuing. A brief summary of the major water supplies is provided below. More information on drinking water sources is provided in **Section 2.7: Water Uses**.

In general, communities in Oxford and Perth Counties depend on groundwater sources for their drinking water supplies. Some Middlesex County communities also use groundwater.

The City of London, which is the largest population centre, has water supplied via pipelines from both Lake Huron and Lake Erie. Several other Middlesex County communities also use water supplied by these pipelines.

Most community drinking water supplies in Elgin, Chatham-Kent and Essex are generally obtained from piped treated surface water from Lake Erie or Lake St. Clair. Only the communities of Highbury and Ridgetown in Chatham-Kent use groundwater sources.

Natural Gas

Most of the urban areas are serviced by piped natural gas.

2.6.10 Wastewater Treatment

Sewage Treatment

Serviced areas are found in larger urban areas and many of the smaller communities throughout the area. The City of London has several waste water treatment facilities all of which discharge to the Thames River watershed. Non-serviced areas are found in rural areas and smaller communities.

Table 2.6.10-1: Wastewater Treatment outlines the communities that have wastewater treatment facilities and also identifies some smaller communities that are served by private sewage disposal (septic) systems. **Map 36: Wastewater Treatment** shows the location of municipal sewage treatment facilities in the Thames Watershed & Region. In general, the boundaries of the areas serviced by the sewage treatment facilities are shown by the urban/industrial land identified on **Map 36** and the areas with higher population densities shown in **Figure 2.6.1-1: Generalized Population Densities**.

Table 2.6.10-1: Wastewater Treatment

Municipality	Community	WWTP, Lagoons or Septic
City of London	London	Adelaide WWTP
		Greenway WWTP
		Vauxhall WWTP
		Pottersburg WWTP
		Oxford WWTP
	Lambeth	Southland WWTP
	Westminister	WWTP

Municipality	Community	WWTP, Lagoons or Septic
Township of Lucan-Biddulph	Granton	WWTP
Township of Thames Centre	Dorchester	WWTP and Septic
Township of Middlesex Centre	Ilderton	WWTP
	Arva	WWTP
	Kilworth Heights	WWTP
	Komoka	WWTP
	Melrose	Septic
	Denfield	Septic
	Delaware	Septic
County of Oxford	Woodstock	WWTP
	Ingersoll	WWTP
	Innerkip	Septic (transitioning to WWTP)
	Tavistock	Lagoons
	Hickson	Septic
	Beachville	Septic
	Mount Elgin	Septic/WWTP (partially serviced)
	Sweaburg	Septic
	Thamesford	WWTP
	Embro	Septic (transitioning to WWTP)
	Lakeside	Septic
City of Stratford	Stratford	WWTP
Town of St. Marys	St. Marys	WWTP
Township of West Perth	Mitchell	WWTP
Township of Perth East	N/A	N/A
Township of Perth South	St. Pauls Station	Septic
	Shakespeare	Septic
Municipality of South Huron	N/A	N/A
Township of Strathroy-Caradoc	Mt. Brydges	Septic
Municipality of Southwest Middlesex	Glencoe	Lagoons
	Wardsville	WWTP
	Melbourne	Septic
	Appin	Septic
Municipality of Dutton/Dunwich	Dutton	WWTP
	Wallacetown	Septic
	Iona and Iona Station	Septic
	Dunwich	Septic

Municipality	Community	WWTP, Lagoons or Septic
Township of Southwold	Shedden	Septic
	Fingal	Septic
Municipality of West Elgin	West Lorne	WWTP
	Rodney	WWTP
	Eagle	Septic
	Port Glasgow	Septic
Municipality of Chatham-Kent	Chatham	WWTP
	Ridgetown	Lagoons/ WWTP
	Blenheim	Lagoons/ WWTP
	Tilbury	WWTP/ Lagoons
	Highgate	Septic
	Thamesville	WWTP
	Erieau	Septic
	Charing Cross	Pipeline to WWTP
	Merlin	Lagoons
	Kent Bridge	Septic
	Shrewsbury	Septic
	Wheatley	STP
	Pain Court	Pipeline to WWTP completion target June 2006
	Erie Beach	Septic
	Cedar Springs	Septic
	Rondeau Bay Estates	Septic
Town of Leamington	Staples	??
	Windfall	Septic
	Goldsmith	Septic
Town of Lakeshore	Strangfield	??
	Lighthouse Cove	??

Stormwater Management

Water that flows across impervious surfaces such as paved areas and enters surface water courses untreated is considered stormwater. It can be contaminated with various pollutants and the Ministry of the Environment issued a Stormwater Management Planning and Design Manual (March 2003). In general, stormwater management is the responsibility of the lower tier government in a multi-tier municipal system and a more significant concern in larger urban centres.

2.6.11 Agriculture

Agriculture has a long history in the Thames Watershed & Region. This region is one of the most productive agricultural regions in the country, supporting a broad range of both specialized and intensive farming operations. The favourable, mild climate, fertile soil and abundant precipitation in the region have contributed to the agricultural success of the area. This productivity and prosperity provided the impetus for local agricultural industries that greatly influenced the settlement and development of villages, towns and cities.

Market conditions and soils have led to cash crop cultivation becoming the dominant land use. However, there is a wide range of specialty crops of tomatoes, fruits and vegetables as well as a variety of livestock operations from beef and dairy cattle to poultry and eggs. As shown on **Map 33: Land Capability for Agriculture**, most of the soils in the region are Class 1, 2 or 3 soils that are suitable for the sustained production of common field crops.

It is not surprising that this region was the site of the first examples of agriculture or horticultural cultivation in Canada. Farming dates back more than 1,000 years in the Thames watershed, when the Woodland peoples grew corn on fertile flood plain lands. The shift from a hunting and gathering society to a crop based one, in Canada, occurred in the Thames watershed between 500 and 1000 A.D.

Early settlements in the Thames valley were situated on the flood plains[173]. These areas were considered to be highly suitable for agriculture as well as trade, transportation and later, industry. The settlers made use of these clear areas for their first crops, and as early as 1793 a visitor remarked on the fine wheat, corn, peas and grass growing along the river. One writer described these lands at the "Moravian" Delaware settlement at Fairfield as "such rich land as we have nowhere seen, being like a dung-heap, and easily cleared."

Some cattle were being raised in the early 1800s, particularly on the natural meadows along the Lake St. Clair shores. They were sold to the military garrisons. In 1819-20 a few Negro runaway slaves introduced tobacco culture to the Lower Thames, and in 1821 it was being raised in some quantity. Most of the development of farmland in the province occurred after the 1830s. At that time, farming was extremely labour intensive and took place on parcels having an area of less than 100 acres.

In 1854 the area's first railroad, the Great Western, was opened through Chatham to Windsor from the east. This opened up the access to American markets and gave impetus to the increase in production of livestock for meat, dairy products and wool. At the same time apparent soil exhaustion and insects and disease took a toll on wheat. The 1860s witnessed a new era of farming with the establishment of cheese-making factories and creameries to process milk into cheese and butter that could be stored and transported to distant markets. The diversification and expansion of the market for dairy products was a direct consequence of the increased demands from the growing local market due to increased populations, as well as from the United States and Great Britain.

Prior to 1860, the great areas of land in the lower Thames and other parts of southwestern Ontario needed drainage and were of little use for farming. In 1872, Ontario passed the Provincial Drainage Act, giving municipal councils the right, on majority demand, to carry out open ditch drainage work. In 1878 The Tile Drainage Act authorized borrowing of up to $1,000 through a municipality for tile drainage. Improved drainage opened up large areas to cultivation[174].

As a result of the increased demand and new market for dairy products, livestock farming increased while wheat declined in importance. This trend continued when wheat prices became unstable after 1873. Between 1900 and 1945, livestock farming became a key component of most farming operations in addition to cash crops.

[173] Jones, R.L. 1946. History of Agriculture in Ontario.
[174] Hamil, F.C. 1951. The Valley of the Lower Thames.

Technological advancements after the 1920s also served to shape the farming economy. With the introduction of the tractor and other farm machinery, more land could be managed with fewer people. This allowed for higher yields of crop production that, in turn, resulted in larger livestock operations.

This trend continued after 1945, when agriculture was driven by the need to lower production costs balanced with maximizing profits and meeting the demands of the marketplace. The size of farming operations continued to increase in size in order to allow for economies of scale.

The 1952 Upper Thames Valley Conservation Report includes a land use inventory for the watershed. As indicated in **Table 2.6.11-1: Land Use in the UTRCA Watershed in 1952**, the inventory consisted of six classes:

- idle
- forest
- pasture
- cultivated
- row crops
- urban use

It should be noted that only one third of the watershed or 313,000 acres was actually measured.

Table 2.6.11-1: Land Use in the UTRCA Watershed in 1952

Land Use	Acreage	Percentage of Land Area
Row Crops	21,597	6.9%
Cultivated	195,983	62.6%
Pasture	69,130	22.1%
Forest	21,684	6.9%
Idle & Urban	4,641	1.5%
Total	**313,031**	**100**

Source: Upper Thames Valley Conservation Report, 1952

At that time, more than 90% of the watershed was used for agricultural activities. For the most part, farming was based on a mixture of crops and the production of beef, dairy products, hogs and poultry. At that time, except in rare cases, the raising of hogs and poultry was secondary to the production of beef and dairy products. It was indicated that more than 30% of the soil in the watershed was inadequately drained naturally, for the production of a full range of crops. For the purposes of the analysis, the Upper Thames watershed was divided into six farm regions as described in **Table 2.6.11-2: Farm Regions in the UTRCA Watershed - 1952**.

Table 2.6.11-2: Farm Regions in the UTRCA Watershed – 1952

Region	Description
Perth County Region	Northern portion (north of Mitchell & Stratford) – dominated by beef production with some dairy herds. Cash Crops included wheat and flax.
London Township Region	Very mixed region. Western limits – distinct beef production – very mixed with respect to the types of herds. Dairy farming and milk production in the vicinity of London. Significant amount of cash cropping – sugar beets, wheat and barley.
Thamesford – London Plain	A considerable amount of cash cropping and dairy farming. Truck crops and fruit were anticipated for the future.
Oxford County Region	Predominantly dairy farms and cheese production. General farming. Demand for winter feed requires that a large proportion of the land is cultivated for grain and legumes.
Lakeside Region	Mix of farms with more beef production. There is a greater proportion of pasture.
Komoka Region	Cash cropping includes tobacco as well as fruit and truck gardening. There is a considerable amount of woodland.

Source: Upper Thames Valley Conservation Report, 1952

Agricultural production became more intensive in the 20th century. Livestock farming has evolved into large, specialized livestock operations. The introduction of the feedlot has allowed farmers to concentrate their livestock operations and utilize the balance of their lands for cropland. Furthermore, farming operations have become more specialized. Specialty crops such as hybrid corn and soybeans are being produced for their high yields. This trend is anticipated to continue into the future.

Table 2.6.11-3: Current Land Use in the UTRCA Watershed. The watershed is still predominantly rural in nature with agriculture being the predominant land use in 26 of the 28 subwatershed units. In 16 of the 28 watersheds, which represent approximately 63% of the total land area in the UTRCA watershed, agriculture accounts for more than 80% of the current land use. Notably, there are four subwatersheds where agriculture accounts for more than 90% of the land use.

Table 2.6.11-3: Current Land Use in the UTRCA Watershed

Subwatershed (County*)	% of Watershed	Agriculture (%)	Woods (%)	Urban (%)	Quarry (%)	Water (%)
Avon River (P)	5.0	74.5	10.9	13.8	0.2	0.5
Black Creek (P)	4.0	82.8	15.5	1.2	0.3	0.3
Cedar Creek (O)	3.0	72.5	12.1	14.2	0.9	0.3
Dingman Creek (M)	5.0	63.8	14.3	21.3	0.4	0.2
Dorchester (M &O)	3.7	67.7	21.1	8.9	1.2	1.1
Fish Creek (H,M,P)	5.0	91.1	8.3	0.2	0.3	0.1
Flat Creek (P)	3.0	89.8	9.8	0.1	0.1	0.2

Subwatershed (County*)	% of Watershed	Agriculture (%)	Woods (%)	Urban (%)	Quarry (%)	Water (%)
The Forks (M)	2.5	4.3	12.9	77.7	3.1	2.0
Glengowan (P)	3.0	87.4	9.7	2.4	0	0.5
Gregory Creek (M,O,P)	2.0	90.8	8.3	0.7	0.2	0
Komoka Creek (M)	1.0	65.2	20.5	9.7	4.0	0.6
Medway Creek (M)	6.0	82.8	10.8	5.8	0.2	0.4
Middle Thames (O)	5.0	84.1	13.0	1.1	1.3	0.4
Mud Creek (O)	4.4	86.9	12.4	0.5	0.1	0.1
North Mitchell (H,P)	5.0	93.0	4.9	1.8	0.2	0.1
North Woodstock (O, P)	7.0	80.1	13.0	5.7	0.1	1.1
Otter Creek (P)	2.0	88.3	10.0	0.5	1.0	0.1
Oxbow Creek (M)	3.0	83.7	15.3	0.8	0.2	0
Plover Mills (M,O,P)	3.0	74.4	11.8	9.1	1.0	3.7
Pottersburg Creek (M)	1.5	39.9	6.9	53.2	0	0
Reynolds Creek (M,O)	5.0	87.1	1.8	0.5	0.3	0.3
River Bend (M)	2.0	48.5	24.0	19.3	5.2	2.9
South Thames (M,O)	6.4	77.2	10.8	10.1	1.3	0.6
Stoney Creek (M)	1.0	69.0	12.4	13.6	4.9	0.5
Trout Creek (O,P)	4.4	77.3	17.4	2.6	0.4	2.3
Waubuno Creek (M,O)	3.0	83.2	11.6	4.9	0	0.3
Whirl Creek (P)	4.0	92.0	6.8	1.2	0	0
Wye Creek (M, O)	1.5	88.8	8.6	1.2	1.3	0.1

Source: The Upper Thames River Watershed Report Cards (2001)
* Counties: H = Huron, M = Middlesex, O = Oxford, P = Perth

2.6.11.1 Agricultural Sector Distribution

The best source of data on the agricultural industry is Census Canada. This data is gathered on the basis of political area or region. There are portions of seven Census Canada Divisions within the Thames Watershed & Region. These are Essex, Chatham-Kent, Elgin, Middlesex, Oxford, Perth and Huron.

Due to a number of factors, including moderate temperatures, adequate rainfall, adequate growing season and good soil, the major land use in the region is agricultural and, more specifically, cash crop land. From **Table 2.6.11.1-1: Agricultural Land Use**, one can see that farmland makes up over 80% of the land use in the region. Also, most of this farmland is used in the raising of field crops.

Table 2.6.11.1-1: Agricultural Land Use

Land Use (hectares)	Essex	Chatham-Kent	Elgin	Middlesex	Oxford	Perth	Huron
Cropland	127,187	208,433	122,147	207,556	151,696	174,141	236,761
Summer fallow	111	114	219	249	162	50	113
Improved Pasture	1,065	2,646	3,693	8,472	4,281	6,547	11,874
Unimproved Pasture	737	1,874	3,091	7,471	4,229	5,165	7,274
Other land	6,115	10,483	21,553	27,287	19,903	17,625	34,968
Total Area of Farms (Ha.)	135,214	223,549	150,703	251,035	180,270	203,527	290,996
Total Area of Region (Ha.)	182,000	249,000	188,400	333,300	202,736	219,121	340,200
Farmland as a % of Total Area	74.3	89.8	80.0	75.3	88.9	92.9	85.5

Sources: 2001 Census of Agriculture and Policy and Programs Branch, OMAF

The cropland is used to produce, in most cases, valuable cash crops. **Table 2.6.11.1-2: Major Field Crops** illustrates the proportion of several major types of crops in the area. Soybeans, corn and wheat are the three main crops. Most of the soybeans are sold for commercial use; however, approximately 10-20% are organically grown and processed into soy foods. Most of the corn grown is also sold for commercial purposes. One of the major customers is Casco, which makes corn starch and sweeteners, in Middlesex County. Winter wheat is still a major crop that is commonly used as a rotation crop.

Other significant crops include tomatoes, sweet corn, peas, and other vegetables or fruits grown for sale to the consumer or the food processing industry. In Essex and other areas of the region, extensive greenhouse operations grow a variety of vegetates.

Table 2.6.11.1-2: Major Field Crops

Major Field Crops (hectares)	Essex	Chatham -Kent	Elgin	Middlesex	Oxford	Perth	Huron
Winter Wheat	9,438	21,132	7,886	19,656	9,738	14,062	23,761
Oats for grain	368	255	667	1,092	970	739	1,366
Barley for grain	140	94	295	1,131	1,338	5,276	7,392
Mixed grains	95	8	261	1,018	1,921	7,409	5,261
Corn for grain	27,447	66,729	40,880	69,500	59,123	54,359	74,224
Corn for silage	821	1,686	2,757	5,333	7,799	8,903	8,806
Hay	2,567	2,241	8,988	17,764	21,407	28,825	27,678
Soybeans	76,501	99,272	46,213	72,586	31,669	40,509	71,211
Dry White Beans	0	913	444	2,015	0	0	7,041
Flue Cured Tobacco	0	979	3,394	0	2,404	0	0
Potatoes	534	110	340	57	245	45	457
Total Area of Major Field Crops	**117,911**	**193,419**	**112,126**	**190,152**	**136,614**	**160,127**	**227,197**

Sources: 2001 Census of Agriculture and Policy and Programs Branch, OMAF

2.6.11.2 Livestock Density (Nutrient Units)

Another major component of the agricultural industry in Ontario is the raising of livestock. **Table 2.6.11.2-1: Livestock Populations** outlines the animal and poultry populations in the region. Hog and poultry production is cost-efficient due to the reliable supply of locally-grown feed grain. Transportation costs are also reduced due to proximity to the U.S. where half of the hogs are exported[175]. Dairy farming is still the main commodity for farm cash receipts in Oxford County, an area historically well known for its milk production.

[175] Agriculture Profile, Sarnia-Lambton Economic Partnership web site August, 2006 www.sarnialanbton.on.ca

Table 2.6.11.2-1: Livestock Populations[176]

Item	Essex	Chatham-Kent	Elgin	Middlesex	Oxford	Perth	Huron
Dairy Cows	1,246	611	7,573	11,766	29,792	29,897	17,746
Beef Cows	1,017	1,744	3,928	11,568	4,535	8,084	18,320
Steers	1,236	5,604	4,945	20,063	7,196	14,340	38,809
Total cattle and calves	6,436	15,364	35,316	91,446	92,162	117,672	147,535
Total pigs	40,028	182,699	91,324	281,677	390,950	570,399	630,316
Total sheep and lambs	2,501	1,001	3,930	13,046	9,145	10,371	20,531
Total hens and chickens	608,091	254,042	893,796	2,021,175	2,847,836	3,829,243	5,030,978
Total turkeys	58,329	151	58,263	491,520	683,651	199,336	231,365

2.6.11.3 Trends in Agriculture

Like any other industry, agriculture has changed, and will continue to evolve with the demands and needs of the time. Again, Census Canada provides important information to show trends in the industry.

Over the last 40 years, a significant trend in the agriculture industry has been the conversion from a mixed land use (livestock pasture and crop cultivation) to crop cultivation land use.

The 1961 Census Information related to the agricultural industry for Kent County (now Chatham-Kent) was used in the Lower Thames Valley Conservation Report in 1965 as representative of the lands in the LTVCA. **Table 2.6.11.3-1: Land Use Changes in Chatham-Kent (Kent County)**, and **Table 2.6.11.3-2: Major Field Crop Changes in Chatham-Kent (Kent County)** show some tends in local agriculture.

Of note in **Table 2.6.11.3-1**, there is the significant increase in the percentage of cropland from 1961 to 2001. By 2001 a full 93% of all farmland in the county was used for the raising of crops. In order to provide for this significant increase, all other categories have seen reductions.

Table 2.6.11.3-2 also illustrates some significant changes. Notably, the land area used in the production of soybeans has increased dramatically in the last 40 years. The other major field crop is corn and the table indicates that the land area used in the production of corn has only slightly increased. Therefore, the land area used for producing soybeans has resulted in significant reductions in the production of wheat, oats, dry beans and hay.

[176] OMAF. 2001 Census of Agriculture and Policy and Programs Branch. www.omafra.gv.on.ca/english/stats/census

Table 2.6.11.3-1: Land Use Changes in Chatham-Kent (Kent County)[177]

Land Use	Percentage of Total in 1961	Percentage of Total in 2001
Cropland	79.65	93.24
Pasture	5.54	1.18
Fallow	0.72	0.05
Other and woodland	7.96	4.69
Scrub	6.13	0.84
Total	100.0	100.00

Note: In 1961 "Woodland" was a separate category and represented 4.48% of total farm lands. No similar category was found in the 2001 census and therefore we assumed that "Woodland" was included in "Other" lands in the 2001 census.
In 1961 "Scrub" was a separate category and represented 6.13% of total farm lands. In the 2001 census there was a category for "unimproved pasture", which was not in the 1961 census, and we assumed that they are similar.

Table 2.6.11.3-2: Major Field Crop Changes in Chatham-Kent (Kent County)

Field Crop	Percentage of Total Area in 1961	Percentage of Total Area in 2001
Grain Corn	29.10	32.70
Wheat	20.03	10.34
Soybeans	19.08	48.65
Oats	9.75	0.13
Dry Beans	5.31	0.45
Hay	5.72	1.10
Vegetables	3.06	4.90
Sugar Beets	2.69	0.00
Ensilage Corn	2.00	0.81
Other Grains	1.63	0.18
Tobacco	1.06	0.46
Fruit	0.32	0.23
Potatoes	0.25	0.05
Total	**100.00**	**100.00**

In the Thames Watershed & Region, another significant trend in the agriculture industry is that the size of individual farm operations has increased substantially. At the same time, the number of farmer operations has reduced an almost equal amount. Some of the recent changes[178] are shown in **Table 2.6.11.3-3: Number of Farm Operations** and **Table 2.6.11.3-4: Number of Hectares per Farm Operation**. In the 20 year period from 1986 to 2006, the number of farm operations has decreased and the farm operation size has increased.

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[177] Department of Energy and Resources Management. 1965. Lower Thames Valley Conservation Report. OMAF. 2001 Census of Agriculture and Policy and Programs Branch.
[178] OMAF. 2001 Census of Agriculture and Policy and Programs Branch.

Many factors have contributed to this change. One of the most interesting is the increased use of reduced and no-till farming practices. While these practices at their initiation were promoted as methods to reduce water runoff and soil erosion, they also reduce costs, maintain crop yields and result in substantial individual productivity increases. Therefore, a single operator was able to work larger acreages. Other factors that have contributed to increased farm productivity are the availability of larger and more efficient farm machinery, better plant hybrids and more effective pest management.

Table 2.6.11.3-3: Number of Farm Operations

District	1986	1991	1996	2001	2006
Chatham-Kent	2,913	2,822	2,690	2,352	2196
Elgin	1,902	1,764	1,808	1,608	1489
Essex	2,644	2,215	2,109	1,789	1740
Middlesex	3,244	3,162	2,987	2,640	2525
Oxford	2,460	2,382	2,342	2,104	1990
Perth	2,927	2,894	2,832	2,570	2438
Huron	3,416	3,260	3,150	2,880	2738

Table 2.6.11.3-4: Number of Hectares per Farm Operation

District	1991	1996	2001	2006
Chatham-Kent	82	88	95	102
Elgin	86	90	96	107
Essex	60	67	76	77
Middlesex	79	87	95	99
Oxford	71	76	86	85
Perth	69	73	79	83

Sources: 2006 Census of Agriculture and Policy and Programs Branch, OMAF

The agriculture industry continues to evolve in response to changing demands and needs. With new technological innovations, it was anticipated that there will continue to be fewer farms that are larger in size. As indicated in **Table 2.6.11.3-5: Area Cultivated in the UTRCA Watershed**, the amount of land being cultivated has not increased substantially. In fact in both Huron and Middlesex Counties, the area being cultivated since 1986 has decreased, then increased, then decreased, etc. This wave-like trend may be attributed to fluctuating crop prices whereby farmers have opted to leave some of their lands fallow until market conditions improve.

Table 2.6.11.3-5: Area Cultivated in the UTRCA Watershed – 1986-2001

County	Year/Farm Size (ha)			
	1986	1991	1996	2001
Huron	289,194	287,945	297,009	290,997
Middlesex	252,374	250,594	259,568	251,036
Oxford	169,410	169,960	178,432	180,271
Perth	196,359	198,890	206,523	203,528

Source: OMAFRA – www.omafra.gv.on.ca/english/stats/census

2.6.12 Recreation

Over one-third of the boundary of the LTVCA is comprised of Great Lakes shoreline. The Lakes provide bountiful recreational opportunities to people in the region. The Thames River itself, due to its large size, also affords multiple recreational prospects to the area residents.

Motorized and non-motorized boating is enjoyed on all of the lakes and motorized boating takes place on the Thames River up to Kent Bridge for most of the year. During the spring, when water levels are higher in the river, motor boats have used the river up to at least Middlemiss. Depths are reduced during the summer and the traffic is limited to canoes at this time. Canoeing can be done in much of the upper Thames and small boats can be used on the impoundments behind some of the dams on the river.

Fishing takes place in these waters and many of the other creeks and streams in the region. The primary impediments to the migration of fish are dams and pumping stations located at the mouths of several watercourses in the LTVCA region, primarily in the communities of Tilbury East, Dover and Raleigh in Chatham-Kent as well as areas near the mouth of the Thames in the Town of Lakeshore. In the upper Thames River, dams also restrict fish migration. However, regardless of these impediments, vibrant populations of fish are able to survive in these watercourses.

Swimming is somewhat limited due to water temperature and water quality. The cooler temperatures in Lakes Erie and St. Clair limit the swimming season to the summer months. No one is encouraged to swim in the lower Thames River due to water quality concerns.

For the majority of the north shore of Lake Erie within the LTRCA watershed, the recreational capability of the shoreline is ranked moderate low to moderate due in large part to the presence of high bluffs that make access to the water's edge difficult.

There are several dive shops within the watershed and several well known dive sites are located within the Thames River, Lake Erie and Lake St. Clair. Leamington's "Erie Quest" diving development project has identified over 50 shipwrecks in the area and is gathering wide enthusiasm and activity from across North America.

Along the shorelines of Lake Erie, Lake St. Clair and the Thames River are pockets of cottages as well as low density residential and estate residential development with direct access to both public and private roads. Permanent dwellings in these locations are attractive because of their scenic vistas, recreational amenities and relatively easy commute to urban centres.

Lake St. Clair and the Thames River up to at least Chatham can normally accumulate at least 30 centimetres of surface ice in the winter. This ice is sufficient to afford the winter sports enthusiast numerous opportunities to snowmobile and ice fish in the winter season.

In addition to the water related activities, there is a wide range of other recreation opportunities including bird watching, golfing, cross country skiing, and various sports.

Beaches and Public Swimming Areas

The shorelines of Lake Erie and Lake St. Clair provide recreational opportunities. As well several conservation areas provide beach and swimming areas.

- Mitchell's Bay
- Clearville Park
- Getty's Beach
- Laverne Kelly Memorial Park (Erieau)
- Terrace Beach Park (Terrace Beach Park)
- Rondeau Beach/Provincial Park
- Wheatley Provincial Park
- Fanshawe Conservation Area
- Pittock Conservation Area
- Trout Creek Reservoir, Innerkip
- Town of St. Marys Quarries
- Wildwood Conservation Area

Trails

In addition to the trails at provincial parks and conservation areas, there are some notable trail systems in the region. Many of these follow parts of various watercourses.

- Avon Trail
- Thames Valley Trail
- Trans Canada Trail
- Chatham-Kent City Trail System

Boating

The Great Lakes and the Thames River provide opportunities for a wide range of recreational activities supported at public and private facilities.

Marinas

- Pittock Conservation Area
- Wildwood Conservation Area
- Luncan Cove
- Radlin
- Erieau
- Pt. Glasgow (Rondeau)

Public Boat Launches

- Fanshawe Conservation Area
- Pittock Conservation Area
- Springbank Park, London
- Wildwood Conservation Area
- Lighthouse
- Prairie Siding
- Thamesgrove
- Big Bend Conservation Area
- Middlemiss Bridge

Sailing
- Fanshawe Conservation Area
- Pittock Conservation Area
- Wildwood Conservation Area
- Lake St. Clair
- Lake Erie
- Rondeau Bay

Rowing and Canoeing
- Fanshawe Conservation Area
- Springbank Reservoir, London
- Sharon Creek Conservation Area
- Thames River
- C.M. Wilson Conservation Area

Campgrounds/Trailer Parks

Many trailer parks, campgrounds and other parks provide recreational access to shorelines throughout the area as shown in **Table 2.6.12-1: Campgrounds in the UTRCA Watershed** and **Table 2.6.12-2: Campgrounds in the LTVCA Watershed**.

Table 2.6.12-1: Campgrounds in the UTRCA Watershed

Private Campgrounds			
#	**Name**	**Location**	**# of Sites**
1	Braemar Valley Park	Woodstock	77
2	Casey's Park	Salford	70
3	Golden Pond RV Resort	Mossley	240
4	Happy Hills Resort	Embro	445
5	Lakeside Resort Ltd	Lakeside	120
6	Prospect Hill Camping Grounds	Granton	165
7	River View Campground	Thorndale	100
8	Science Hill Country Club	St. Marys	83
9	Willow Lake Park	Woodstock	63
10	Windmill Trailer Park	Fullarton	215
11	Woodland Lake Camp & RV Resort	Bornholm	189
12	Anthony's Mobile Home Park	Thames Centre	100
13	Unnamed	Thames Centre	23
14	KOA Campground	Thames Centre	80
Municipal, Provincial and Conservation Authority Campgrounds			
#	**Name**	**Location**	**# of Sites**
15	Fanshawe Conservation Area (UTRCA)	London	657
16	Pittock Conservation Area (UTRCA)	Woodstock	249
17	Wildwood Conservation Area (UTRCA)	St. Marys	470
	No municipal or provincial campgrounds		

Table 2.6.12-2: Campgrounds in the LTVCA Watershed

#	Name	Location	# of Sites
Private Campgrounds			
#	**Name**	**Location**	**# of Sites**
1	Camper Cove	Wheatley	324
2	Holiday Harbour Resort	Wheatley	100
3	Jefferson Junction Family Campground	Appin	129
4	Lakeside Village Motel & Campground	Wheatley	71
5	Lakewood Trailer Estates	Rodney	227
6	Rondeau Shores Trailer Park	Morpeth	123
7	Sturgeon Woods Campground & Marina	Leamington	375
8	The Summer Place Marina & Campground	Morpeth	190
9	Trout Haven Park	Strathroy	70
10	Leisure Lake Campground	Ruthven	450
11	Bethel Park	Rodney	190
12	Enchanted Hideaway	Rodney	90
13	Leisure Heights	Rodney	35
14	Hickory Grove	Rodney	200
Municipal, Provincial and Conservation Authority Campgrounds			
#	**Name**	**Location**	**# of Sites (size)**
15	Big Bend Conservation Area (LTVCA)	Southwest Middlesex	16ha
16	C.M. Wilson Conservation Area (LTVCA)	Chatham-Kent	100 (30ha)
17	E.M. Warwick Conservation Area (LTVCA)	West Elgin	(14ha)
18	Longwoods Road Conservation Area (LTVCA)	Strathroy-Caradoc	(63ha)
19	Rowsom’s Tilbury West Conservation Area (LTVCA)	Lakeshore	(25ha)
20	Sharon Creek Conservation Area (LTVCA)	Middlesex Centre	(118ha)
21	Two Creeks Conservation Area (LTVCA)	Chatham-Kent	(33ha)
22	Wheatley Provincial Park (MNR)	Wheatley	220
23	Rondeau Provincial Park (MNR)	Morpeth	262
24	Port Glasgow (West Elgin)	Rodney	166

Golf Courses

There are numerous public and private golf courses located throughout the Thames Watershed & Region including several that incorporate lands (flood plains) adjacent to local watercourses. Water taking for irrigation of golf courses will be reviewed as part of the Conceptual Water Budget.

Golf Courses in Chatham-Kent

- Baldoon Golf Course
- Blenheim Community Golf Course
- Chatham Golf & Fun Centre

- Countryview Golf Course
- Deer Run Golf Course
- Gladyacres The Range
- Golf Land Driving Range
- Maple City Golf Course
- Ridgetown Golf Course
- Rolyn Golf Trails
- Talbot Trail Golf Club
- The Links of Chatham-Kent
- Tilbury Golf & Curling Club

Golf Courses in the UTRCA Watershed

• Twin Streams Golf Course	Delaware
• Pine Knot Golf & Country Club	Dorchester
• Dorchester Golf & Country Club	Dorchester
• Fox Golf Club	Granton
• Ingersoll Golf & Country Club	Ingersoll
• Innerkip Highlands	Innerkip
• The Oaks Golf & Country Club	Komoka
• Oxbow Glen Golf & Country Club	Komoka
• Echo Valley Golf Club	Lambeth
• Greenhills Country Club	Lambeth
• Fire Rock Golf & Country Club	Komoka
• Fanshawe Golf Club	London
• Forest City National Golf Club	London
• Highland Country Club	London
• Llyndinshire Golf & Country Club	London
• London Hunt & Country Club	London
• Maple Ridge Golf Club	London
• River Road Golf Club	London
• Sunningdale Golf & Country Club	London
• Thames Valley Golf & Country Club	London
• West Haven Golf & Country Club	London
• Westminster Trails Golf Club	London
• Hickory Ridge Golf Club	London
• East Park Golf Gardens	London
• Mount Elgin Golf Club	Mount Elgin
• Tamarack Ridge Golf Course	Putnam
• River Valley Golf & Country Club	St. Marys
• Science Hill Country Club	St. Marys
• St. Marys Golf & Curling Club	St. Marys
• Cobble Hills Golf & Ski Club	Thamesford
• Craigowan (Oxford) Golf & CC	Woodstock
• Creekside Golf Course	Woodstock
• Mitchell Golf & Country Club	Mitchell
• Stratford Municipal Golf Club	Stratford
• Stratford Country Club	Stratford
• Cedar Creek Golf Club	Woodstock
• Woodstock Meadows Golf Club	Woodstock
• Tavistock Golf Club	Tavistock

2.6.13 Protected Areas

Specific areas are protected from developmental changes that could alter the natural character. This protection is designated through federal, provincial and local initiatives. Depending on the degree of protection, “protected areas” are not likely to change over time and will encounter minimal human disturbance. A list of significant natural areas and wetlands in the UTRCA watershed is provided in Appendix C.

2.6.13.1 Municipal Official Plans - Protection of Natural Environmental Features

In general, municipal official plans provide an initial source of information on significant natural environmental features and the level of protection provided to these areas. Information from the Official Plans for Middlesex and Chatham-Kent is summarized below.

Middlesex

The County of Middlesex Official Plan[179] identifies features that are important parts of the ecosystem. The features identified as part of the Natural Environmental Areas designation on **Figure 2.6.13-1: Schedule A Land Use – Middlesex County** preclude development. As such, these features have restrictive Official Plan policies associated with them. This designation includes wetlands, flood regulated watercourses and associated flood plains.

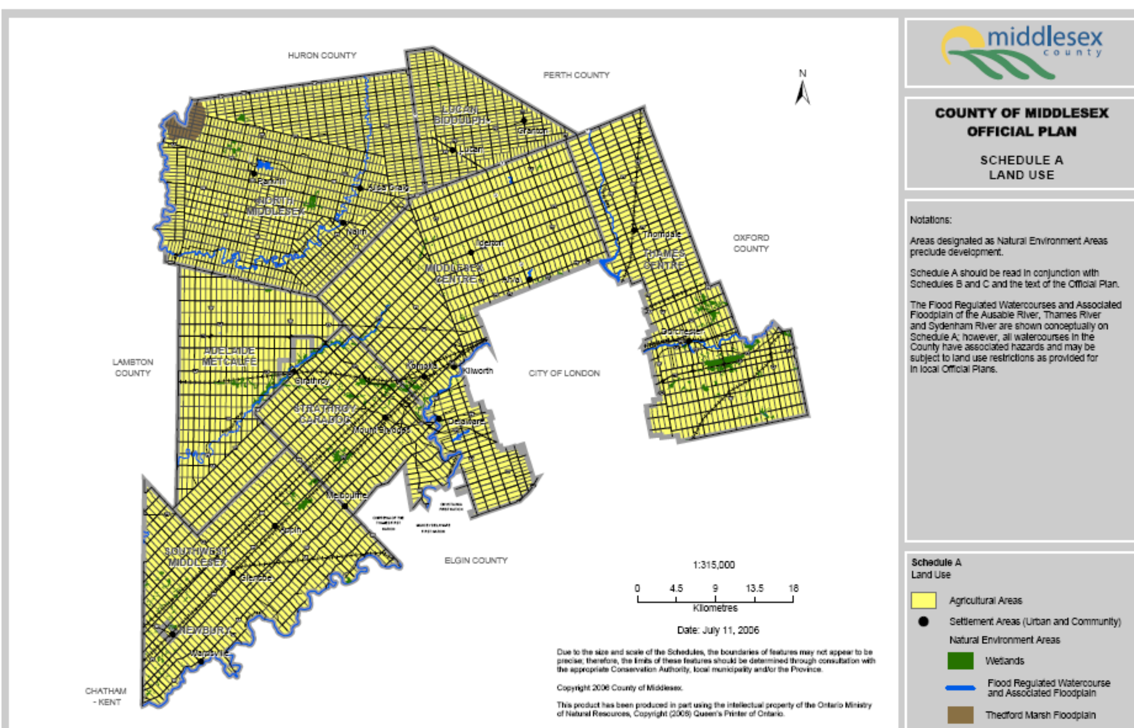

Figure 2.6.13-1: Schedule A Land Use – Middlesex County

In addition to the features identified in Schedule A, a wide range of ecosystem elements are identified in **Figure 2.6.13-2: Schedule C Natural Heritage Features – Middlesex County**. While Schedule C features do not preclude development, there is an interest in protecting them from incompatible development. A Development Assessment Report (DAR) is required when there is an application for development within a Natural Heritage Feature or within the adjacent lands of the elements as identified in **Table 2.6.13-1: Areas Subject to Development Assessment Report – Middlesex County**.

[179] Middlesex County. Middlesex County Official Plan. Adopted by County Council September 9, 1997, Amended By Official Plan Amendment No. 2, July 11, 2006.

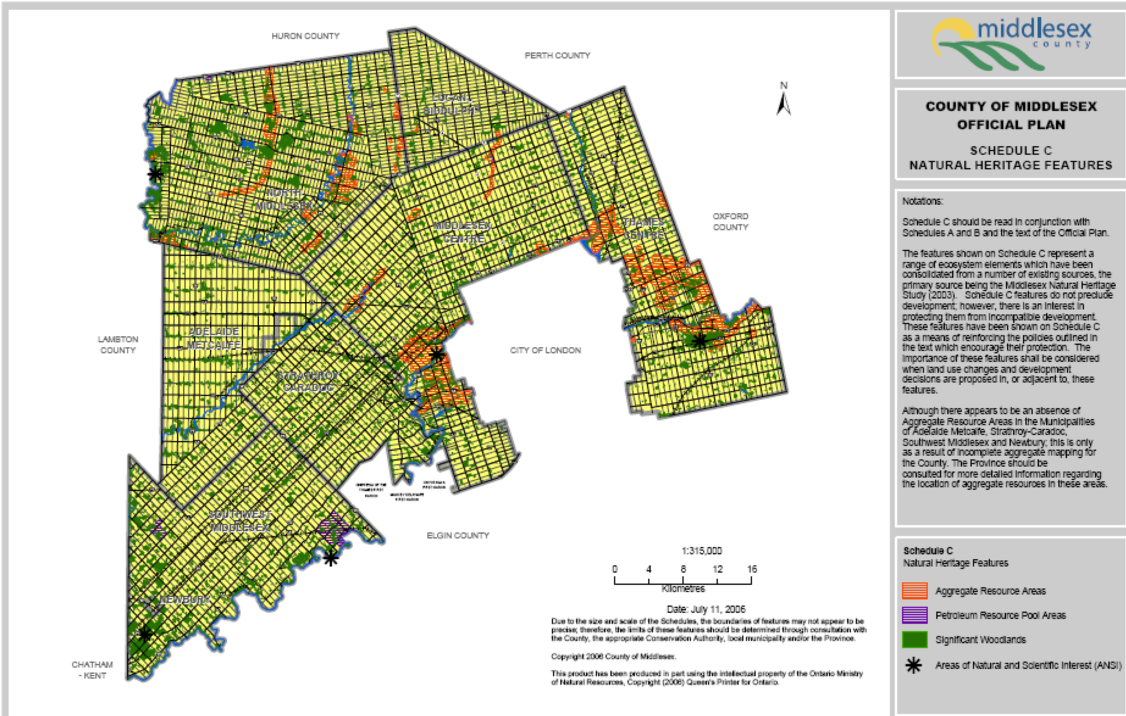

Figure 2.6.13-2: Schedule C Natural Heritage Features – Middlesex County

Natural heritage features include:

- Significant woodlands
- Wildlife habitat
- Endangered and threatened species habitat
- Aquatic ecosystems including fish habitat
- River, stream, ravine and upland corridors
- Areas of natural & scientific interest (ANSIs)

Table 2.6.13-1: Areas Subject to Development Assessment Report – Middlesex County

Natural System Element	Development Adjacent to Natural System Element	Development within Natural System Element
Wetlands and adjacent lands within 120 metres or connecting individual wetlands in a wetland complex	DAR required within 120 m	Not Permitted
Significant habitat of endangered or threatened species	DAR required within 100 m	Not Permitted
Flood plains and flood prone areas mapped or regulated by a Conservation Authority	DAR Required within 50 m	Not Permitted
Significant Woodlands and ANSIs as identified in Schedule "C"	DAR Required within 50 m	DAR Required
Significant Wildlife Habitat	DAR Required within 50 m	DAR Required
Significant Valley Lands	DAR Required within 50 m	DAR Required
Fish Habitat	DAR Required within 30 m	Not Permitted

City of London

In the City of London, 16 natural areas are currently designated as "Environmentally Significant Areas" (ESA). These areas represent a variety of habitats including upland forests, wetlands and river corridors. The ESAs are an integral part of London's proposed Natural Heritage System connecting parks, valleylands and other open spaces. The UTRCA manages the following ESAs in partnership with the City:

- Kains Woods
- Kilally Meadows
- Meadowlily Woods
- Medway Valley Heritage Forest
- Sifton Bog
- Warbler Woods
- Westminster Ponds/Pond Mills Conservation Area.

Chatham-Kent

The Chatham-Kent Official Plan[180] includes a Natural Heritage System that is based on the Community Strategic Plan Objective of Sustaining and Enhancing Environmental Assets. The system identifies:

- Lands where natural heritage features will be protected from development and site alteration through an "Open Space and Conservation" designation.
- Lands and natural heritage features where an Environmental Impact Statement (EIS) is needed before any development or site alteration can proceed.
- Policies for lands adjacent to natural heritage lands to ensure that negative impacts do not occur.
- Natural corridors and linkages to be considered in any future development or site alteration.

No development or site alteration is permitted in natural heritage features such as provincially significant wetlands and significant portions of the habitat of endangered, threatened and vulnerable species. An Environmental Impact Statement is required for development adjacent to these areas. Chatham-Kent is host to 11,500 hectares of provincially significant wetlands along Lake St. Clair, including the St. Clair National Wildlife Area, which is a globally important bird area.

Natural heritage features where an Environmental Impact Statement is required include fish habitat, significant woodlands, significant areas of natural and scientific interest, and features of local significance.

Perth

Land use activities and land clearing practices that occurred years ago have resulted in the amount of remaining natural resource/environmental areas being quite small. The Official Plan through the "Natural Resources/Environment" designation intends to provide policy directed towards the preservation and protection of the remaining areas and encourages the enhancement and improvement of these areas[181]. The areas are shown on Schedule "A" (Land Use Plan).

Oxford

The Oxford County Official Plan designates Environmental Protection Areas that include the following provincially significant natural heritage features:

- Significant wetlands
- Significant portions of the habitat of endangered or threatened species and other significant wildlife habitat
- Fish habitat

[180] Municipality of Chatham-Kent. Chatham-Kent Official Plan, Adopted January 10,2005.
[181] Perth County website. www.countyofperth.on.ca

- Significant valleylands
- Significant woodlands
- Significant life science areas of natural and scientific interest

These are identified in Schedule C-1 of the Official Plan[182].

Elgin

Data Gap – Elgin Environmental Protection Areas.

2.6.13.2 Significant Protected Areas

There are a number of nationally, provincially and locally significant environmental areas in the Thames Watershed & Region. The control or ownership of these properties often provides an additional degree of protection.

Most of the St. Clair National Wildlife Area is in the Lower Thames Valley Conservation Authority (LTVCA) watershed. It is owned by Environment Canada and is a part of the Eastern Lake St. Clair Important Bird Area. The St. Clair National Wildlife Area is included in the International Ramer Convention on Wetlands. This treaty is intended to conserve wetlands and the resources in them.

Rondeau Provincial Park, which is Ontario's second oldest provincial park, is located on the Lake Erie shoreline of the LTVCA watershed. Formed by the erosion and deposition of sand and gravel, the Rondeau peninsula constitutes one of North America's best examples of a Cuspate Sandspit. It is now a 3254 ha 'Natural Environment' park.

The Ellice Swamp covers approximately 856 hectares and is the largest woodlot in Perth County. The swamp is drained by two Black Creeks, one of which flows southwest to join the North Branch of the Thames River and the other flows north to the Nith River which is a tributary of the Grand River. The area is largely owned by the UTRCA.

The Golspie Swamp covers 295 hectares and represents the third largest forested area remaining in Oxford County. Approximately half of this area is owned by the UTRCA, while the remainder is held in private ownership.

The Dorchester Swamp is a 548 hectare site that is recognized as a Class 1 Significant Wetland, a Carolinian Canada Site and an Area of Natural and Scientific Interest (ANSI). The swamp is recognized by the Township of North Dorchester and the County of Middlesex in their Official Plans. However, the wetland is divided by Highways 401 and 73 and there are many activities affecting its future. The Dorchester Swamp Management Strategy is a strategy for addressing human pressures that affect this significant natural area.

The Sifton Botanical Bog in the City of London is a Class 2 provincially significant wetland and the most southerly large acidic bog in Canada. The 28 hectare ESA is owned by the UTRCA. It was acquired through a grant from the Province of Ontario and a donation by the Sifton Construction Company.

Westminster Ponds/Pond Mills Conservation Area is comprised of some 300 hectares with six major ponds over an area 3 km long and 1.5 km wide. Much of the land is owned by the City of London or the UTRCA. The Western Ontario Fish and Game Protection Association owns a pond that bears its name. Saunders Pond and adjacent lands are owned by the Victoria Hospital Corporation.

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[182] Oxford County website. www.county.oxford.on.ca

2.7 Water Uses

Numerous human activities and ecosystems within the Thames Watershed & Region benefit from an essential supply of water.

Municipalities draw both surface water and groundwater to supply treated water to the public, businesses and industries. Individuals and businesses in rural communities rely on groundwater sources for drinking water. Industries may take water directly from groundwater or surface water sources for cooling, washing and other plant operations. Agricultural businesses use water to irrigate crops and nourish livestock. Golf courses, a component of the commercial business sector, are dependent upon a reliable supply of water for irrigation. A variety of other recreational activities, such as boating, fishing and swimming, also depend on good quality water. Each sector has its individual demand on available water supplies. Ecosystems contain a variety of aquatic and non-aquatic species that also rely on good quality water for habitat and health.

Water takings in Ontario are governed by the Ontario Water Resources Act (OWRA) and the Water Taking and Transfer Regulation (ONT Reg. 387/04) which is a regulation under the OWRA Act. Section 34 of the OWRA requires any one taking more than a total of 50,000 litres of water per day to acquire a Permit To Take Water (PTTW). [183]

Map 16: Permit to Take Water Locations shows the locations of water takers that have water taking permits in the Thames River & Region watershed. **Map 17: Permit to Take Water General Purpose of Taking** shows the various types of water takers. Permit holders draw water from both groundwater and surface water sources for a variety of applications. In the upper portion of the watershed, permit holders mainly use groundwater as their source whereas in the lower portion of the watershed, permit holders mainly draw water from surface water sources. Many of agricultural and commercial (golf course) water users store water from spring runoff in ponds for application later in the summer.

Water takings that are exempt from the requirement to obtain a permit include takings by an individual for ordinary household purposes, water takings for the direct watering of livestock or poultry, and water for firefighting.

The Ministry collects water taking permit information and stores the information in a database. The number of permits for various water taking purposes (as listed in the OMOE database) in the Thames Watershed & Region is summarized in **Table 2.7-1: Number of Water Taking Permits by Sector**. The total number of PTTWs listed in the database for the area is 905. However, many of the permits still listed in the database have expired dates listed beside them and it is unclear if these permits have been updated or renewed.

[183] OMOE. April 2005. Guide to Permit to Take Water Manual.

Table 2.7-1: Number of Water Taking Permits by Sector Thames Watershed & Region[184]

Water Taking Sector	Water Use	Number of Permits	Percent of Total Permits
Agricultural	Field and Pasture Crops, Fruit Orchards, Market Gardens / Flowers, Nursery, Sod Farm, Tender Fruit, Tobacco	300	33%
Commercial	Aquaculture, Bottled Water, Golf Course Irrigation, Mall / Business, Snowmaking,	158	17%
Construction	Construction, Road Building	10	1%
Dewatering	Construction, Pits and Quarries	52	6%
Industrial	Aggregate Washing, Cooling Water, Food Processing, Pipeline Testing, Power Production	92	10%
Institutional	Hospitals	1	0%
Miscellaneous	Dams and Reservoirs, Heat Pumps, Other - Miscellaneous, Pumping Test, Wildlife Conservation	57	6%
Recreational	Aesthetics, Other - Recreational, Wetlands	12	1%
Remediation	Groundwater, Other - Remediation	6	1%
Water Supply	Campgrounds, Communal, Municipal, Water Supply	217	24%

In general, the existing permits only set limits on the maximum water taking per day and it is difficult to determine how much water each sector actually demands. However, new requirements introduced as of January 1, 2005 require permit holders to collect, record and submit daily taking volumes to the Ministry on an annual basis.

Permit holders, such as large consumptive water users, covered under Phase 1[185] must start on July 1, 2005. Phase 2 and 3 permit holders will also eventually be required to measure, record and submit takings. These phases combined will cover all permit holders. As water taking data is recorded, more representative water use values for the various sectors in the watershed will exist.

2.7.1 Drinking Water Sources

The majority of the population is supplied with treated surface water from Lake Huron, Lake Erie and Lake St. Clair. However, groundwater is an important source of drinking water for rural residents throughout the region and for several urban communities.

Table 2.7.1-1: Drinking Water Sources by Municipality shows a breakdown of the drinking water sources located in the Thames Watershed & Region. The percentage of the population served by public/municipal/communal water ranges from a high of 100% in urban areas to as low as 0% in some rural municipalities.

[184] OMOE. Permit To Take Water (PTTW) database.
[185] OMOE. October 2005. Technical Bulletin: Permit to take Water - Phase 1 Monitoring and Reporting. Phase 1 permit holders are outlined in this bulletin, and generally include large consumptive takings such as drinking water, beverage manufacturing, certain aggregate processing plus others.

Table 2.7.1-1: Drinking Water Sources by Municipality

County/ Municipality	Municipality	Water Source	Water Supply System	Population Served by Municipal Water
Middlesex[186]	City of London	Lake Huron	Lake Huron Primary Water Supply System (LHPWSS)	99%
		Lake Erie	Elgin Area Primary Water Supply System (EAPWSS)	
	Township of Lucan-Biddulph	Lake Huron	LHPWSS	58%
	Municipality of Thames Centre	Groundwater	Municipal and Private Wells	38%
	Township of Middlesex Centre	Lake Huron	LHPWSS	42%
		Lake Erie	EAPWSS	
		Groundwater	Municipal and Private Wells	
		Groundwater/ Lake Huron	LHPWSS and Private Wells	
	Municipality of Southwest Middlesex	Lake Erie/ Groundwater	West Elgin Water Supply System (WEWSS) and Private Wells	41%
Oxford[187]	City of Woodstock	Groundwater	Municipal Wells	100%
	Town of Ingersoll	Groundwater	Municipal Wells	100%
	Township of Blandford-Blenheim	Groundwater	Municipal and Private Wells	N/A
	Township of East Zorra-Tavistock	Groundwater	Municipal and Private Wells	46%
	Township of Norwich	Groundwater	Municipal and Private Wells	N/A
	Township of South-West Oxford	Groundwater	Municipal and Private Wells	40%
	Township of Zorra	Groundwater	Municipal and Private Wells	38%

[186] Figures taken from: Dillon Consulting and Golder Associates. July 2004. Middlesex-Elgin Groundwater Study, Final Report.
[187] Figures taken from: Oxford County. 2005. (2001 population statistics from website, serviced statistics from Linda Truscott, Water and Wastewater Operations Coordinator)

<table>
<tr><th>County/ Municipality</th><th>Municipality</th><th>Water Source</th><th>Water Supply System</th><th>Population Served by Municipal Water</th></tr>
<tr><td rowspan="5">Perth[188]</td><td>City of Stratford</td><td>Groundwater</td><td>Municipal Wells</td><td>100%</td></tr>
<tr><td>Town of St. Marys</td><td>Groundwater</td><td>Municipal Wells</td><td>100%</td></tr>
<tr><td>Township of West Perth</td><td>Groundwater</td><td>Municipal and Private Wells</td><td>53%</td></tr>
<tr><td>Township of Perth East</td><td>Groundwater</td><td>Municipal and Private Wells</td><td>16%</td></tr>
<tr><td>Township of Perth South</td><td>Groundwater</td><td>Private Wells</td><td>4%</td></tr>
<tr><td>Huron</td><td>Municipality of South Huron</td><td>Groundwater</td><td>Private Wells</td><td>N/A</td></tr>
<tr><td rowspan="3">Elgin[189]</td><td>Municipality of Dutton/Dunwich</td><td>Lake Erie/ Groundwater</td><td>WEWSS and Private Wells</td><td>40%</td></tr>
<tr><td>Township of Southwold</td><td>Lake Erie/ Groundwater</td><td>EAPWSS and Private Wells</td><td>50%</td></tr>
<tr><td>Municipality of West Elgin</td><td>Lake Erie/ Groundwater</td><td>WEWSS and Private Wells</td><td>47%</td></tr>
<tr><td rowspan="3">Chatham-Kent[190]</td><td rowspan="3">Municipality of Chatham-Kent</td><td>Lake Erie</td><td>South Chatham-Kent WTP/ Chatham Water System</td><td rowspan="3">76%</td></tr>
<tr><td>Lake Erie</td><td>Wheatley WTP</td></tr>
<tr><td>Groundwater</td><td>Municipal and Private Wells</td></tr>
<tr><td rowspan="2">Essex</td><td>Town of Leamington</td><td>Lake Erie</td><td>Wheatley WTP and Union WTP</td><td>100%</td></tr>
<tr><td>Town of Lakeshore</td><td>Lake Erie/ Groundwater</td><td>Wheatley WTP and Private Wells</td><td>74%</td></tr>
</table>

* This table includes municipal population outside the Thames and Region Watershed
** People that do not have piped public water obtain drinking water from private groundwater wells.

188 Figures taken from: Waterloo Hydrogeologic. April 2003. Perth County Groundwater Study.
189 Figures taken from: Dillon Consulting and Golder Associates. July 2004. Middlesex-Elgin Groundwater Study, Final Report.
190 Figures taken from: Dillon Consulting and Golder Associates. December 2004. Essex Region/Chatham-Kent Region Groundwater Study.

Urban residents in the northern part of the Thames watershed (Oxford and Perth Counties) rely on treated groundwater for their drinking water. Some communities in Chatham-Kent and parts of Middlesex County also have municipal systems that use groundwater sources.

The majority of urban residents are supplied with treated municipal water supplies taken from the Great Lakes. Residents in the City of London and some neighbouring Middlesex communities use treated surface water piped from Lake Huron and Lake Erie. Most of the water for residents in Elgin County, Chatham-Kent and Essex County obtain water from Lake Erie. A few communities in Essex have treated Lake St. Clair water.

Table 2.7.1-2: First Nation Drinking Water Sources provides a summary of the drinking water sources for First Nations located in the Thames Watershed & Region. Most residents of the First Nation communities rely on groundwater sources for their drinking water. The percentage of the population served by community water ranges from a high of 100% to as low as 0%.

Table 2.7.1-2: First Nation Drinking Water Sources

First Nation	Water Source	Water Supply System	Population Served by Community Water
Caldwell First Nation	Groundwater	Private wells	0%
Chippewas of the Thames First Nation	Groundwater	Chippewas of the Thames WTP	100%
Delaware Nation	Groundwater	Delaware WTP	100%
Munsee-Delaware First Nation	Groundwater	Chippewas of the Thames WTP, private wells	50%
Oneida Nation of the Thames	Groundwater	Oneida Nation of the Thames WTP, private wells	75%

2.7.1.1 Groundwater – Municipal Wells

Residents in many urban centres across the area rely on municipal wells for drinking water. Water from municipal well fields is pumped from the aquifer to a local water treatment plant (WTP) where the water is treated and stored in a reservoir or pumped directly to residents via pipeline.

Communal wells also function to service a cluster of homes such as in a rural subdivision. A small pumping station is used to supply raw water or moderately treated water through pipes to homes in the immediate area. Many of these systems are being replaced where possible with a piped supply from a larger municipal system. The Rondeau Bay Estate Well System in Chatham-Kent is one example of a communal well system in the Region that has been replaced by piped municipal water.

The locations of the municipal drinking water supply systems that use groundwater are shown on **Map 38: Drinking Water Supplies/Intakes**.

Basic groundwater studies were funded by the Ministry of the Environment in 2002. The initial funding for the groundwater studies was provided at the County level. Since the studies were done on a County-wide basis, the groundwater information has been extracted from these reports and presented for each county. There are some other reports such as the Oxford County Groundwater Study that were completed prior to or after 2002 and information from these reports has also been used to prepare an information summary.

By 2004, all of the counties (Oxford, Middlesex, Elgin, Perth, Lambton and Essex/Chatham-Kent) in the region had a groundwater model based primarily on the OMOE water well information database. The municipal groundwater studies addressed several technical tasks:

- definition of the regional geology;
- the evaluation of the regional hydrogeology;
- an assessment of the groundwater use;
- the identification of existing and potential sources of groundwater contamination;
- a preliminary groundwater vulnerability definition;
- a brief summary of potential groundwater management and protection activities; and
- the development of a groundwater model based on the water well information database.

As a follow-up to the county studies, six conservation authorities (Ausable Bayfield, Maitland Valley, St. Clair Region, Essex Region, Lower Thames Valley and Upper Thames River Conservation Authorities) have commissioned a study to complement the groundwater modelling. Gamma ray geophysical logs were collected throughout the Six Conservation Authority Study area and a report on a regional groundwater model is being prepared.

The following is a synopsis of information from the individual groundwater studies.

Perth County

In the Thames-Sydenham & Region Source Protection Region, six Perth County communities (Mitchell, Sebringville, St. Pauls, St. Marys, Shakespeare and Stratford) are supplied by municipal groundwater supply systems. These municipal systems are serviced by one to 10 wells. Average pumping rates vary depending on the size of the community with Stratford having the highest rate at 14,600 m^3/day and St. Pauls having the lowest rate of approximately 24 m^3/day.

In 2003 Waterloo Hydrogeologic (WHI) completed the Perth Groundwater Study in order to develop an improved understanding of local groundwater conditions within the context of larger regional groundwater flow systems. The Ministry of the Environment (OMOE) was the project's major funding organization and provincial partner. Perth County (includes Municipalities of Perth South, Perth East, North Perth and West Perth), the City of Stratford, the Town of St. Marys and the UTRCA were also major partners of the study that provided funding and contributed technical staff and project management resources.

The estimated municipal water takings and the residential component of the municipal water use are presented in **Table 2.7.1.1-1: Perth Municipal Water Use by Community**. Total municipal groundwater taking is estimated to be 21,940 cubic metres per day. These values are taken from the Perth County Groundwater Study[191] which was completed in the spring of 2003 by Waterloo Hydrogeologic Incorporated. The Town of St. Marys has provided more up-to-date information based on 2006 water usage for their system and this information is shown in addition to the original values reported in the study.

[191] Waterloo Hydrogeologic. April 2003. Perth County Groundwater Study, Final Report. p4-4.

Table 2.7.1.1-1: Perth Municipal Water Use by Community

Community	Average Pumping Rate (m^3/day)	Breakdown of Municipal Water Use
Mitchell	2,660	35% residential, 65% commercial/ industrial
Sebringville	35	100% residential
St. Pauls	24	100% residential
St. Marys	4,551 (3844*)	67% residential, 33% commercial/ industrial (44% residential, 56% industrial*)
Shakespeare	60	80% residential, 20% commercial/ institutional
Stratford	14,610	51% residential, 49% commercial/ industrial
Total	21,940	

* 2006 St. Marys average pumping rate and usage breakdown[192]

The final groundwater model encompassed three hydrostratigraphic layers: an upper fine-grained aquitard layer (overburden), a middle thin weathered bedrock aquifer layer, and a lower thick fractured bedrock layer. The overburden includes a succession of fine grained tills with some surficial glaciofluvial deposits. Tills mapped within the County include the Stratford, Rannoch, Mornington, Tavistock, Elma, and Wartburg.

The analysis of well water records from the Water Well Information System (WWIS) concluded that over 80% of the wells in Perth County are completed to bedrock. Static water levels indicated that bedrock groundwater flows from the northeast to the southwest. Some of the important groundwater features in Perth County are discussed in the following paragraphs.

Along the boundary between the Grand River and Thames River watersheds is the Easthope Moraine which sits on top of a bedrock high. This increase in the bedrock topography acts as the divide for groundwater between the Thames River and the Grand River watersheds.

A buried bedrock channel was also found north of the Thames watershed near Gowanstown, Listowel, Atwood, and Mitchell. Although this channel appeared to have more sand and gravel in comparison to the rest of Perth, it did not appear to affect the overall regional groundwater flow.

Karst (sinkhole) features have been identified in western Perth County (Perth County Groundwater Study) and the ABCA Sinkhole Investigation, (Abbey et al., 2004[193]). Karst may not have an effect on groundwater flow, but may be more important from a recharge potential and for contamination potential. At this time, the groundwater flow through the system is poorly understood. Due to the lack of information on sinkholes and their location outside of the Thames Watershed, these features will not be discussed further in this report.

Detailed groundwater studies were completed for the Town of St. Marys[194] and the City of Stratford[195], in Perth County. These municipalities lie on a sequence of fine-grained glacial till, and the municipal wells are completed in bedrock in both cities.

[192] Town of St. Marys. September 2007. Comments on Interim Watershed Description Report.
[193] Waterloo Hydrogeologic. 2004. Ausable Bayfield Sinkhole Investigation. Unpublished report.
[194] International Water Consultants. 2002. The Town of St. Marys Groundwater Report.
[195] Golder Associates. 2001. Groundwater Study for the City of Stratford.

St. Marys groundwater flows from the northeast to southwest and recharge zones include flat lands north of Otter Creek, sections of the Thames River that flow over bedrock, and areas with outwash deposits, mainly under the south central part of town. With regards to the St. Marys well supply, International Water Consultant completed a hydrogeological investigation[194] to determine the status of groundwater under direct influence (GUDI) wells and also Wellhead Protection Area (WHPA) modelling that was incorporated in the Perth Groundwater Study. The previous study delineated time of travel (TOT) zones for the study partners within the WHPA but the study did not establish the 100 metre and five year TOT zone. This is being addressed in the technical study that is currently underway pertaining to the protection of municipal drinking water systems under the groundwater drinking water system grant program.

The Stratford report concluded that the City's groundwater recharge zone extended beyond the city's limits to the north and east within Perth County.

Map 35: Municipal Wellhead Protection Areas shows the estimated groundwater capture zones for aquifers supplying various municipal wells in Perth County.

Overall, the vast majority of the water in Perth County is non-consumptive on a watershed level since it is returned to the respective watershed from which it came. However, usage tends to convert groundwater to surface water when treated sewage is discharged to local watercourses. Similarly, deep aquifer groundwater may be moved to shallow aquifers via private sewage disposal (septic) systems serving rural residents. Also, some uses do result in losses such as irrigation water which can be lost to the atmosphere via evaporation or evapotranspiration.

The total groundwater takings were calculated by adding the takings for large agricultural, domestic (rural and municipal), industrial, institutional and commercial water users. At the watershed level, more than half (60%) of groundwater taken within Perth County occurs in the UTRCA watershed and is estimated to be approximately 31,912 m^3/day. Based on the previous calculations for municipal (21,940 m^3/day) and rural (2,242 m^3/day) domestic water usage, the non-domestic water usage appears to be about 7,800 m^3/day.

Oxford County

Oxford County's 97,510 people (in 2000) are exclusively reliant on groundwater for their drinking water supplies. There are 19 municipal systems throughout the County that draw on 60 municipal wells to serve 70% of the population. The County of Oxford became responsible for all of the municipal water supply systems in 2000. The Department of Public Works, Water Services Group maintains and operates the municipal wells.

The Regional Oxford County Groundwater Study was conducted by Golder and Associates in 2001[196]. The purpose of the County of Oxford Phase II Groundwater study was to identify areas of significant aquifers and their corresponding recharge areas. Once the areas of these aquifers were identified, the groundwater flow patterns, both vertical and horizontal, were characterized using water level data from the OMOE well record database. This information, together with topographic data from the area, was used to identify areas of high hydraulic head (recharge areas) as well as low head (discharge areas).

As shown in **Table 2.7.1.1-2: Municipal Wells Oxford County**, municipal systems draw water from both overburden aquifers and bedrock aquifers within the County. The overburden aquifers extend throughout the study area as the County is dominated by glacial deposits and landforms. The bedrock geology of Oxford County consists of a series of subcropping Silurian through Middle Devonian age strata of predominantly limestones, dolostones and shales.

[196] Golder Associates. 2001. Phase II Groundwater Protection Study: County of Oxford.

Phase I of the Oxford study included collecting and compiling information on each of the municipal wells. **Table 2.7.1.1-2: Municipal Wells Oxford County**, as modified from Phase I, lists each of the communities, the number of municipal wells in each, and the aquifer(s) that they tap. Some communities listed in the table may not be part of the UTRCA watershed. Also, since the information in the original table was collected as part of the Golder Study, there have been some changes in the systems and wells supplying water to communities in Oxford County. Changes to the table have been made based on information supplied by the County of Oxford[197].

Table 2.7.1.1-2: Municipal Wells Oxford County[196]

Municipality/Location	Number of Wells	Aquifer(s)
Beachville	1	bedrock
Bright	2 (4*)	overburden
Brownsville	2	overburden
Dereham Centre	1	bedrock
Drumbo	3	overburden
Embro	2	bedrock
Hickson	1	bedrock
Ingersoll	7 (8*)	bedrock
Innerkip	2 (5*)	bedrock
Lakeside	1	bedrock
Mt. Elgin	2 (4*)	overburden, (*bedrock**)
Norwich	4	bedrock
Otterville – Springford**	4 (3*)	overburden
Plattsville	2	overburden
Princeton	0 (2*)	receives water from other Oxford County Systems (*overburden**)
Sweaburg	0 (2*)	Connected to Woodstock well field (overburden*)
Tavistock	3	overburden, bedrock
Thamesford	3 (5*)	overburden, bedrock
Tillsonburg	10 (12*)	overburden
Woodstock	10 (11*)	overburden, bedrock

* Number of wells and sources reported in Golder and Associates, 2001
** Springford was reported in Golder and Associates, 2001 as a separate system with three overburden wells that have been decommissioned

A key component in the development of wellhead protection areas (WHPAs) for the County of Oxford was the determination of time-related capture zones for each of the water supply wells or water supply systems. **Map 35: Municipal Wellhead Protection Areas** shows the estimated groundwater capture zones for aquifers supplying various municipal wells in Oxford County.

[197] Oxford County. September 10, 2007. Letter providing comments on the Interim Watershed Description Report.

Middlesex and Elgin Counties

Dillon Consulting Limited in association with Golder Associates completed the Middlesex-Elgin Groundwater study in 2004[198]. The information included in this section is derived from this study.

In the Thames Watershed & Region portion of Middlesex-Elgin, three municipalities operate a number of public groundwater supply systems. These include:

- Middlesex Centre (three systems: Melrose, Komoka-Kilworth, Birr)
- Thames Centre (two systems: Dorchester, Thorndale)
- Strathroy-Caradoc (one system: Mount Brydges)

The Strathroy municipal well supply was replaced with a supply of piped Lake Huron water in 2006.

The Middlesex-Elgin Groundwater Study included the City of London, the City of St. Thomas, all of Middlesex County and the majority of Elgin County. **Table 2.7.1.1-3: Summary of Potable Water Sources, Middlesex-Elgin** provides information on the overall water sources for communities in these Counties.

Map 35: Municipal Wellhead Protection Areas shows the estimated groundwater capture zones for aquifers supplying various municipal wells in Middlesex County.

Essex County and the Municipality of Chatham-Kent

The results and analysis of water use estimates was derived directly from the study[199] completed by Dillon Consulting Ltd. and Golder Associates Ltd. There are two municipal well systems that supply Ridgetown and Highgate.

Ridgetown is supplied by two well fields both completed in the same aquifer system. The Ridgetown well field supplies 11,900 m^3/day. The well fields are located in an area consisting of 20 to 40 m clay/till aquitard covering the sand and gravel aquifer that overlies black shale bedrock.

The Highgate water supply system consists of two wells serving approximately 150 homes in the hamlet of Highgate. The system demand is approximately 500 m^3/day. The wells are deep (>50 m) and tap a sand and gravel aquifer that is protected by a thick aquitard consisting of low permeability clay and silt soils.

Map 35: Municipal Wellhead Protection Areas shows the estimated groundwater capture zones for aquifers supplying Ridgetown and Highgate.

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198 Dillon Consulting and Golder Associates. 2004. The Middlesex - Elgin Groundwater Study. Unpublished report.

199 Dillon Consulting and Golder Associates. December 2004. Essex Region/Chatham-Kent Region Groundwater Study.

Table 2.7.1.1-3: Summary of Potable Water Sources, Middlesex-Elgin

Municipality	Total Population	Population on Municipal Groundwater Wells	Population on Municipal Surface Water	Population on Private Wells	% Population supplied by Groundwater		
					Total	Private Wells	Municipal Wells
Middlesex County							
Thames Centre	13,125	5,031	0	8,093	100%	62%	38%
Lucan-Biddulph	4,388	0	2,538	1,850	42%	42%	0%
Middlesex Centre	14,664	2,863	3,225	8,576	78%	58%	20%
North Middlesex	7,839	0	6,837	1,002	13%	13%	0%
Adelaide-Metcalfe	3,257	0	0	3,257	100%	100%	0%
Southwest Middlesex	7,077	0	2,932	4,145	59%	59%	0%
Strathroy-Caradoc	20,706	15,707	0	4,999	100%	24%	76%
Newbury	422	0	422	0	0%	0%	0%
Elgin County							
Central Elgin	12,360	1,788	3,913	6,658	68%	54%	14%
Southwold	4,487	0	2,244	2,244	50%	50%	0%
Dutton Dunwich	3,696	0	1,490	2,206	60%	60%	0%
West Elgin	5,464	0	2,571	2,893	53%	53%	0%
Surface Water and Groundwater							
Total – Elgin	41,942	1,788	17,659	22,496	58%	54%	4%
Total – Middlesex	71,478	23,601	15,942	31,922	78%	45%	33%
City of London	336,539	0	331,539	5,000	1%	1%	0%

2.7.1.2 Groundwater – Private Wells

Private wells comprise an important source of water for domestic supply and other uses in rural areas and small hamlets. **Map 34: Water Well Record Locations** shows the wells recorded in the Ministry of the Environment Water Well Information System Database. Most of these wells were drilled to serve individual residences or farms. The rural population reliant on groundwater varies significantly across the length of the region with the highest numbers in Perth and Oxford Counties.

In Perth County, it is estimated that approximately 12,800 people in the UTRCA watershed depend on drinking water from private wells based on the percentage of the municipality in the UTRCA watershed. The analysis of well water records from the Water Well Information System (WWIS) concluded that over 80% of the wells in Perth County are completed to bedrock.

The rural residents of Oxford County rely on groundwater for domestic, commercial and most agricultural water supplies. Private wells provide water to 30% of the population (approximately 30,000) not served by a municipal system. Of the close to 6,000 wells listed in a 1987 summary, some 85% were drilled for domestic or livestock purposes, 3.7% for municipal or public supply, 3.5% for industrial/commercial use, 2.5% for irrigation and 0.2% for cooling or air conditioning.

The Middlesex-Elgin Groundwater Study included the City of London, the City of St. Thomas, all of Middlesex County and the majority of Elgin County. Based primarily on maximum permitted total volumes, self supply (private) was estimated to be 88% of use of groundwater. This percentage will increase with the conversion of the Strathroy public supply to piped Lake Huron water. The largest water users are the quarry and mining industry which accounts for 35% of the groundwater use. The distribution of groundwater use by category was reported to be:

- Public Supply: 12%
- Self Supply, Domestic (residential) 12%
- Self Supply, Domestic (commercial/institutional) 12%
- Self Supply, Irrigation 19%
- Self Supply, Livestock 9%
- Self Supply, Industrial (manufacturing) 1%
- Self Supply, Industrial (mining) 35%
- Self Supply, Other <1%

Domestic-Residential Self Supply makes up approximately 12% of the groundwater use. **Table 2.7.1.1-3: Summary of Potable Water Sources, Middlesex-Elgin** provides information on the overall use of private wells for communities in these Counties.

Based on information from the 1998 MUD survey, the majority of the residents of Essex and Chatham-Kent obtain their domestic water from municipal water systems that take their water from Lake Erie, Lake St. Clair, the St. Clair River, or the Detroit River. The proportion of the population that obtains their domestic water from private or non-municipal communal wells (Domestic Self Supply) accounts for only 9% of total water use.

2.7.1.3 Groundwater – Regulation 252/05 Wells

Ontario Regulation 252/05 came into effect on June 30, 2005 and applies to water systems serving facilities that have non-residential or seasonal uses. Under an intended transfer of responsibility from the Ministry of the Environment to the Ministry of Health and Long-Term Care, it is anticipated that public health units will oversee these small drinking water systems.

The categories of drinking water systems being transferred include:

- Large municipal non-residential, such as municipally owned airports, industrial parks, sports facilities and recreation complexes

- Small municipal non-residential, such as small community centres, libraries, sports and recreation facilities
- Non-municipal seasonal residential, such as private cottages on communal drinking water systems
- Large non-municipal, non-residential, such as large motels and resorts
- Small non-municipal, non-residential, such as motels, restaurants, gas stations, churches, bed and breakfasts

Systems serving designated facilities, such as schools, day care facilities, children's camps, etc., would not be affected by this bill and would remain regulated by the Ministry of the Environment.

At the time this report was being prepared, the transfer was in transition and exact information on the number and location of Reg. 252/05 facilities in the Thames Watershed & Region was not available. It is estimated that there may be approximately 1,200 Reg. 252/05 systems in the Thames Watershed & Region. This estimate is based on information obtained from discussions with local health units and the percentage of each municipality in the region.

Most of the Reg. 252/05 would be in the Middlesex, Perth and Oxford part of the watershed. The areas where these facilities are located would be similar to areas where the private water wells are in use. The groundwater sources for these systems would follow the pattern of overburden and bedrock wells as discussed in the section on private wells and as shown in **Map 34: Water Well Record Locations**.

2.7.1.4 Surface Water Intakes

Treated surface water is the primary source of drinking water for residents in the Thames Watershed & Region. Pumping stations pump raw water from Lake Huron, Lake Erie and Lake St. Clair to Water Treatment Plants (WTPs) where the water is treated, often stored in reservoirs and passed through pipelines to residents. The locations of the intakes are shown on **Map 38: Drinking Water Supplies/Intakes**. The map also shows the communities that receive water from these sources. Three surface water intakes are located within the region and four are outside the region.

Surface Water Intakes within the Thames Watershed & Region

The three intakes in the region all take water from Lake Erie. One intake supplies water to both the South Chatham-Kent and Chatham Water Treatment Plants. The other two intakes supply the Wheatley WTP and the West Elgin WTP.

The South Chatham-Kent WTP has an intake at Erie Beach in Lake Erie and supplies water to the lower portion of the Municipality of Chatham-Kent. The WTP came into operation in May 2003 and replaced both the Erie Beach-Erieau Water System and the Blenheim Area Water System. It also serves the communities of Charing Cross, Merlin, Port Alma, Rondeau Bay Estates, Shrewsbury and South Buxton.

The Chatham WTP receives its raw water from the same raw water pumping station as the South Chatham-Kent WTP at Erie Beach. The Chatham WTP supplies treated water to Chatham and the central parts of Chatham-Kent including the communities of Pain Court, Grande Pointe, Mitchell's Bay, Dresden, Tupperville and Thamesville. The plant has a maximum flow capacity of 68,190 cubic metres per day and serves a population of 60,000.

The Wheatley WTP derives its surface water from Lake Erie south of Wheatley. The Wheatley WTP supplies drinking water to the communities of Wheatley and Tilbury in Chatham-Kent. It also supplies water to portions of Mersea and Lakeshore Townships. The plant has a treatment capacity of 10,200 m^3/day and serves a population of 3,800.

The West Elgin Water Treatment Plant has a Lake Erie intake south of West Lorne at Eagle. The plant serves the Municipalities of West Elgin, Dutton Dunwich, and Southwest Middlesex. It also supplies water to the Village of Newbury and the community of Bothwell in Chatham-Kent. The plant has a maximum capacity of 6,829 m^3/day and serves a population of 9,985 people.

Surface Water Intakes outside the Thames Watershed & Region

The water for most of the population of the Thames Watershed & Region comes from water treatment plants that are located outside the area. The surface water intakes[200] for the City of London are located in Lake Huron at Grand Bend and in Lake Erie east of Port Stanley. These plants also supply water to other local communities.

The Lake Huron Primary Water Supply System (LHPWSS) services the City of London and Municipalities of Middlesex Centre, Lucan-Biddulph and Strathroy-Caradoc in the Thames Watershed & Region. The WTP is located north of the community of Grand Bend on Lake Huron. The plant has a current treatment capacity of 340 million litres per day (75 million Imperial gallons per day) and serves a population of approximately 325,000 people.

The Elgin Area Primary Water Supply System (EAPWSS) services the communities of London and Southwold in the Thames Watershed & Region. The WTP is located east of the village of Port Stanley in Central Elgin on Lake Erie. The plant has a current treatment capacity of 90 million litres per day (20 million Imperial gallons per day) and supplies water to a population of approximately 94,400 people.

The Stoney Point Water Treatment Plant is located in the Town of Lakeshore in Essex County. It takes surface water from Lake St. Clair and serves the northeastern portion of the Town of Lakeshore. The plant has a maximum capacity of 4,600 m^3/day and serves a population of 5,800.

The Union Water Treatment Plant is located west of Leamington in Essex County. It takes surface water from Lake Erie and serves the Town of Leamington and parts of the Town of Lakeshore. The plant has a current rated capacity of 124,589 m^3/day and services an estimated population of 56,000.

2.7.2 Recreational Water Use

The Thames River, due to its large size and length, affords multiple recreational prospects to the residents. Also, over one-third of the boundary of the LTVCA is comprised of Lake Erie or Lake St. Clair shoreline. This provides bountiful recreational opportunities to people in the region.

Fishing takes place in these waters and many other creeks and streams in the region. The primary impediments to the migration of fish are dams and pumping stations located at the mouths of several watercourses in the lower regions of the LTVCA and dams located on the tributaries of the Thames River in the UTRCA area. However, regardless of these impediments vibrant populations of fish are able to survive in these watercourses.

Motorized and non-motorized boating is enjoyed on Lake Erie and Lake St. Clair. Both commercial and recreational vessels move through the region on the lakes. On the Thames River, motorized boating takes place up to Kent Bridge for most of the ice free year. There are several marinas, boat launches, and public docks in the region. Also, numerous private facilities and docks located along the shoreline give cottage and homeowners the ability to use the waterways in the watershed. On the Thames River, the municipal docks at Chatham have facilities to accommodate transient boats. The upper portions of the Thames River are generally limited to non-motorized use such as canoeing. The impoundment areas behind some of the dams in the upper Thames provide localized recreational opportunities for sailing and rowing.

Beaches along Lakes Erie and St. Clair provide good swimming during the summer months. No one is encouraged to swim in the Thames River due to potential water quality concerns.

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[200] City of London website. October 19, 2005. http://watersupply.london.ca

Lake St. Clair and the Thames River up to at least Chatham can normally accumulate at least 30 centimetres of surface ice in the winter. This ice is sufficient to afford the winter sports enthusiast numerous opportunities to snowmobile and ice fish in the winter season. These recreational activities extend into the upper Thames River watershed.

Open water viewing areas such as parklands and watercourse road crossings continue to maintain a recreation quality for birding and aesthetic enjoyment of our water resources. Other recreational activities that benefit from abundant water range from campgrounds along the shores of the watercourse to numerous golf courses that use water for the irrigation of greens and fairways.

2.7.3 Ecological Water Use

The Thames Watershed & Region has a wide variety of water bodies and watercourses ranging from Lake Erie to small intermittent streams. The area is almost entirely within the Carolinian Forest zone. As a result, there are many different types of habitat and ecological groups including open water communities, wetlands, river channel communities, abandoned river channel communities, upland forests, residual tall grass prairie and transitional zones of scrub, savannah, meadows, marshes and beaches. The different habitats, combined with a climate moderated by the Great Lakes, results in biodiversity of native flora and fauna.[201]

The Thames River supports an astounding diversity of aquatic species. At least 20 species of mussels and 90 species of fish have been found there. Many of these are rare and were discussed at greater length in **Section 2.5: Aquatic Ecology**.

In Chatham-Kent, Ducks Unlimited has a large Permit To Take Water (PTTW) for wetland flooding. The actual water used is not recorded and is believed to be far less than these permits allow since the pumps are generally operated for a few days per year.

2.7.4 Agricultural Water Use

As discussed in **Section 2.6.11: Agriculture**, this area is a highly productive agricultural region with a wide variety of farming operations. As shown in **Map 33: Land Capability for Agriculture**, most of the soils are suitable for sustained production of common field crops.

The region normally receives about 900 mm of precipitation per year. Given the soil types and temperatures in the region there is usually an adequate amount of rain for a farm operator to produce field crops. Specialized crops such as tobacco and ginseng, and market crops including potatoes, beets, carrots and tomatoes, are irrigated on a regular basis to maintain yield and quality. As shown in **Table 2.7-1: Number of Water Taking Permits by Sector**, agricultural operations have 33% of permits issued in the Thames Watershed & Region.

Groundwater is identified as an important source of agricultural water in the Chatham-Kent Groundwater Study. The overall breakdown of agricultural water sources across the Essex Region/ Chatham-Kent region study area is roughly 60% groundwater and 40% surface water.

In general, irrigation of cash crops, such as corn and soybeans, is not practiced in the region. However, drought-like conditions can occur and during a dry year, some farm operators have irrigated field crops. Even with access to bountiful surface water for irrigation in the LTVCA area and a suitable high value crop, it is a borderline economic decision for the farm operator to invest in the capital equipment for irrigation of crops such as corn as there are many years where it is not needed.

[201] Lake St. Clair Canadian Watershed Coordination Council. 2005. Lake St. Clair Canadian Watershed Draft Technical Report: An examination of current conditions.

The most dependable source of irrigation water is the surface water of the Great Lakes, including the lower reaches of the Thames River and creeks which are influenced by the lake levels of Lakes St. Clair and Erie. Due to the topography of the lower Thames watershed, the still water elevation of Lake St. Clair extends up the Thames River to approximately Kent Bridge. Upstream of Kent Bridge on the Thames River the gradient increases to the point where there is no influence from Lake St. Clair. However, there are some farm operations in this area that use the Thames River for irrigation.

Chatham-Kent has recently encouraged the construction of a greenhouse industry. These are relatively high volume users of water and need a secure water supply for crop production. These operations usually use municipal water supplies.

As noted in **Section 2.6.11: Agriculture**, livestock numbers vary widely across the area. Livestock is a component of the agricultural industry that requires sufficient water on a daily basis. Many farm operators obtain drinking water from groundwater supplies and large livestock operations can potentially be a stressor on groundwater supply systems. Livestock will naturally gravitate to streams and watercourses to obtain water and farm operators are encouraged to limit livestock access to them.

Agricultural water used for irrigation and in livestock and poultry operations has not been monitored in the region and, as a result, the amount of water use required by agriculture is undetermined for the Thames Watershed & Region. However, groundwater studies provide some estimates for agricultural water usage in Lambton County, Middlesex County, Elgin County, Perth County, Oxford County and the Municipality of Chatham-Kent as summarized in **Table 2.7.4-1: Agricultural Water Use**. While the table includes areas that are outside the Thames Watershed & Region, it helps to show the differences in agricultural water usage across southwestern Ontario.

Table 2.7.4-1: Agricultural Water Use (m^3/yr)*

Municipality	Number of Farms	Livestock Watering	Field Crops	Fruit Crops	Vegetable Crops	Specialty Crops	Total
Chatham-Kent	2,299	840,754	927,806	315,456	1,257,748	355,611	3,697,375
Lambton	2,346	1,625,661	79,143	243,621	918,217	172,566	3,039,208
Middlesex	2,515	2,551,461	856,073	347,628	82,723	2,013,392	5,851,278
Elgin	1,323	949,481	1,822,950	390,102	114,189	596,364	3,873,085
Perth	2,522	4,393,943	44,055	82,088	116,471	80,884	4,717,333
Oxford		2,929,855	2,519,960	500,780	239,075	305,140	6,494,810

*Figures taken from the Essex/Chatham-Kent Region Groundwater Study, the Lambton County Groundwater Study, the Middlesex-Elgin Groundwater Study, the Perth County Groundwater Study and Phase II Groundwater Study County of Oxford.

The volumes of water used for livestock watering and crop irrigation will be reviewed and updated estimates provided in the Water Budget Report.

2.7.5 Industrial/Commercial

As shown in **Table 2.7-1: Number of Water Taking Permits by Sector**, commercial operations have 17% of the permits and industrial have 10% of the permits. In addition, 6% of the permits are issued for dewatering of pits, quarries and construction sites.

In the commercial sector, water for irrigation of golf courses is a significant water usage. Water sources for golf course irrigation include groundwater, surface water from storage ponds and water taken directly from local watercourses.

In the UTRCA area, large aggregate and quarry operations take water for washing gravel and dewatering the sites.

Throughout the watershed, rural businesses and industries that are not connected to municipal supplies obtain their potable drinking water from private wells. However, many rural industries and businesses, especially in Chatham-Kent and Essex, have access to municipal water by a network of pipelines along local roads.

In urban areas, much of the water for industrial and commercial operations in the Thames Watershed & Region is supplied as part of the municipal water supply system. **Table 2.7.1.1-1: Perth Municipal Water Use by Community** shows that commercial/industrial operations can use as much as 65% (Mitchell) of the municipal water supply.

In the LTVCA area of the watershed, there used to be numerous agricultural canning plants that were all large water users in Chatham but most of these plants have closed. With the capacity in the municipal system that previously was needed for these industries, the municipality has constructed water pipelines from Chatham to small communities in Chatham-Kent and is encouraging the growth of local greenhouse operations.

2.7.6 Water Use Comparison

The **Draft Conceptual Water Budget** for the Thames-Sydenham & Region provides some comparisons of estimates for municipal, agricultural and unserviced domestic annual water uses. For the Conceptual Water Budget, the Thames Watershed & Region was split into four subwatershed catchments.

The 'North' Catchment Delineation is the North Branch of the upper Thames River. The 'South' Catchment Delineation is the combination of the South Branch and the Middle Branch of the upper Thames River. The 'Central' Catchment Delineation is the lower Thames River from the Forks of the Thames to the Thamesville gauge plus the Lake Erie drainage area south of this part of the river. The 'Lower' Catchment Delineation is the lower Thames River from the Thamesville gauge to the mouth of the Thames River plus the Lake Erie drainage area south of this part of the river and the area draining directly to Lake St. Clair.

The estimated water use is summarized in **Table 2.7.6-1: Estimated Annual Water Use** based on information taken from the June 7, 2007 Version 2.0 of the Draft Conceptual Water Budget[202].

[202] Thames-Sydenham & Region Source Protection Region. June 7, 2007. Thames-Sydenham & Region Draft Conceptual Water Budget. Version 2.0 Final Draft.

Table 2.7.6-1: Estimated Annual Water Use in mm/watershed Area

Sub-Watershed	Water Use Sector					Total
	Municipal Surface Water	Municipal Groundwater	Private Groundwater	Livestock Watering	Crop Irrigation	
North	9	5	0.7	7	9	30.7
South	13	7	0.7	5	11	36.7
Central	13	0	0.6	3	6	22.6
Lower	9	3	0.6	1	5	18.6

The estimates provided in **Table 2.7.6-1** are based on a number of assumptions that are provided in the Draft Conceptual Water Budget. A more detailed review of water use is underway as part of the Tier 1 Water Budget being prepared for the Thames Watershed & Region.