Grand River Watershed Characterization Report

DRAFT

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1.0 INTRODUCTION

Following the public inquiry into the Walkerton water crisis, Justice Dennis O'Connor released a report in 2002 containing 121 recommendations for the protection of drinking water in Ontario. Since the release of the recommendations, the Government of Ontario has introduced legislation to safeguard drinking water from the source to the tap, including the *Clean Water Act* in 2006, which provides a framework for the development and implementation of local, multi-stakeholder source protection plans.

The Clean Water Act focuses on the protection of municipal drinking water supplies. It sets out a risk-based process on a watershed scale to identify vulnerable areas and associated drinking water threats, and requires the development of policies and programs to reduce or eliminate the significant risks to sources of municipal drinking water sources. The Province, through the Ministries of the Environment (MOE) and Natural Resources (MNR), is working in partnership with municipalities, Conservation Authorities, Conservation Ontario, water users, land owners and other stakeholder groups to develop the local science based source protection plans.

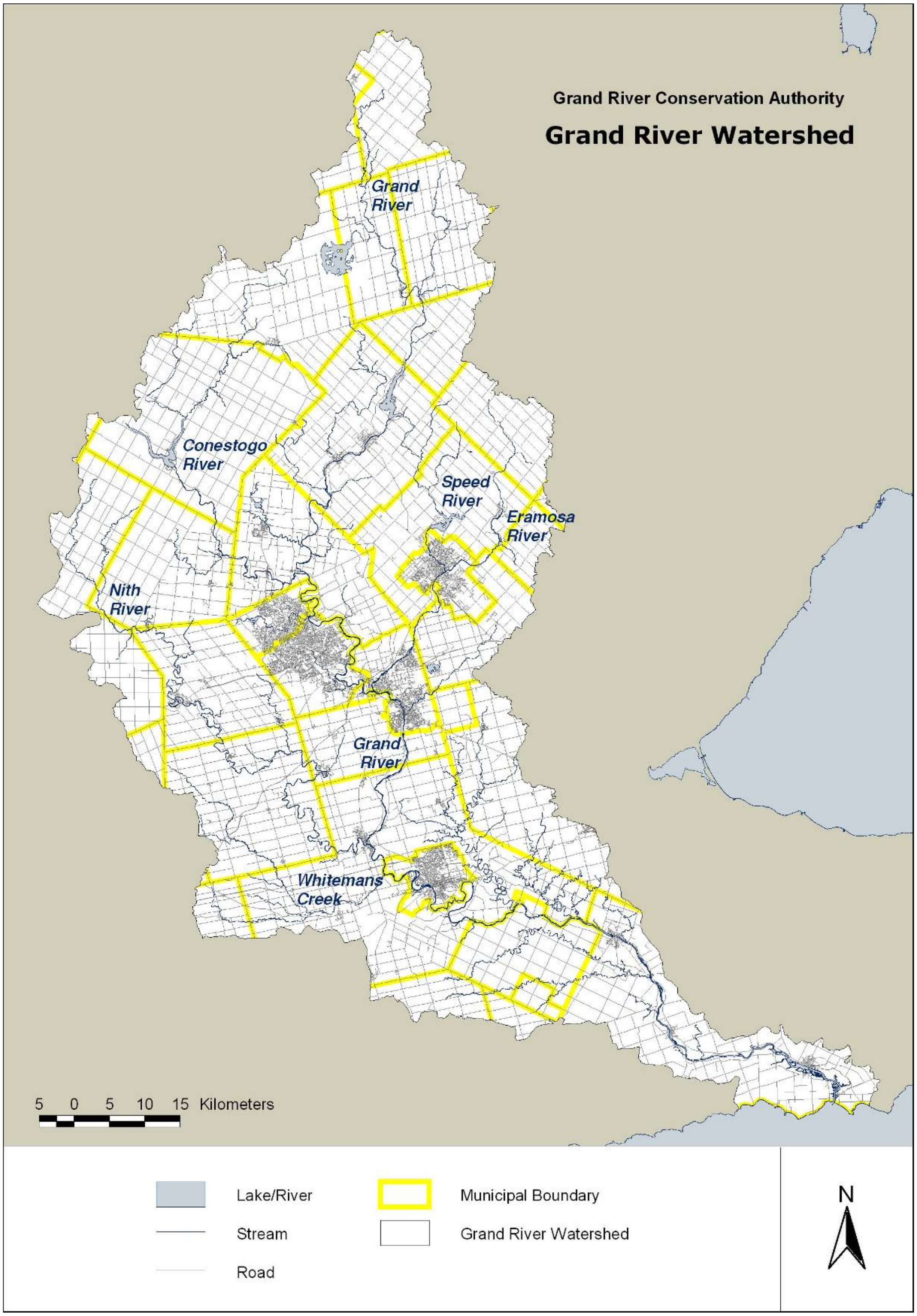
The first step in the development of the plan is to describe the physical and human characteristics of the watershed. The Watershed Characterization Report provides information ranging from geology, hydrology and hydrogeology, groundwater and surface water quality, population distribution, land uses, municipal and private water use, a description of the water supplies, potential drinking water threats and issues, and a brief description of existing policies and programs to protect drinking water sources. The Watershed Characterization Report forms the foundation of the Technical Assessment Report, which will identify all known drinking water source issues and significant threats in the watershed, and the Source Protection Plan.

The first chapter of the report provides an overview of the watershed and the Lake Erie Source Protection Region, and introduces the main stakeholders and partners in the local source protection planning process. Chapter Two is a summary of the physical characteristics of the watershed, while Chapter Three provides an overview of the human characteristics, including population and land use. Summaries of water management strategies and water use in the watershed are provided in Chapters Four and Five. Chapter Six describes both private and municipal drinking water sources in the watershed, and provides some preliminary discussion of the types of potential threats to the sources of municipal drinking water. Chapter Seven follows with a discussion of potential drinking water issues in the watershed and lists the main data and knowledge gaps in determining and documenting drinking water issues. Chapter Eight concludes the report with a description of the existing policies and programs that already provide protection of sources of drinking water.

1.1 Grand River Source Protection Area

The Grand River watershed covers an area of approximately 6,800 square kilometres in south-central Ontario, and contains a population of over 800,000 people. The watershed contributes about ten percent of the drainage to Lake Erie. The length of the Grand River itself is 300 kilometres, while the average width of the watershed is 36 kilometres. **Map 1.1** shows the boundaries of the Grand River watershed, along with the municipalities it contains.

Map 1.1: The Grand River Watershed



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Surface elevation in the watershed ranges from 173 metres above sea level at the mouth of the Grand River on Lake Erie, to 535 metres above sea level in the northern headwaters. The major tributaries of the Grand River include: the Conestogo and Nith, draining the western half of the watershed; and the Speed, which drains the north-east. Several smaller tributaries drain the southern half of the watershed. The largest of these include the Fairchild, Whiteman's and McKenzie creeks.

The Grand River watershed has a long history of settlement that has drastically altered the landscape and impacted surface water and groundwater quality and quantity.

1.2 Lake Erie Source Protection Region

In response to the Walkerton water crisis, and the ensuing recommendations made by Justice O'Connor from the Walkerton Inquiry, the Province of Ontario has undertaken a process to protect the quality and quantity of sources of drinking water. Key partners included in the process are municipalities and conservation authorities. Conservation authorities will coordinate the development of technical and scientific knowledge, and facilitate the planning process. Municipalities will participate in the planning process and play a lead role in implementing the plans.

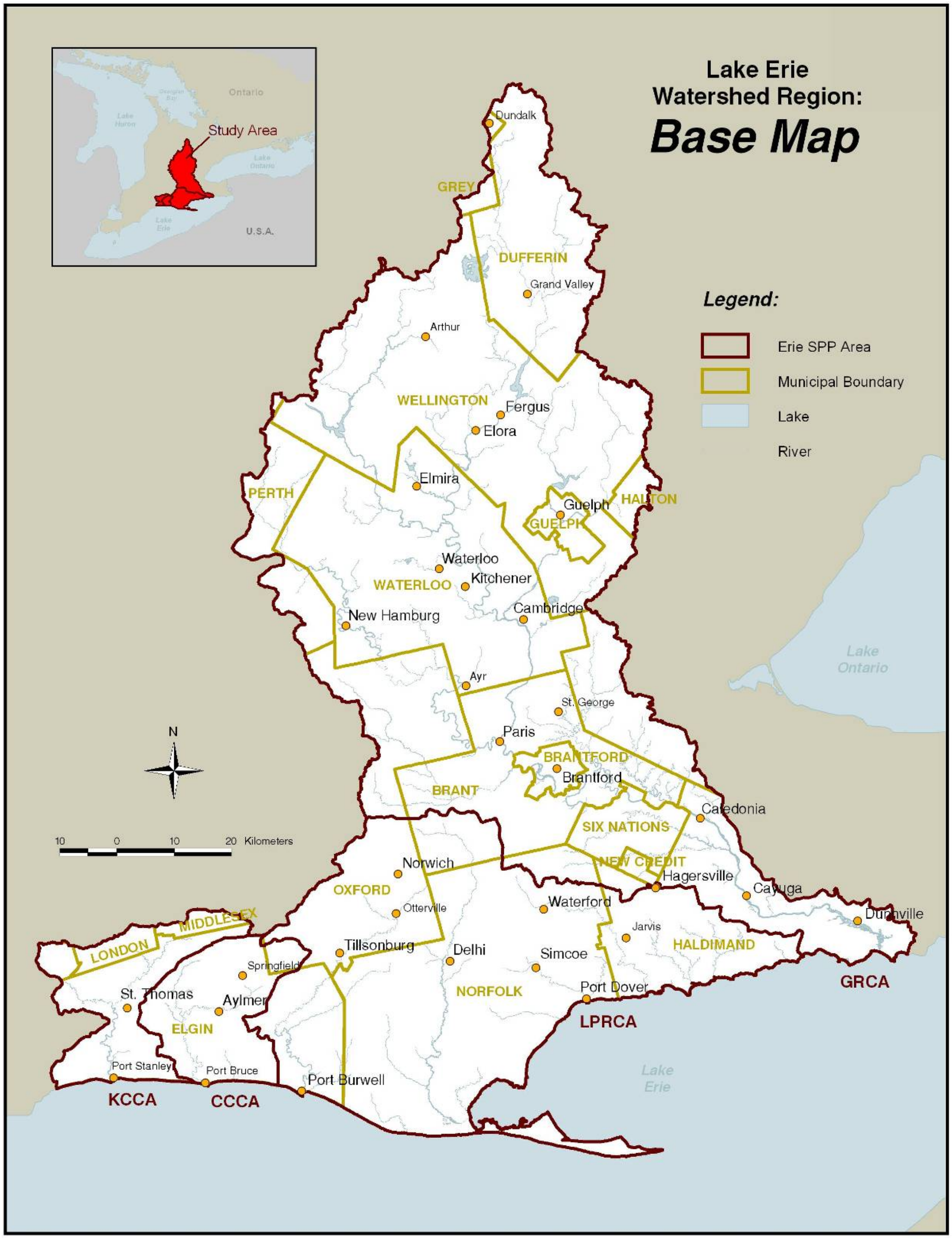
In an effort to share knowledge and resources, a partnership was formed in 2004 between the Grand River, Long Point Region, Catfish Creek and Kettle Creek Conservation Authorities to form the Lake Erie Source Protection Region. The Grand River Conservation Authority (GRCA) acts as the lead authority for the region. **Map 1.2**, in Appendix A, shows the territory covered by the Lake Erie Region, including municipal boundaries and main rivers and tributaries. The four Conservation Authorities agreed to jointly undertake research, public education, and watershed planning and management for the advancement of drinking water source protection for the respective watersheds. The watersheds have a long history of partnership and cooperation, and also have a natural association by containing most inland rivers and streams flowing from Ontario directly into Lake Erie.

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

1.3 Watershed Partners and Stakeholders

Several partnerships and relationships have been formed to discuss and manage watershed-related issues in the Grand River watershed. Partners include the 36 Upper and Lower Tier municipalities, two First Nations communities; federal and provincial governments; non-governmental organizations; private landowners; the Grand River Conservation Authority; Conservation Ontario; partner and neighbouring conservation authorities; and academic institutions.

Map 1.2: Lake Erie Source Protection Region



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A strong forum for partnerships for dealing with watershed-scale issues has existed in the Grand River watershed for decades. The watershed municipalities have managed natural resources on a watershed-scale basis through the Grand River Conservation Authority (GRCA) for over fifty years. The GRCA and municipalities have also coordinated the efforts of government agencies and other partners to carry out a wide range of watershed conservation programs and activities.

As an example, in 1996, the GRCA invited watershed partners to set priorities for action and pool their efforts for the biggest benefit to watershed health. The process is called The Grand Strategy. The partnership includes representatives of provincial and municipal governments, agencies, First Nations, educational institutions, community interest groups and the public and private sectors. The Grand Strategy sets the stage for long-term shared management, integrating not only water supply and quality issues, but natural heritage, recreational, economic and human heritage considerations.

A vast amount of research and work in watershed management has been undertaken by partners in the watershed, in conjunction with the GRCA, including municipalities, federal and provincial agencies, individual landowners and organizations and First Nations. Recent studies have focused on the development of a comprehensive watershed management plan, including a fisheries management plan; a wetlands policy; a watershed forest plan; surface water and groundwater quality studies; an overall water budget for the watershed; water use and in-stream flow studies; and a rural water quality program geared at agricultural best practices, to name a few.

In cooperation with municipalities, the province and the GRCA, municipal groundwater studies were completed for most municipalities in the watershed. The studies identify, to varying degrees, the characteristics of regional aquifers, their vulnerability and associated threats.

Together, the studies provide insight and direction for the overall management of groundwater resources, land use and water use, as well as providing information on protecting the quality and quantity of surface water and groundwater for drinking water, recreation and natural processes; reducing flood damage; and protecting natural areas.

2.0 PHYSICAL CHARACTERISTICS OF THE GRAND RIVER WATERSHED

Understanding the physical characteristics of the watershed is key to protecting and managing water. Interactions between surface water, groundwater and potential sources of contamination require an understanding of the physical characteristics of the bedrock and surficial geology, physiographic regions and significant natural features within the watershed. The following sections are intended to provide descriptions of these characteristics, as well as some discussion surrounding their significance to drinking water sources.

In a general sense, the geology of the Grand River watershed can be classified into three types of unconsolidated sedimentary material overlying bedrock. The northern portion of the watershed is comprised of till and related materials, the central portion of the watershed is comprised of a series of northeast-southwest trending, typically coarse-grained moraine sediments, and the southern portion of the watershed is comprised of fine-grained glaciolacustrine sediments. Each of these categories of unconsolidated sediments is unconformably underlain by sedimentary bedrock.

2.1 Bedrock Geology

Beneath the Grand River Watershed, bedrock formations generally outcrop or subcrop in long parallel bands of varying width, aligned in a north-west to south-east direction. The bedrock subcropping within the watershed consists of Ordovician to Devonian-aged sedimentary rocks, deposited in a marine environment that existed in this area between 345 to 370 million years ago (Sibul et al., 1980). The Grand River Watershed spans both the Michigan Basin in the northern part of the watershed and the Appalachian Basin in the southern part of the watershed. The Algonquin Arch, which occurs in the Brantford area, separates the two basins.

Bedrock outcrops are most commonly found in the central-eastern and southern areas of the watershed. Within the central-eastern area, outcrops, which are commonly found along river valleys, generally consist of the Guelph and Amabel Formations. In the southern part of the watershed, outcrops are generally associated with the Onondaga Escarpment and consist of the Bass Island, Bertie and Bois Blanc Formations (Karrow, 1973).

In total, there are 11 different bedrock formations outcropping or subcropping within the Grand River watershed, all of which were initially deposited horizontally. Regionally, they now dip approximately 2 degrees to the west as a result of subsequent structural deformation. **Map 2.1** shows the bedrock formations of the Grand River Watershed, while **Figure 2.1** is a cross-section which illustrates the stratification of the bedrock complexes across the watershed from east to west.

The following provides a brief description of the bedrock formations within the watershed.

Map 2.1: Bedrock Geology of the Grand River Watershed

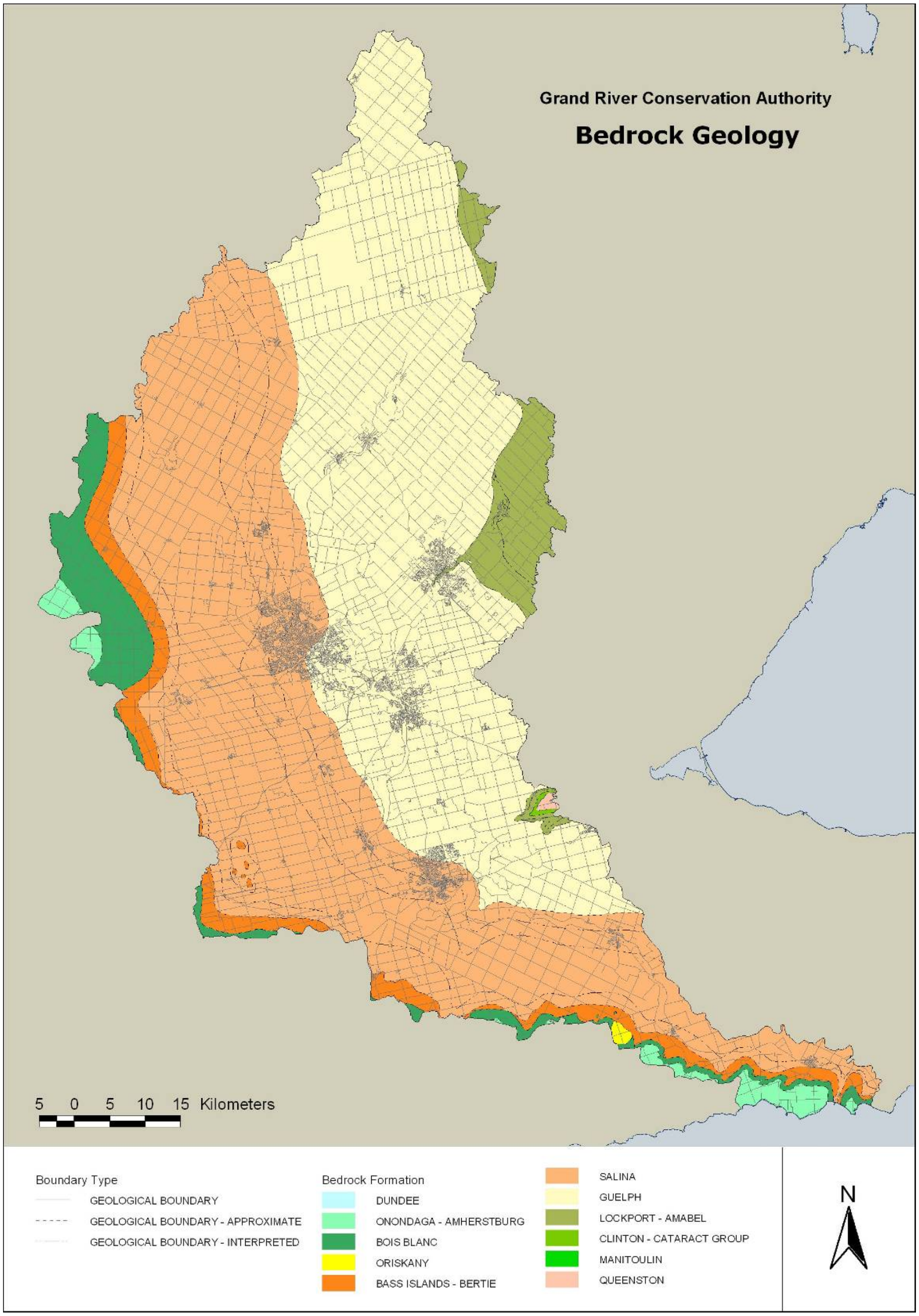

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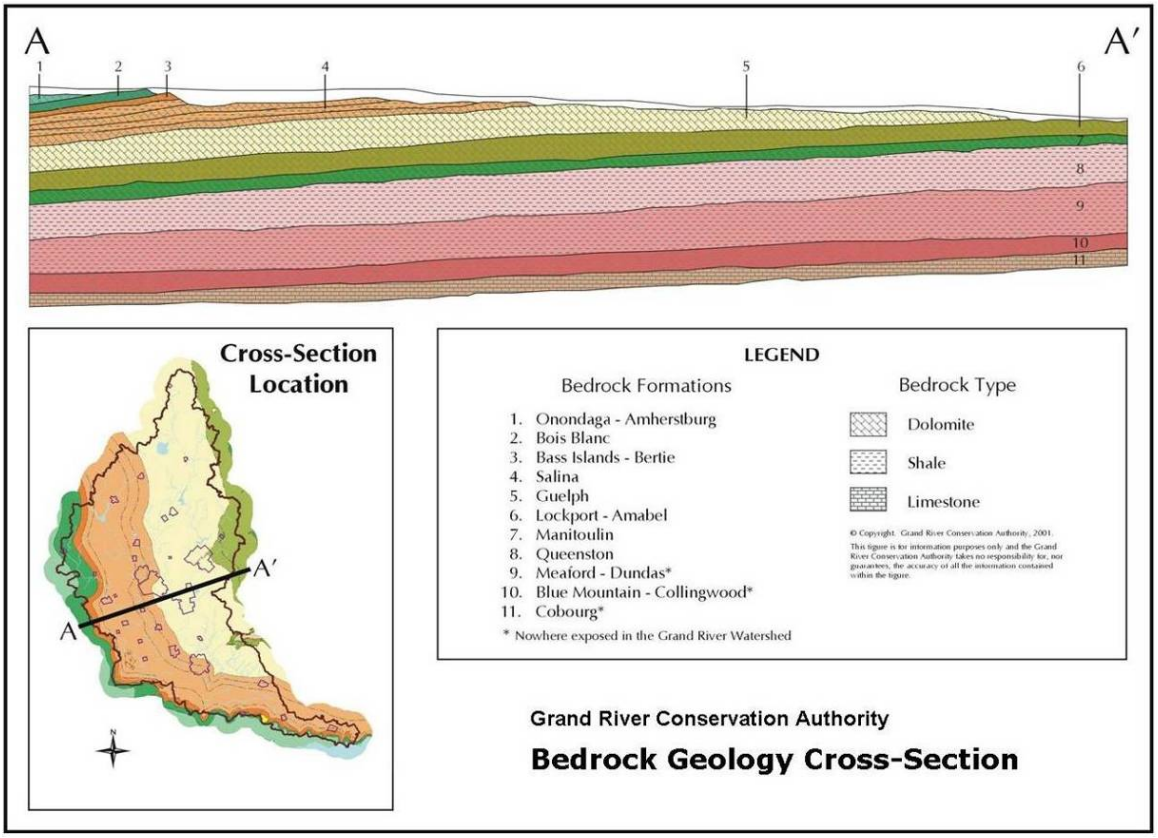
Figure 2.1: Bedrock Cross Sections of the Grand River Watershed



Various Authors, 1967-1993, Paleozoic Geology, Southern Ontario, Ontario Geological Survey.
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2.1.1 Queenston Formation

The Queenston Formation, which is also commonly known as the Queenston Shale, is the oldest Paleozoic bedrock formation within the watershed and forms the uppermost bedrock formation in a small area in the Dundas Valley in the vicinity of Copetown. It was formed during the Upper Ordovician period (458 to 443 million years ago), generally consists of red shale interbedded with limestone and siltstone, and ranges in thickness from 135 m to 335 m. (Telford et al., 1976).

2.1.2 Clinton–Cataract Group

The Clinton-Cataract Group overlies the Queenston Formation. From **Map 2.1**, a narrow band representing the Clinton-Cataract Group subcrops in an area surrounding the Queenston Formation in the Dundas Valley area. The Clinton-Cataract Group is composed of several different bedrock formations, however these formations have not been differentiated on **Map 2.1**. This group, which is exposed along the face of the Niagara Escarpment, was deposited during the Lower to Middle Silurian period, 443 to 428 million years ago and overall, generally consists of grey to dark grey shale, sandstone, limestone and dolostone (Telford et al., 1979).

2.1.3 Lockport–Amabel Formation

The Lockport-Amabel Formation, which is generally comprised of limestone and dolostone, overlies the older Clinton-Cataract Group. The name ‘Lockport’ is typically used to describe this formation in areas east of Burlington whereas the formation is commonly referred to as the ‘Amabel’ Formation to the west and north. This formation surfaces in the watershed at three points along the eastern boundary of the Grand River Watershed: i) in Amaranth Township near Laurel; ii) in a relatively large area surrounding the town of Rockwood; and, iii) in a band surrounding the Dundas Valley. This unit was deposited during the Middle Silurian period, approximately 423 million years ago.

The formation is recognized as the cap rock of the Niagara Escarpment and is much harder than the underlying shales and sandstones of the Cataract-Clinton Group and the Queenston Formation. However, despite being resistant to erosion, the formation is subject to karstification due to its surface or near-surface exposure. Karst features tend to develop over time by the dissolution of limestone (and to a lesser extent dolostone) bedrock which enhances the porosity of the bedrock, making it easier for groundwater to move though the rock. Beneath the City of Guelph, the middle portion of the Amabel Formation is heavily karstified and often referred to as the ‘Production Zone’ as it provides water for a number of the City’s supply wells.

There are several sub-members of the Lockport-Amabel formation, two of which can be found within the Grand River watershed. The Eramosa Member, which is subdivided in the Rockwood area, is composed of dark brown or black bituminous dolostone, and provides significant protection for the underlying Amabel Formation. The Goat Island Member is subdivided in the Dundas Valley and is composed of light brown dolostone (Telford et al., 1976). Overall, in its unsubdivided form, the Lockport-Amabel formation is generally composed of light brown to grey or blue grey dolostone. The Amabel Formation is a significant regional bedrock aquifer yielding large quantities of good quality groundwater in the eastern portion of the watershed.

2.1.4 Guelph Formation

Overlying the Amabel Formation, the Guelph Formation is one of the most important bedrock formations in terms of groundwater supply in the watershed. Several municipal wells for the City of Guelph and the Regional Municipality of Waterloo extract water from this bedrock unit. The Guelph Formation is the uppermost bedrock layer over a large portion of the watershed, stretching in a 30 km wide swath from Dundalk to Carluke (east of Brantford). It is middle Silurian in age, and is generally composed of brown or tan dolostone (Telford et al., 1976).

2.1.5 Salina Formation

The Salina Formation overlays the Guelph Formation and, similar to the Guelph Formation, it also underlies a large portion of the Grand River Watershed, stretching from Drayton to Dunnville. The formation, which was deposited during the Upper Silurian period, approximately 420 million years ago, is comprised of several sub-members, four of which can be found in the watershed. From east to west, these sub-members are labeled A, C, E, and F. Similar to the main geological formations, the sub-members are aligned in long parallel bands, with the geology of each sub-member differing slightly. The A sub-member of the Salina abuts the Guelph Formation and consists of tan dolomite and grey mudstone. Immediately west is the C member, consisting of grey and olive green shale containing lenses of anhydrite and gypsum. The E member generally consists of tan dolomite with lenses of anhydrite or gypsum. Finally, the westernmost F member is made up of grey and red shale containing lenses of anhydrite or gypsum (Sanford, 1969). The gypsum mines present in the Caledonia area are set within the Salina Formation. Generally, the Salina Formation has poor water quality, forcing many municipal systems in the western portion of the watershed to rely on overburden aquifers for drinking water supplies.

2.1.6 Bass Islands–Bertie Formation

The Bass Islands-Bertie Formation, which conformably overlies the Salina Formation, subcrops immediately to the west of the Salina Formation, as shown on **Map 2.1**. Although not nearly as wide in subcrop as the Guelph or Salina Formation, this formation also extends beneath a significant portion of the watershed, from Millbank south through Port Maitland. The Bass Islands-Bertie Formation, deposited during the Upper Silurian period, is generally composed of cream and tan to greyish-tan dolomite (Sanford, 1969).

2.1.7 Bois Blanc Formation

The Bois Blanc Formation unconformably overlies the Bass Islands-Bertie Formation to the west. The formation subcrops in a band roughly paralleling the western boundary of the watershed from approximately Conestogo Lake south. This unit was deposited during the Lower Devonian period, 418 to 394 million years before present, and primarily consists of grey and grayish-brown dolomite, limestone and nodular chert (Sanford, 1969).

2.1.8 Oriskany Formation

The Oriskany Formation is a unique bedrock formation found between the Bass Islands-Bertie and Bois Blanc Formations just west of Cayuga. This unit has largely been eroded from the watershed so that the upper surface represents an unconformity within the Lower Devonian period. The Oriskany Formation underlies an area of roughly 6 km^2 and consists of white or grey, fossiliferous, quartzose sandstone (Telford and Tarrant, 1975).

2.1.9 Onondaga – Amherstburg Formation

The Onondaga-Amherstburg Formation is the youngest and westernmost bedrock formation that can be found in the watershed, although present in only two locations, in the County of Perth and along the western boundary of the watershed west of Dunnville. The Onondaga-Amherstburg Formation was deposited during the Middle Devonian period, 394 to 382 million years ago. The formation is primarily composed of fossiliferous limestone, which is variably cherty and includes some shale (Telford and Tarrant, 1975).

2.1.10 Bedrock Surface

The bedrock surface, and in particular areas of low elevation, can be very important from a hydrogeological perspective. If these depressions are partially infilled with either coarser grained deposits or finer grained deposits with sufficiently high transmissivity, they can behave as high-yielding aquifers. Buried bedrock valleys, which are likely pre-glacial erosional features, are an important feature within the Grand River Watershed. These features not only provide important targets for municipal groundwater exploration, but can also serve as conduits to transport groundwater between subwatersheds and surrounding watersheds. These deeper aquifers are advantageous as municipal water supplies since their depth tends to provide protection from surficial contamination, separating them from surface water, and limit interference from other pumping wells. Overall, these aquifers are therefore often more reliable and less prone to degraded water quality.

Map 2.2, which was developed by Holysh et al. (2001), shows the bedrock surface for the watershed with interpreted buried bedrock valley thalwegs. The highest bedrock elevations of approximately 525 masl are located in the northern extents of the watershed coincident with the 'Dundalk Dome' to the north, one of the highest bedrock elevations in southern Ontario. From the north, the bedrock surface slopes uniformly to the south and Lake Erie.

Bedrock features within the Grand River Watershed include the Dundas Buried Bedrock Valley, the Rockwood Valley and the Onondaga Escarpment. The Dundas Valley, aside from having some of the lowest bedrock surface elevations in the watershed, is a buried bedrock valley with little to no surface expression. The valley trends east-west from Hamilton Harbour towards Brantford, turns northwards within the Salina Formation, then trends to the west through Wellesley within the north Waterloo area. The valley is thought to be a pre-glacial drainage system incised into the bedrock that has been subsequently infilled with glacially-derived sediments. The Rockwood Valley is also a buried bedrock valley system with no surface expression, potentially a tributary to the Dundas Valley, which trends northeast-southwest from the Rockwood area to the northwest of Guelph, emerging within the Eramosa River Valley. The Onondaga Escarpment is a feature which has created a margin of exposed Paleozoic bedrock along the southwestern edge of the watershed, near Cayuga. The Escarpment extends from Buffalo and trends along the west side of the watershed, south of Brantford. The Bois Blanc Formation forms the cap rock; the escarpment was formed as a result of differential erosion between the harder cap rock and the underlying, softer Salina Formation. The escarpment resulting from the differential erosion is found along the Salina Formation extending to Lake Huron.

2.2 Quaternary Geology

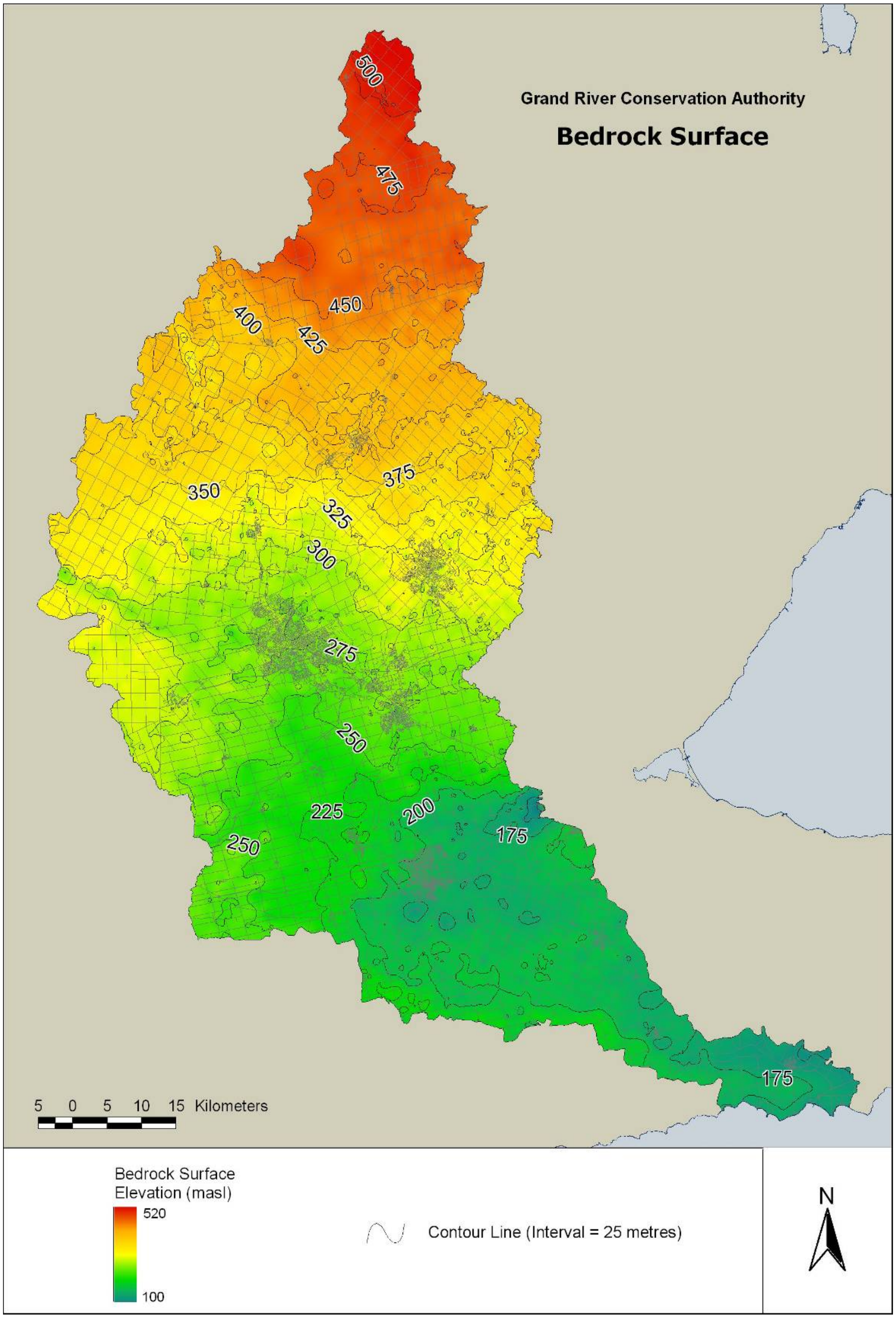
The understanding and interpretation of the Quaternary geology of the Grand River watershed is largely confined to the Late Wisconsinan time period, which began around 25,000 years ago. Prior to this time the geological record within the watershed is vague; however, it is known that Early and Middle Wisconsinan sediments and even pre-Wisconsinan sediments might underlie parts of the watershed.

Map 2.3 shows the Quaternary geology of the watershed. The surficial overburden in the watershed can be divided into three general areas:

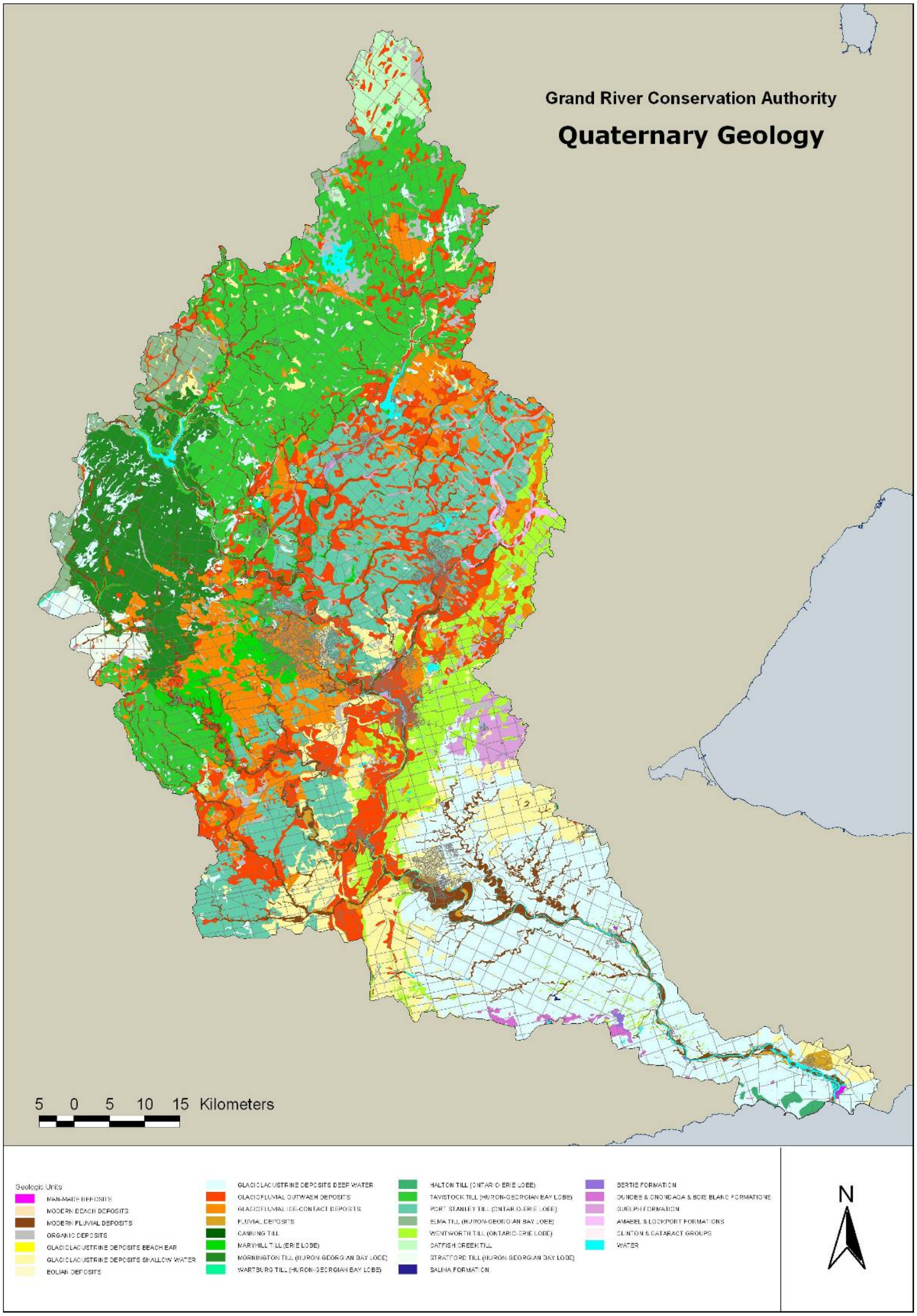
- The northern portion of the watershed which largely consists of till plains with varying relief and lower permeability;
- The central portion of the watershed which is characterized by sand and gravel kame moraines and recessional moraines with moderately high relief and higher permeability;
- The southern portion of the watershed which is comprised of lacustrine clay plains with lower permeability and low relief.

Surficial geology plays a crucial role in the hydrologic and hydrogeologic characteristics of the watershed. Deposits of clay and till, as found in the northern and southern extents of the watershed, form relatively impermeable barriers to the infiltration of water, and as a result, runoff to nearby watercourses is increased.

Map 2.2: Bedrock Surface of the Grand River Watershed



Map 2.3: Quaternary Geology of the Grand River Watershed



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Glacial moraines and drumlins, located in the central portion of the watershed, often allow for high levels of infiltration through permeable sand and gravel deposits. Groundwater recharge then occurs when surface water percolates down through soils to reach the water table. These areas of higher permeability however, although very important to groundwater recharge, also increase the vulnerability of the groundwater sources beneath them to contamination carried down by surface water.

The most recent glacial history of southern Ontario can be summarized as three episodes of glaciation, the Nissouri, Port Bruce, and Port Huron Stadial events, separated by three ice-free periods, the Erie, Mackinaw and the current interstadial events. Numerous surficial landforms were deposited within the Grand River Watershed with each stadial and interstadial event.

The first widely recognized Late Wisconsinan event is associated with the Nissouri Stadial ice advance about 20,000 years ago (Karrow, 1993). Catfish Creek Till, which is believed to generally underlie the entire Grand River Watershed, is representative of the Nissouri Stadial. It is often used as a stratigraphic marker bed as a result of its overall consistency in composition (Barnett, 1992). During the Nissouri Stadial, thick ice spread over the entire southwestern Ontario area and into the northern United States as far south as Ohio. The ice advance was quite strong and was believed to have progressed unimpeded by any of the subtle topographical features in southern Ontario. Approximately 18,000 years ago, the ice began to retreat from Ohio, and 16,000 years ago the glacier covering southern Ontario was believed to have split along a line from the Kitchener-Waterloo area to northeast of Orangeville (Sibul et al., 1980). Where the ice lobes broke apart, the low areas between the separating ice lobes became the focus for sediment-laden meltwaters. Over time, as the meltwaters flowed into these low areas, large deposits of sands and gravels built up and subsequently formed interlobate moraines. Upon full retreat of the ice, these deposits remained behind as topographical highs. Initial deposition of the Waterloo and Orangeville interlobate moraine complexes were thought to have taken place at this time (Sibul et al., 1980). As the ice retreated, meltwaters flowed across the area, resulting in extensive glaciofluvial deposits and numerous small lakes and ponds were formed on the surface of the Catfish Creek till.

Within the Grand River watershed, subsequent glaciation and the resulting sediment deposition occurred as a result of the advance of three ice lobes: the Georgian Bay lobe, the Huron lobe, and the Lake Erie-Ontario lobe. The lobes were centered in the lows provided by the Great Lake basins and advanced out of, and retreated back into these basins. A strong re-advancement of ice during the Port Bruce Stadial, about 15, 000 years ago, resulted in the deposition of the Maryhill Till and later the Port Stanley Till by the Erie-Ontario lobe which advanced from the south. The Guelph Drumlin field was also formed at this time. At the same time, the Huron-Georgian Bay lobe advanced from the north and deposited the Stirton Till followed by the Tavistock Till. Local short-lived re-advancements of the retreating Huron and Georgian Bay lobes resulted in the deposition of the Mornington Till, the Stratford Till, and the Wartburg Till. A stronger re-advancement about 14,500 years ago, resulted in the deposition of the Elma Till (Sibul et al., 1980).

Retreat of the ice during the late Port Bruce Stadial resulted in extensive kame and outwash deposits throughout the central parts of the watershed. The Waterloo, Elmira, Easthope and Orangeville Moraine complexes were either further built upon or created at this time. Meltwaters flowing to the south created a complex of outwash channels, now occupied by many present day streams. These channels are commonly filled with coarser grained sediments. A series of terminal moraines (and associated kame and outwash deposits) are found to the southwest of Brantford marking the retreat of the Lake Ontario/Erie ice lobe. At the time of the Mackinaw Interstadial, about 13,300 years ago, the entire Grand River Watershed was ice free.

The Port Huron Stadial, which began approximately 13,000 years ago, marked an advancement of ice back into the Grand River Watershed, however at this time, ice only advanced from the Lake Ontario/Erie lobe. The Wentworth Till was deposited at this time as the ice advanced to the Paris Moraine. During the recession of the Port Huron ice, ice contact sediments were again laid down, further building the Paris and Galt Moraine systems.

With the final retreat of ice from the Grand River Watershed, Lake Whittlesey was created. A series of large glacial lakes continued to occupy the Lake Erie basin until about 12,000 years ago, when the present day drainage system was created. In the Brantford and Paris areas, shallow water deltaic sediments were deposited closer to the shoreline of Lake Whittlesey. In contrast, the deep water clay and silt sediments south and east of Brantford, were deposited in the basin at the time of the deeper Lake Warren II. At this time, Halton ice advanced out of the Lake Ontario basin (east of the watershed) thus preventing the escape of meltwaters from the Lake Erie basin.

Since the final glacial retreat from southwestern Ontario, the present day stream system has eroded through the pre-existing surficial geology to create the current landscape. The retreat also resulted in the formation of major moraines within the Grand River Watershed.

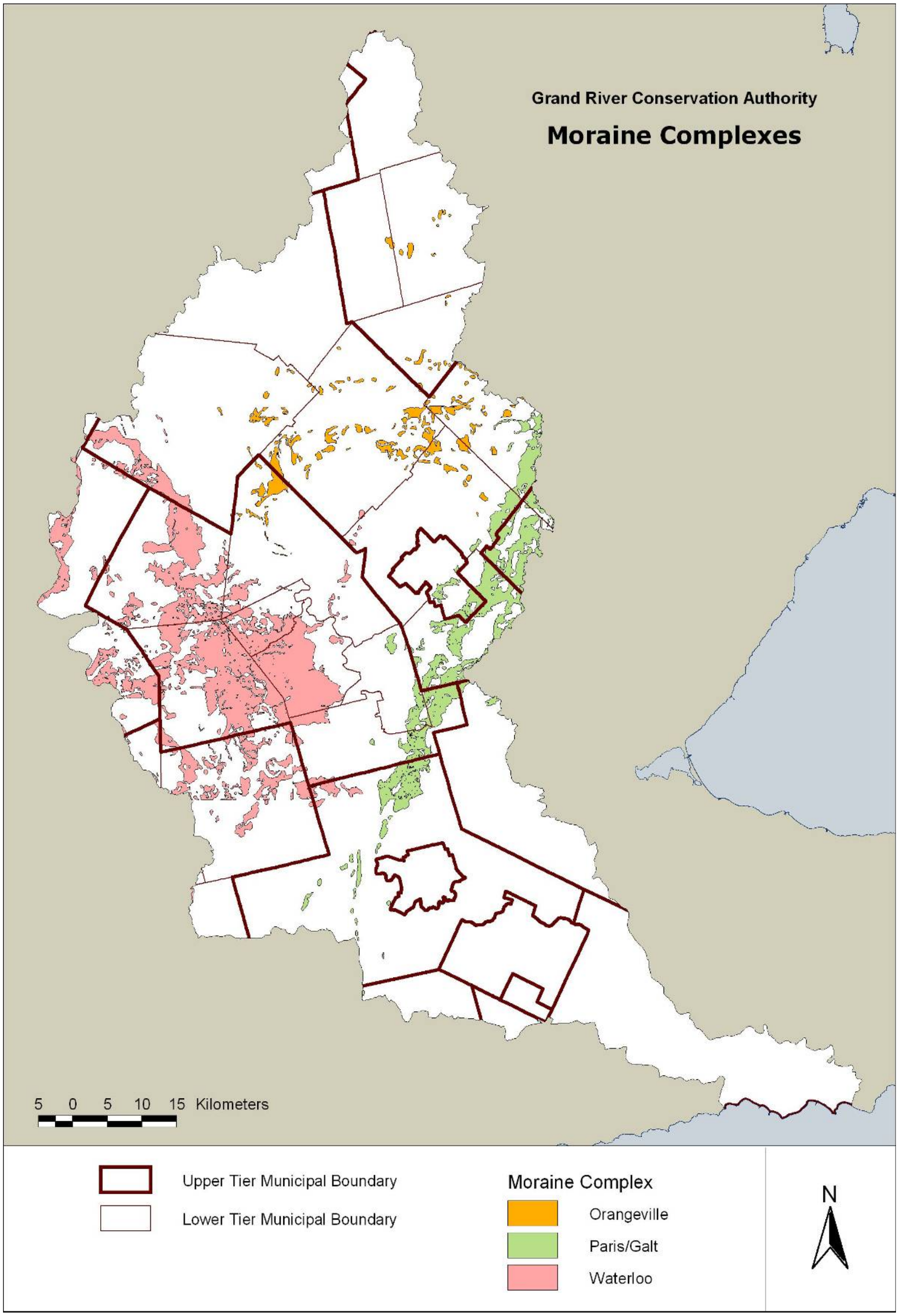
The Grand River Integrated Water Budget Report has identified moraines as the predominant physiographic features within the central part of the watershed (AquaResource, 2006). Fourteen unique moraines have been identified within the central portion of the watershed, characterized as higher permeability, moderate to high relief kame & kettle moraines and recessional moraines:

- Macton Moraine
- Elmira Moraine
- Orangeville Moraine
- Paris Moraine
- Galt Moraine
- Chesterfield Moraine
- Ingersoll Moraine
- Moffat Moraine
- Milverton Moraine
- Breslau Moraine
- Easthope Moraine
- Waterloo Moraine
- Norwich Moraine
- Tillsonburg Moraine

These 14 unique features have been grouped into 3 moraine areas by the GRCA, as is shown on **Map 2.4** (Orangeville, Paris/Galt, and Waterloo Moraines). By definition, a moraine is an accumulation glacially deposited materials that are predominantly coarse-grained. Due to the irregular and inconsistent movement and depositional characteristics of glaciers, the 14 moraines across the watershed have very unique geologic and physiographic qualities. However, they generally share the characteristics of having higher permeability soils, hummocky terrain, and closed depressions (kettle lakes), supporting high recharge rates and often supporting significant overburden aquifers.

Moraines provide numerous ecological functions. The vegetated portions of moraines support habitats for rare plants, animals and vegetation communities, and act as a breeding area for amphibians and waterfowl. Headwaters of watersheds also originate in a moraine because of their height and groundwater discharged from moraines typically sustains wetlands around its perimeters.

Map 2.4: Moraines in the Grand River Watershed



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In Aqua Resource's latest draft of the Integrated Water Budget Report, the 14 unique moraines have been generalized into four moraine assessment areas as shown on **Map 2.5** and summarized below:

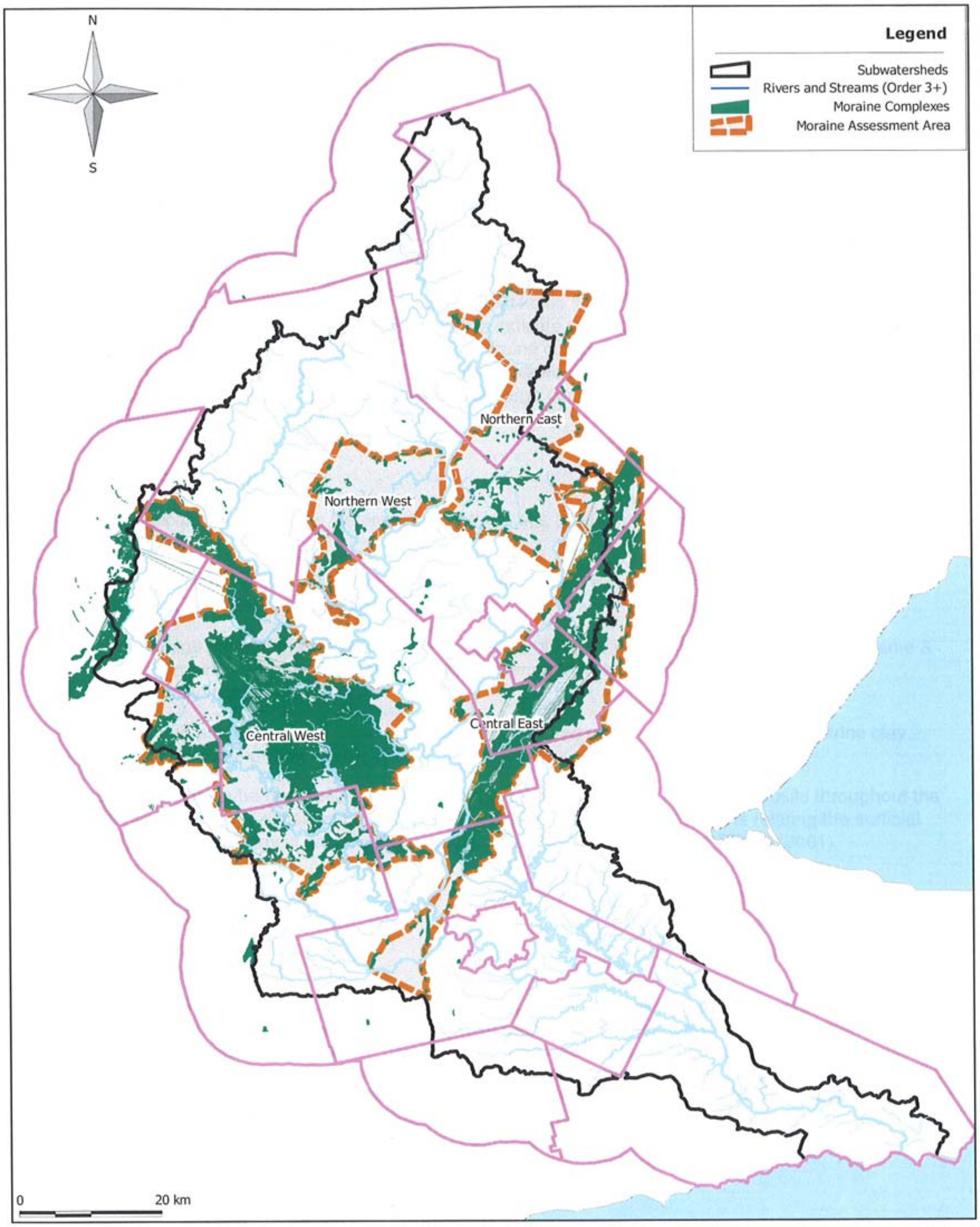
- **Central West Moraine Assessment Area**. The Central West Assessment area encompasses a significant area in the western portion of the Grand River watershed. The primary moraine structure within this assessment area is the Waterloo Moraine which is the largest moraine in the watershed. This moraine is referred to as an Interlobate Moraine (Chapman and Putnam, 1984) formed by the separation of the Georgian Bay and Ontario ice lobes. It contains a series of large aquifers which discharge to and maintain the base flow for the Grand River, Nith River and many of their tributaries. These aquifers are also the source for approximately 50 percent of all the groundwater used within the Region of Waterloo water supply system. In some places, the deposits within the Waterloo Moraine are 120 metres thick. This assessment area has been extended to include the Macton and Milverton moraines.

- **Northern East Moraine Assessment Area.** The predominant feature within the Northern East Moraine Assessment area is the Orangeville Moraine which is found on the east side of Belwood Lake, and extends to the west side of Orangeville, in the upper reaches of the Speed River. Similar to the Waterloo Moraine, this moraine was built between the Ontario and Georgian Bay Ice Lobes, but most of the deposits are considered to be provided by the Ontario Lobe (Chapman and Putnam, 1984). The Moraine is composed of ice contact and stratified drift, which is comprised of sand and/or gravel. It is a highly permeable feature and acts as a significant recharge area.

- **Northern West Moraine Assessment Area**. The predominant feature within the Northern West Moraine Assessment area is the Elmira Moraine which is located on the western side of the Grand River, predominately in the Elmira area. The Elmira Moraine shares many of the characteristics as the Orangeville Moraine. It is composed of ice contact and stratified drift, with significant deposits of sand and/or gravel. It is a highly permeable feature and acts as a significant recharge area.

- **Central East Moraine Assessment Area**. The main moraine features contained within the Central East Moraine Assessment area are the Paris/Galt Moraines, which were created by the scouring action of the Ontario ice lobe. The Paris Moraine crosses the watershed from east to west from the headwaters of Mill Creek (east of Aberfoyle), through Cambridge and South to Paris and Burford along the west side of the Grand River. The Galt Moraine lies just south of the Paris Moraine and forms the southern edge of the Mill Creek subwatershed before following the east side of the Grand River through St. George and Brantford. These moraines are evident as broad topographic ridges with irregular, hummocky topography and numerous closed depressions and kettle lakes. The moraines are composed of Wentworth Till (Karrow 1987) although well logs indicate significant but discontinuous sand and gravel deposits are present. Also part of this moraine complex is the Moffat Moraine, which is found along the eastern extent of the watershed in the Rockwood / Acton area. Collectively these moraine features are considered to provide important recharge contributions to the local and regional aquifer systems.

Map 2.5: Moraine Assessment Areas in the Grand River Watershed



2.3 Physiographic Regions

Physiography plays an important role in the hydrologic and hydrogeologic systems within the Grand River Watershed. In total, there are 11 physiographic regions within the Grand River Watershed, which are described by Chapman and Putnam (1984). The regions are described below, from north to south, and shown in **Map 2.6**

2.3.1 Dundalk Till Plain

The Dundalk Till Plain, generally located north of County Road 109, is a major headwater area for the Grand and Conestogo Rivers. It includes most of Dufferin County and portions of the Townships of Wellington North and Mapleton.

The till plain is gently undulating, and consists of a mix of clay, gravel and boulders deposited by retreating glaciers. Elevations within the till plain range from 425 masl to 530 masl.

The till plain supports extensive wetland complexes, wet meadows, and agricultural land in four major source areas: Dundalk, Melancthon, Amaranth, and Keldon. An extensive network of agricultural drains and small watercourses which link the numerous wetlands drain the till plain.

Two large eskers and a series of small drumlins, which are located at the northwest boundary of the watershed, add considerable diversity to the habitat of the till plain. The western esker runs through the Keldon Swamp southeasterly to the north bog at Luther Marsh Wildlife Management Area.

Luther Marsh is a 5,679 ha complex of bog, marsh, mixed deciduous-coniferous swamp, upland deciduous forest, plantation, meadow and agricultural fields. The Luther Dam has created a lake-wetland area of about 2,000 ha.

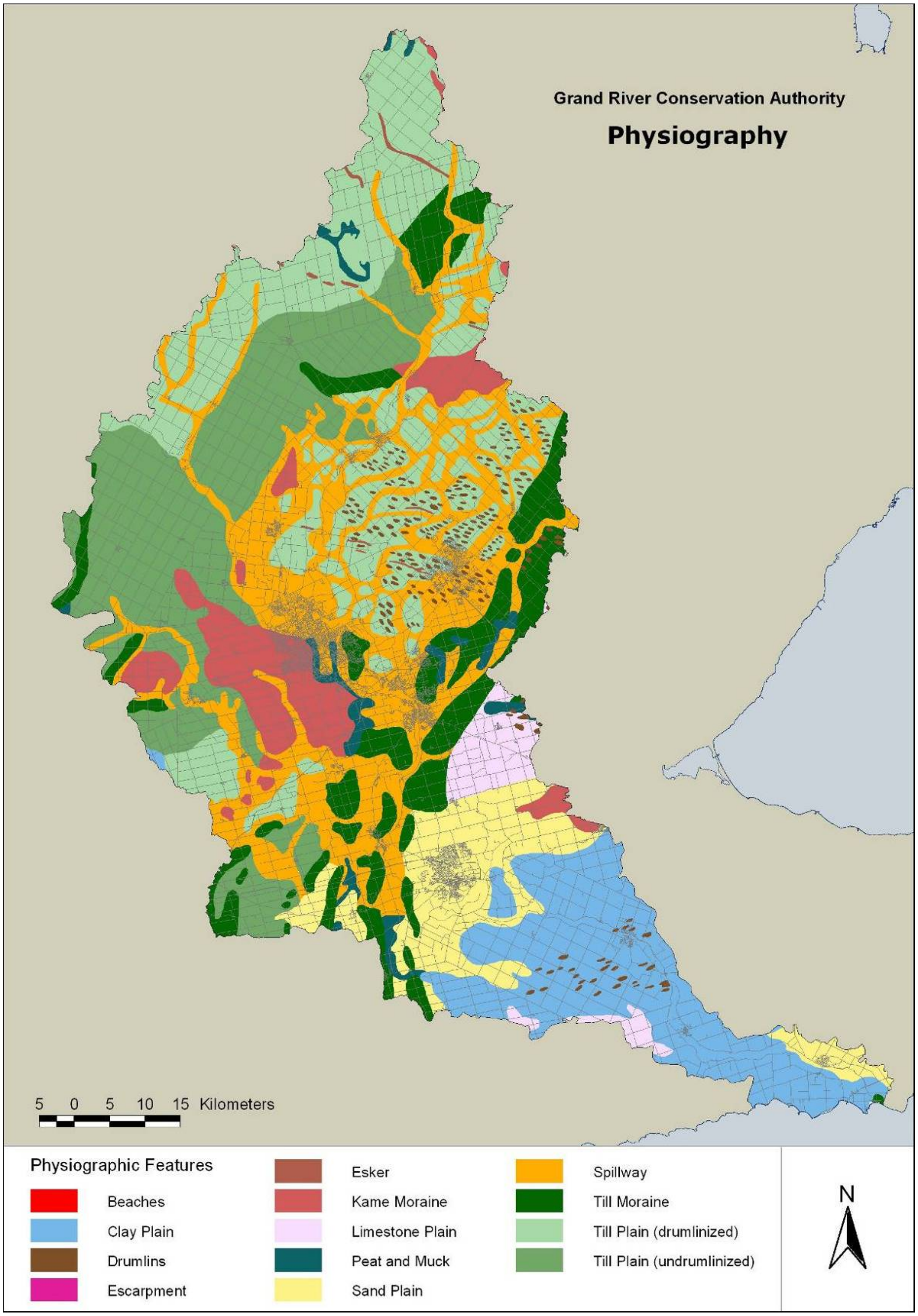
The well-vegetated Horseshoe Moraine and Niagara Escarpment physiographic regions border the till plain on its east side. There is a noticeable transition from scarce natural vegetative cover along the west side of the till plain to extensive cover in the east.

2.3.2 Stratford Till Plain

The Stratford Till Plain is located to the south of the Dundalk Till Plain and includes parts of Dufferin County, Wellington County, Waterloo Region and Perth County. This flat clay plain is wedge-shaped with its broadest sector in the west, between New Hamburg, Millbank and County Road 109. The point is in the east, between Belwood and County Road 109. The terrain, which is generally level and often poorly drained, is characterized by silty clay-rich soils. Artificial drainage has made this a rich and productive agricultural region and, as a consequence, only a small portion of the land remains unimproved in woodlot, marsh or rough pasture.

Natural vegetative cover is more extensive in the east. The valleys of the Conestogo, Irvine and Grand Rivers are deeply cut through the till plain. The headwater area of the Nith River, in the western sector, is very open and there is little wildlife habitat. Slightly better, covered drainage ditches and small watercourses are located to the east, in the northerly source area for the Speed River.

Map 2.6: Physiographic regions in the Grand River Watershed



Chapman, L.J. and Putnam D.F. 1984: Physiography of Southern Ontario; Ontario Geological Survey, Map P.2715 (coloured). Scale 1:600 000.

Conestogo Lake and the river's valley lands in the Drayton area have the most extensive habitat. Between Glen Allen and Wallenstein, along the Conestogo River, there is a diverse valley forest accompanied by floodplain meadows.

2.3.3 Hillsburg Sandhills

In the Township of East Garafraxa and the Town of Erin, the Hillsburg Sandhills form a natural boundary on the southeastern flank of the Dundalk and Stratford Till Plains. The sandhills have a minimum elevation of 425 masl with some ridges reaching elevations of 490 masl.

This region is characterized by rough topography, sandy soils and swampy valleys. Agricultural use is limited due to topographical and drainage factors. The region is approximately 30% forested and much of the forest is composed of provincially significant swamps located in the valleys between the hills.

2.3.4 Guelph Drumlin Field

The watersheds of the Speed and Eramosa Rivers lie within Guelph Drumlin Field which also includes the City of Guelph and parts of Wellington County and Waterloo Region. In this region there are approximately 300 drumlins, which are characterized as broad, oval shaped hills with low slopes.

The general landform pattern in the Guelph Drumlin Field consists of drumlins or groups of drumlins fringed by gravel terraces and separated by swampy valleys. Tributaries of the Grand River flow through these valleys. The dominant soil materials are the stony tills of the drumlins and deep gravel terraces.

This region has the most extensive network of forest habitat in the watershed. Large forests typically cover the valleys between the numerous hills and drumlins. The areas of lowest elevation are swamp and floodplain.

At the northwest corner of the drumlin field, in the Lutteral Creek watershed, there is swamp-upland forest known as the Speedside Forest. The Ariss woods are located on a significant esker and have importance due to size and botanical features. The Eramosa River Valley follows a lengthy glacial spillway from Brisbane to Guelph. The Brisbane Swamp, which is a major headwater area for the river, and the upper river valley, above Ospringe, are within the drumlin field. From Ospringe, the Eramosa River flows through the Horseshoe Moraine physiographic region to its confluence with the Speed River.

2.3.5 Horseshoe Moraine

As the name suggests, the Horseshoe Moraine region consists of a series of moraines surrounding much of southwestern Ontario. The "toe" of the horseshoe is at the north, near Georgian Bay. The moraines run roughly parallel to the Lake Huron shoreline on the west, Georgian Bay along the north and the Niagara Escarpment to the east.

The eastern leg of the horseshoe runs along the eastern boundary and through the central part of the Grand River Watershed, from the Town of Erin in the north, past Guelph and Cambridge to Paris and Brantford in the south.

Some of this region is very hilly, often with steep irregular slopes and small enclosed basins which contain water in the spring and early summer, often referred to as kettles.

Two large moraines dominate the Horseshoe Moraine region: the Paris and Galt moraines.

The Paris Moraine runs from Erin to Paris and then through the southwestern part of Brant County. South of Paris, the surface is sandy and to the north it consists of loose bouldery loam. Broad gravel terraces, often at one or more levels, with swampy stretches in the lowest one, can be traced along the length of the Paris Moraine. For part of its length, the moraine provides a channel for the Eramosa River.

The Galt Moraine runs parallel to and east of the Paris Moraine, never more than a few kilometres away and touching it in some places, such as near the City of Guelph. The soils are quite similar to the Paris Moraine as well: sandier in the region south of Brantford, and loose loamy till north of Brantford.

The Horseshoe Moraine region of the Grand River Watershed has large sand and gravel deposits with many extraction operations in southern Wellington County, southern Waterloo Region and northern Brant County.

The Horseshoe Moraine region is a very dynamic area and provides extensive habitat, including 5,000 ha of wetlands. Approximately 30% of the moraine region is forested, field sizes are slightly smaller, and fencerow vegetation is often very well developed. The region hosts a number of cold-water watercourses, including the Eramosa River and Mill Creek, which are fed by groundwater. Groundwater discharge also feeds the Grand River itself, between Cambridge and Paris, providing a significant share of its flow during summer months.

Groundwater discharge also affects soil formation and causes wetland development on steep slopes.

2.3.6 Waterloo Hills

The Waterloo Hills region is located within the centre of the watershed, mostly within the Regional Municipality of Waterloo. This area has the greater portion of the watershed population and urban development.

This area is characterized by sand hills, gravel terraces and many swampy valleys. The soils of the hilly areas are rich and well drained.

Water from precipitation infiltrates in the sand hills and discharges as groundwater to the headwater wetlands and source areas of the streams, creating fens, bogs, kettle lakes, swamps, marshes and baseflow in streams.

The Grand River has cut its valley in a north-south direction through the eastern half of the region, and two of its major tributaries, the Conestogo and Speed, converge on the Grand in this area.

2.3.7 Flamborough Plain

The western side of the former Township of Beverly (now part of the City of Hamilton) lies within the Flamborough Plain. Shallow soils over bedrock in the Sheffield-Rockton area create areas of swamps, marshes and bedrock outcrops. Soils are either wet or stony and shallow. The west end of the Beverly Swamp and the headwater area of Fairchild Creek are located in this region.

The 2000 ha Beverly Swamp is the third largest remaining interior wetland in Southern Ontario. There are relatively flat exposed bedrock plains in the Kirkwall-Rockton area.

2.3.8 Norfolk Sand Plain

The portion of the Norfolk Sand Plain in the Grand River watershed covers parts of Brant and Oxford Counties. The sands and silts of this region were deposited as a delta of the ancient Grand River when water from melting glaciers made its way south.

There are two parts in this plain region, one being west of the southern Horseshoe Moraine region, the other to the east.

The western portion covers the watershed from Ayr to Princeton and southerly to the watershed boundary in the vicinity of Scotland and Oakland. The western leg of the sand plain is drained by Whiteman's Creek, which joins the Grand River near Brantford. There are also large wetlands near Falkland, Oakland and Burford. The headwaters of McKenzie Creek and Boston Creek are in this region.

Fairchild Creek and Big Creek drain the eastern portion of the Norfolk Sand Plain region, in the Peter's Corners, Ancaster and Cainsville area. Wetlands in the Fairchild Creek watershed complex are important to this region. Most natural areas are small, fragmented and narrowly sinuous along streams and steep slopes.

2.3.9 Oxford Till Plain

The Oxford Till Plain is located in the Plattsville, Drumbo, Princeton, Woodstock area and is a source area for Black Creek and Whiteman-Horner Creek.

All of the blocks of natural habitat of any significant size are wetlands in this region. The Black Creek complex drains to the Nith River. The upper Whiteman's Creek complex has a number of wetlands within it which are provincially significant. They include Chesney Bog, Pine Pond, Lockart Pond, Buchanan Lake, and Benwall Swamp. Soils and drainage in this region are considered to be good.

2.3.10 Mount Elgin Ridges

The Kenny Creek watershed is located in this northeastern tip of the Mount Elgin Ridges region which covers parts of Oxford and Brant Counties within the Grand River Watershed. The landscape is dominated by a succession of ridges composed of imperfectly drained clay or silty clay and hollows supporting alluvial swamps, along with deposits of sand and silt. The wetlands of the Kenny Creek watershed, which are mainly riparian swamps, are provincially significant and the creek supports a warm water fishery.

2.3.11 Haldimand Clay Plain

The lower Grand River watershed, southeast of a line through Alberton, Onondaga, and Bealton, is within the Haldimand Clay Plain region. The Grand River has cut a deep valley into the clay and silt below Brantford. Soils tend to be clay-rich and are poorly drained in places. There are however, some siltier and better drained soils in the Caledonia area and south of the Grand River.

The river corridor is well developed with extensive marshes, floodplain meadows, oak savannahs, woodlands, and willow lined riverbanks, between the roads that parallel the river.

The Six Nations and New Credit Indian Reserves have almost 50% forest cover. Other large forested areas of importance are the North Cayuga slough forest, the Oriskany Sandstone woodland and Dry Lake wetland complex, the Taquanyah wetland complex, the lower Grand River marshes, the Dunnville northwest woodland and wetland complex, and the Mount Healy woods.

2.4 Natural Features

2.4.1 Forest and Vegetation Cover

Forest and vegetation cover are important factors in overall watershed health. In particular, increased forest and vegetation cover greatly reduces soil erosion and surface water runoff, which are often significant sources of contamination in streams, rivers and lakes. These areas contribute to improved water quality and quantity by slowing erosion and runoff, increasing evapotranspiration, increasing groundwater infiltration and uptake of nutrients and other contaminants. Reduced erosion and runoff translates into fewer contaminants and sediments entering surface waters.

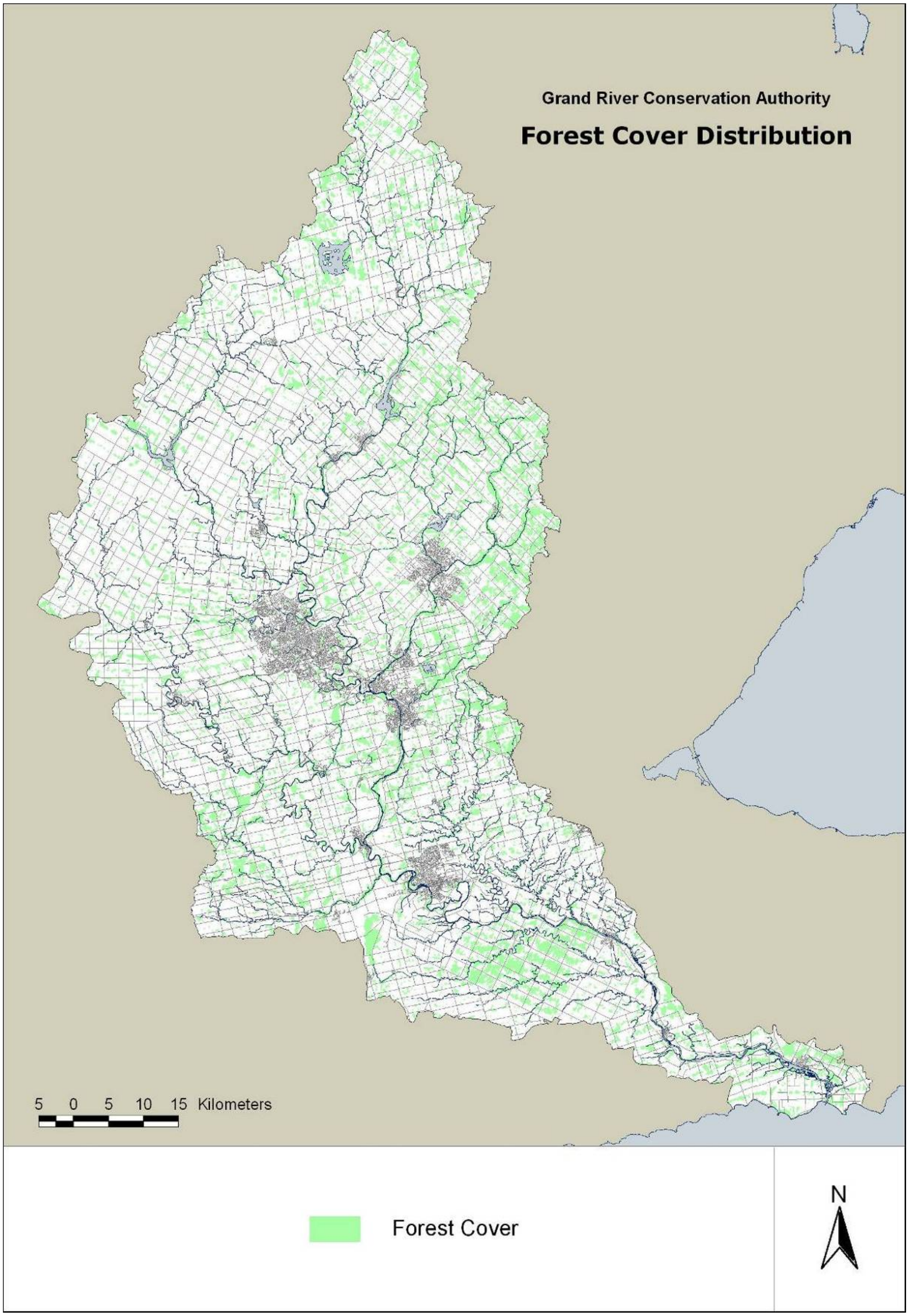
As determined from **Map 2.7**, forested areas in the Grand River watershed make up approximately 19 percent of the total land cover. A minimum forest cover of 30 percent is advocated by Environment Canada to be necessary to sustain the health of a watershed.

The Carolinian Forest type reaches its northern limit in the Grand River watershed in the area of the City of Cambridge. In general, this forest type is dominated by sugar maple and beech along with basswood, silver maple, and several species of oak. Other less prominent species include several species of elm, ash and hickory, black cherry, and yellow birch. Numerous characteristic plants and animals, having a broad distribution southward, reach their northern limit in the southern half of the watershed. Among these are several trees, including the hickories, sycamore, sassafras, black oak, Chinquapin and dwarf Chinquapin oaks, and (formerly) American chestnut (Watershed Forest Plan, 2004).

In the northern half of the watershed, the Great Lakes–St. Lawrence Forest predominates, containing eastern hemlock, white pine and eastern white cedar. In addition, balsam fir, white spruce and white birches reach their southern limit in this zone. In some of the upper reaches of the watershed, cool hollows of wetland vegetation similar to the muskeg of the Boreal forest can be found. The characteristic tree species of these sites is black spruce (Watershed Forest Plan, 2004).

In the watershed, there are no known examples of large areas untouched by human activities. There are, however, many areas where the trees are older than 100 years.

Map 2.7: Forest Cover in the Grand River Watershed



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Recent studies have discovered several eastern white cedars over 400 years old on the cliffs of Elora, Rockwood and Everton, and some over 500 years old, representing the oldest known trees in the watershed.

There are many woodlands that exhibit old growth characteristics in the watershed, but with the possible exception of the cliffs, there are probably no 'virgin' forests. In addition, only a handful of forests in the watershed are larger than the 400 hectares deemed necessary for significant interior habitat. Throughout the watershed many stands of trees, wetlands and other natural landscape features have been converted for housing, industry, agriculture and recreation. Summer logging, land grading, and artificial land drainage have impacted remaining woodlots (Grand River Conservation Authority, 1998).

There is currently a high edge-to-interior ratio in forests of the Grand watershed. Conditions are far from ideal in most parts of the landscape for species that require forest interior habitat.

Some of the main issues threatening forests in the watershed include invasive species and disease; urbanization; climate change; and pollution. As part of the Grand Strategy, the GRCA, in partnership with local stakeholders and the public, completed a forest management plan in 2004 entitled *A Watershed Forest Plan for the Grand River* to help develop a plan to deal with these issues on a watershed scale.

The management of the Grand River watershed's forests is a difficult task, considering that forest cover is dictated by private landowners and their communities. A comprehensive management plan requires the cooperation of all stakeholders.

As a first step in the development of the plan, a stakeholder group came together in 1998 to develop a reference guide with suggested actions for improving the Grand River watershed forest. The plan stresses best management practices and offers targets to work toward, including:

- Improving the integrity of the forest;
- Increasing forest coverage; and
- Improving social and economic benefits from the forest;

A key purpose of the plan is to foster dialogue within the community related to forest management, as well as increasing awareness of the watershed forest and related issues and opportunities. The document would also serve as a foundation and reference for efforts and funding proposals of those taking action to improve the watershed forest (Watershed Forest Plan, 2004).

Recent trends indicate that forest cover is improving in many parts of the watershed. Historical practices such as pasturing in woodlands is virtually non-existent today, and during the past three decades many floodplain pastures have been abandoned and reforested, or now offer opportunities for forest restoration. This general trend away from livestock grazing in forests and floodplains may in fact be one of the most far-reaching influences on the current state of the watershed landscape.

Additional programs and projects occurring throughout the watershed to improve forest and vegetation cover include:

- A GRCA pilot project near Dunnville on the south end of the watershed to restore sensitive pit and mound forest microtopography, which has the potential to dramatically improve infiltration of precipitation and snow cover to groundwater aquifers;

- A City of Guelph project to reforest land over the Arkell Springs to protect the aquifer, increase infiltration and reduce runoff; and

- As mentioned in the previous section, the protection of environmentally sensitive landscapes, including existing forest and vegetation cover under the Region of Waterloo's ESL designation.

This progress will translate into continued and expanding protection of water quality in streams, rivers and wetlands by providing a natural buffer that reduces contaminants from entering the water courses. Reduction in common pollutants associated with urban and rural runoff, including phosphorus, nitrogen and suspended sediments will improve the quality of both surface and groundwater drinking water sources.

2.4.2 Wetlands

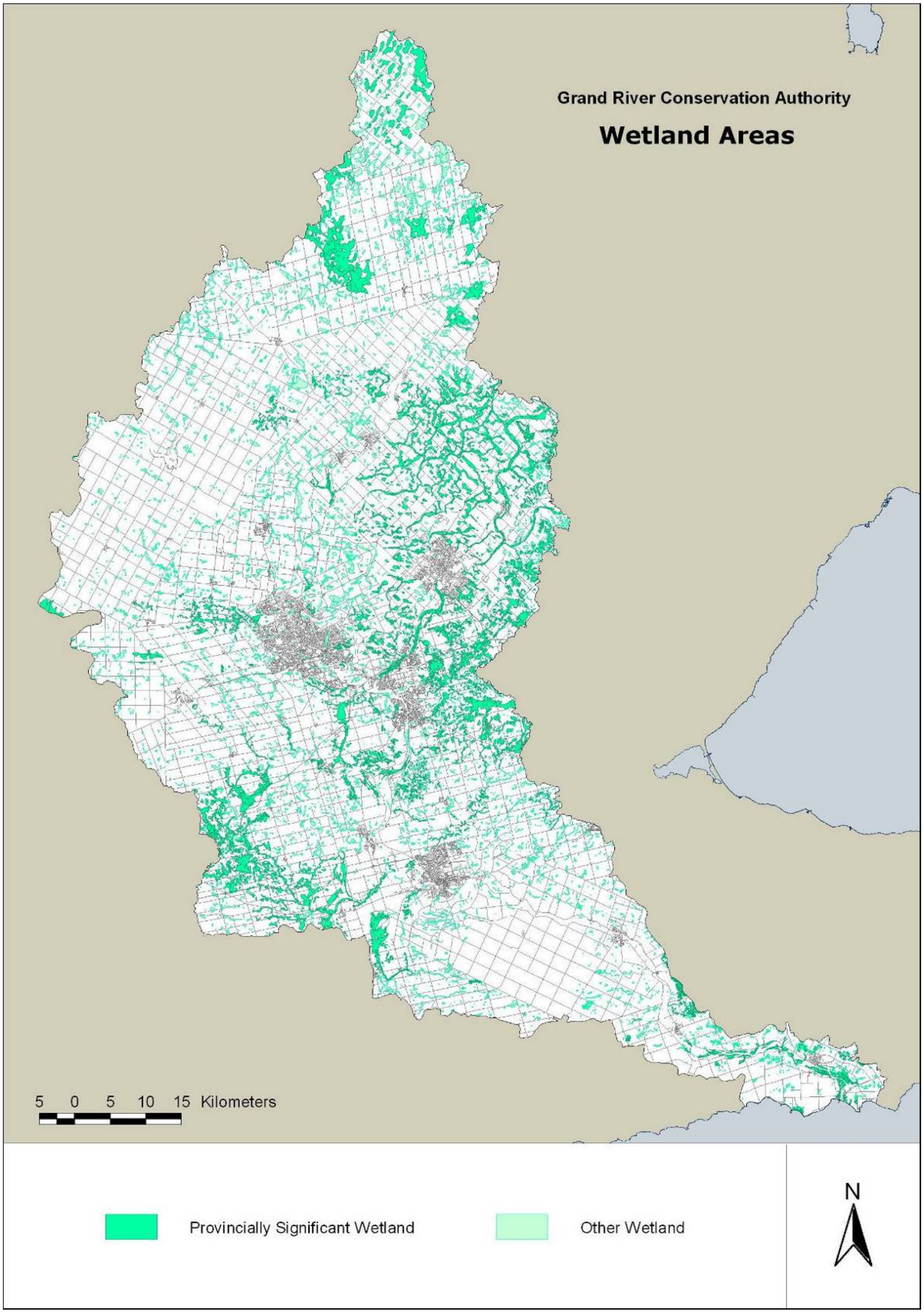
Wetlands are a significant landscape feature in terms of providing habitat to a diverse range of species, as well as providing moderation to surface water flow by absorbing surface water runoff and releasing it slowly. This process acts as a filter and can reduce contamination reaching downstream surface and groundwater sources, thereby improving water quality and drinking water sources.

Wetlands often contribute to groundwater recharge, especially in areas of permeable soils (gravel, sand or loam). Where groundwater is used for drinking water or other uses, these wetland recharge areas can play a significant role in enhancing groundwater resources. However, contamination of the wetlands and upstream water can lead to contamination of groundwater sources, as wetlands recharging groundwater provide a direct conduit to aquifers.

Wetlands can also be areas of groundwater discharge, where aquifers located close to the surface release water. These are significant areas for habitat creation and species diversity, and can moderate surface water flow conditions and temperatures of streams and rivers that drain wetlands.

However, within the Grand River watershed, over 65 percent of historical wetlands have been lost. In some areas of the watershed this exceeds 85 percent. A minimum of ten percent wetland coverage within a watershed is thought to be required to indicate a healthy watershed. Overall wetland coverage in the Grand River watershed meets this goal. However, in over half of the subwatersheds the percentage of existing wetlands is significantly lower, indicating considerable regional variation in wetland loss from one sub-watershed to another. **Map 2.8** shows the distribution of wetlands throughout the Grand River watershed.

Map 2.8: Distribution of Wetlands in the Grand River Watershed



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Despite the historical loss of these areas, there are many significant wetland complexes found throughout the watershed, including:

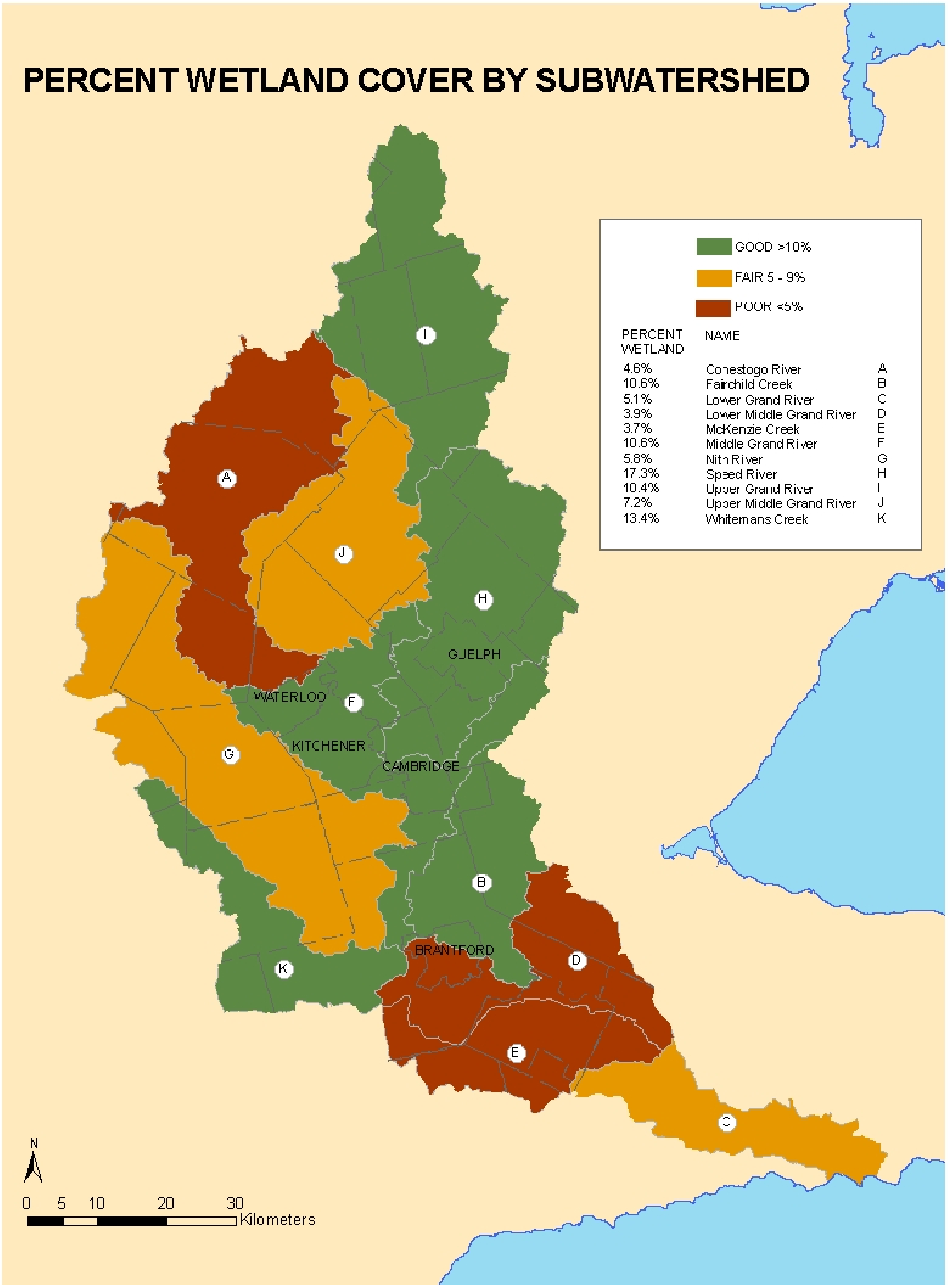
- Luther Marsh – covering approximately 3,000 hectares in the Dundalk Till Plain at the headwaters of the Grand River;
- Brisbane Swamp – a major headwater for the Eramosa River in the Guelph Drumlin Field;
- Horseshoe Moraine – over 5,000 hectares of groundwater fed wetlands;
- Beverly Swamp – at approximately 2,000 hectares, it is the third largest remaining interior wetland in Southern Ontario in the southeast portion of the watershed;
- Keldon Source Area in the north;
- Amaranth Source Area in Dufferin County;
- Roseville Swamp in North Dumfries Township;
- Several provincially-significant wetlands in the Oxford Till Plain draining into Whiteman's Creek; and
- Provincially-significant alluvial and riparian swamps in the southwest portion of the watershed in the Mount Elgin Ridges Region, providing warm water fishery habitat.

As indicated on **Map 2.9**, the highest concentrations of wetlands are located in the eastern portion of the watershed, in the Speed and Eramosa subwatersheds, as well as in Puslinch Township. The northern most portion of the watershed, near the towns of Dundalk, Grand Valley and Damascus, also holds significant wetland complexes. The wetlands and wet meadows in the poorly drained till plains and clay and gravel soils in the north are very significant source areas for the headwaters of the Grand, Nith and Conestogo Rivers.

Several initiatives in the Grand River watershed have recently been undertaken that have the potential to provide greater conservation and protection of existing wetlands in the watershed. In particular, in 2003 the GRCA undertook a review and update of existing wetland policies. The result is a comprehensive plan providing guidance to strengthen the delivery and effectiveness of GRCA programs relating to wetlands management and promotes a collaborative planning process with member municipalities surrounding decisions on wetlands management (Grand River Conservation Authority Wetlands Policy, 2003).

The Regional Municipality of Waterloo, in the central portion of the watershed, is also working towards improving the ability of sensitive lands, such as wetlands, to be better protected. Through the Environmentally Significant Landscapes (ESL) designation, the Region will be able to limit, or in some cases prohibit, certain incompatible land uses in areas that are considered environmentally significant. Currently, the Region is recommending two areas for ESL designation: the Laurel Creek Headwaters, a significant groundwater recharge area; and the Blair-Bechtel-Cruickston area.

Map 2.9: Percent Wetland Cover by Subwatershed



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Provincial initiatives that enable better protection of existing wetlands include the amended *Development, Interference with Wetlands and Alterations to Shorelines and Watercourses, Ontario Regulation 97/04*. Specifically, the new regulation under the *Conservation Authorities Act*, 1946 now enables conservation authorities to:

- prohibit, regulate or provide permission for straightening, changing, diverting or interfering in any way with the existing channel of a river, creek, stream, watercourse or changing or interfering with a wetland; and

- prohibit, regulate or provide permission for development if the control of flooding, erosion, dynamic beaches, pollution or the conservation of land may be affected by the development.

The newly amended regulation also allows conservation authorities to regulate lands adjacent to wetlands that are shown to contribute to the overall function of the ecological system. This broader scale of protection provides a buffer for the natural feature that is necessary to maintain the health of the wetland, floodplain, or watercourse.

In addition, the recently updated Provincial Policy Statement (PPS) strongly discourages development and site alteration in or near sensitive surface water and groundwater features such that their hydrologic functions be protected, improved or restored. (Provincial Policy Statement, Section 2.1 Natural Heritage, 2005).

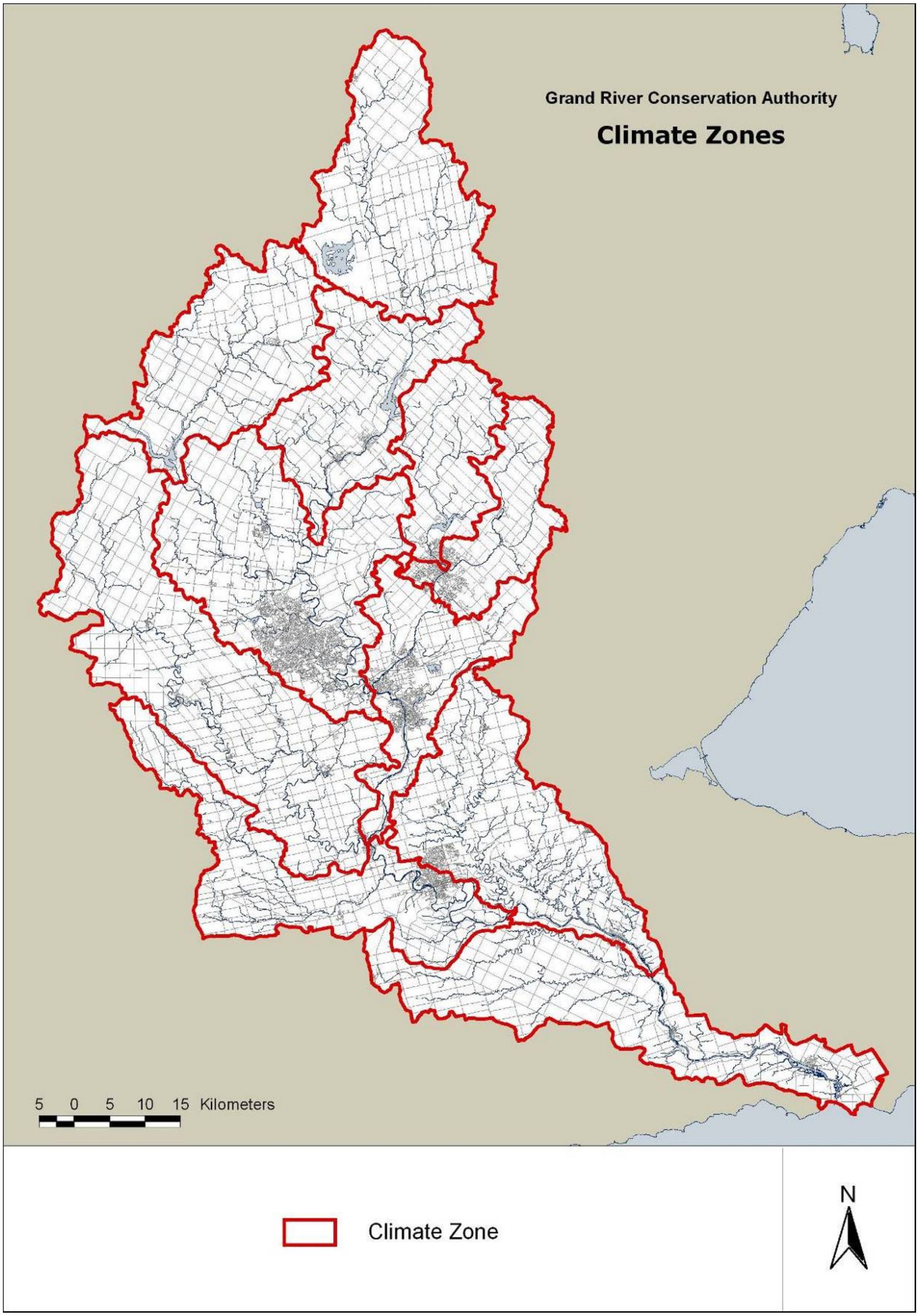
Although wetlands were drastically reduced throughout the watershed during the period of European settlement, and more recently through the processes of agricultural drainage and urbanization, they continue to play a significant role in water quality improvement and surface water flow regulation, as well as providing habitat for a diverse range of species. The above mentioned initiatives will undoubtedly play a role in protecting the natural features of the Grand River watershed, and in so doing, help to improve source water by maintaining and improving the ecological function of natural ecosystems.

2.5 Climate

In general terms, the climate of the Grand River watershed is reflective of its position at the heart of southwestern Ontario. The climate of southern Ontario is considered to be moderate to cool temperate (see **Map 2.10**), and the Grand River watershed is in both these regions. The headwaters area of Dufferin County is about 500 metres above sea level, in the cool temperate region, and the mouth of the river at Lake Erie is substantially lower, at 175 metres, in the moderate temperate zone.

Weather patterns in both regions consist of four seasons, including winters that see the majority of the precipitation in the form of snow, and summers which are hot and humid. There is no rainy season in this region; precipitation is fairly evenly distributed throughout the year. However, in any given month the amount of rain and snow varies greatly and a dry month will cause noticeably lower streamflows, while a month of rainy weather will saturate the soil and raise river levels. A winter with little snow accumulation will lead to moderate spring flows, whereas cold winters with heavy snow can lead to heavy spring runoff and floods.

Map 2.10: Climate Regions in the Grand River Watershed



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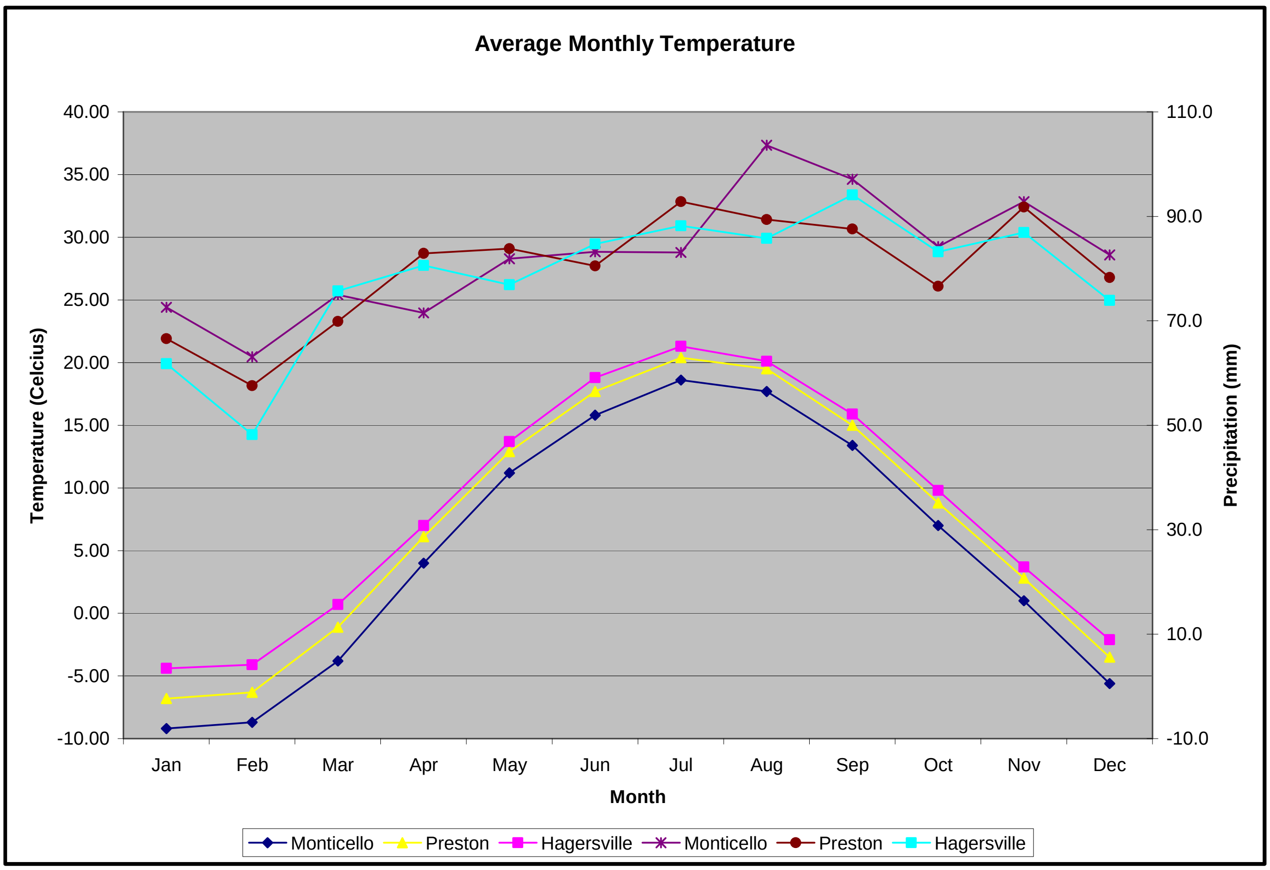
The four distinct seasons have transitional periods between them which results in noticeable variations in weather patterns across the watershed and can give unpredictable weather. This region is affected by lake effects from the Great Lakes, jet streams, high and low pressure cells and weather coming from the Arctic and the Gulf of Mexico.

The Grand River watershed covers several climatic regions which result in slight differences in temperature and precipitation and onset of the seasons. Average monthly temperatures are coldest (-9.2 degrees Celsius) in January in the north to the warmest temperatures (21 degrees Celsius) further south in the month of July. Extreme temperatures can reach as low as -35 degrees Celsius in the winter and up to 40 degrees Celsius in the summer and temperatures in the urban regions tend to be slightly higher than their surrounding regions. **Figure 2.2** shows the average temperatures and precipitation in the Grand River watershed in select locations. There are large differences in average winter temperatures between Monticello in the north and Hagersville in the south of almost five degrees Celsius. July is the hottest month throughout the watershed, with an average temperature difference of less than three degrees Celsius from the headwaters to the mouth. The daily weather patterns within a day can show dramatic temperature fluctuations.

Figure 2.2: Long-Term Monthly Average Temperature and Precipitation in the Grand River Watershed



The Grand River watershed can be divided into four climate regions, from north to south including the Dundalk Uplands, the Huron Slopes, the South Slopes and the Lake Erie Counties. They are each described below.

2.5.1 Dundalk Uplands

The Dundalk Uplands include Dufferin County, Grey County and northern Wellington County. Here, the higher altitude produces a cooler climate. Winters are colder and the snow stays longer in the spring. The winter months are generally indicated by temperatures below zero degrees Celsius, while temperatures over 20 degrees Celsius could be considered summer. With this classification, the Dundalk Uplands experiences winters that last six months, summers of three months, the month of May is spring and fall occurs during September and October. Any moisture left in the winds after they pass over the Huron Slopes is dropped on this tableland as snow or rain. The average annual temperature in this region is about five to six degrees Celsius. Average annual rainfall is about 950 to 1,000 millimetres.

2.5.2 Huron and South Slopes

These two areas – the Huron Slopes and the South Slopes – rise from the plains bordering Lakes Erie and Huron and include the central portion of the watershed: Waterloo Region, most of Wellington, Perth, Oxford and northern Brant. Moisture, picked up by winds blowing over Lake Huron, condenses as snow or rain on the slopes. This creates a "snow belt" area on the west side of the Grand River watershed between Arthur and Stratford, with a higher than average rainfall and snow accumulation. Across the Huron and South Slopes regions, the average annual temperature is about six to seven degrees Celsius. Winter lasts five months from November to March, summer is June to September, spring is April to May and fall is October. Average annual precipitation ranges from 850 to 950 millimetres.

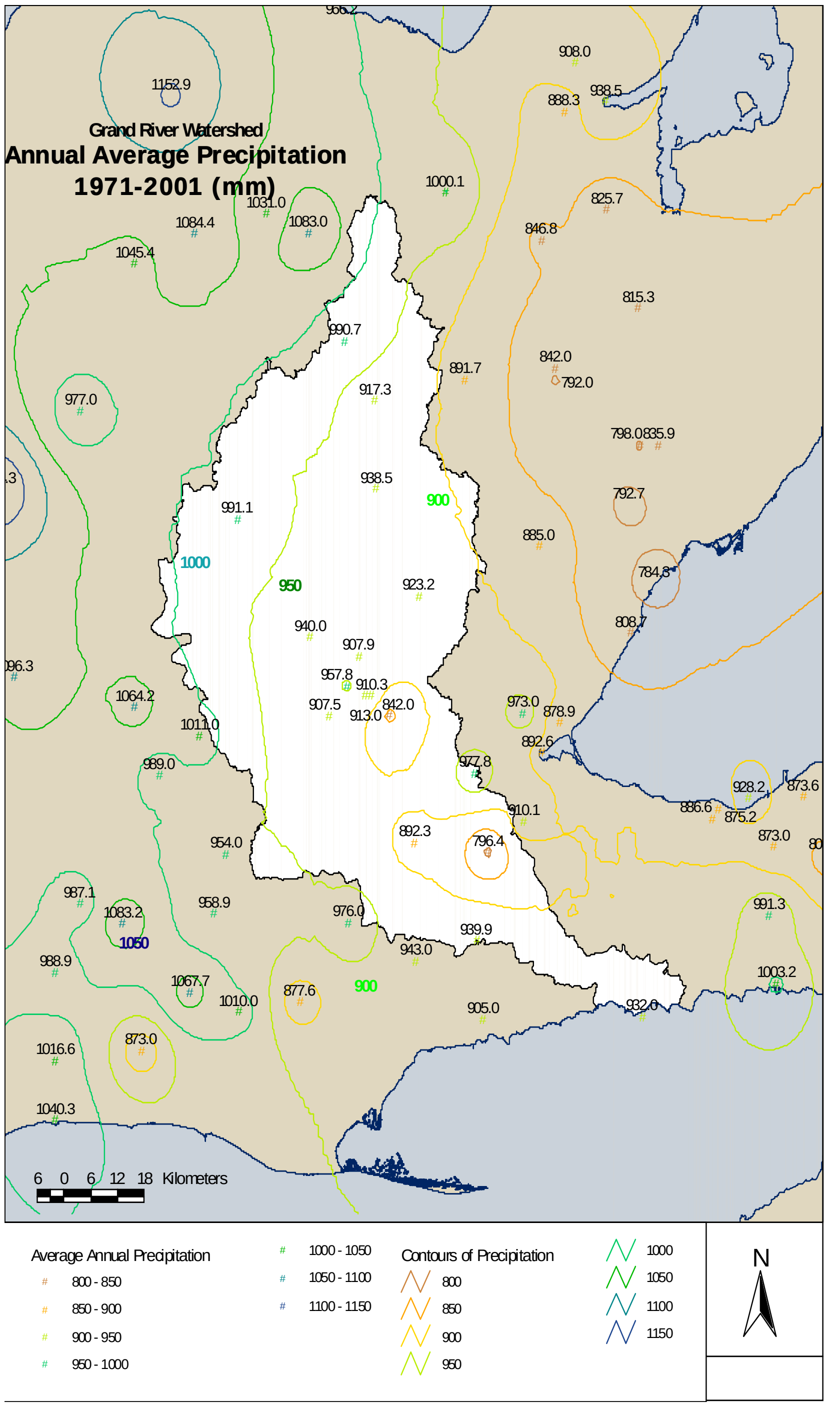
2.5.3 Lake Erie Counties

In the Lake Erie Counties zone, from Brantford to the Lake Erie shore, winds passing over the lake are warmed in winter and cooled in summer. This produces a warmer climate with a longer frost-free growing season in the lowland plains from the mouth of the Grand River northwards to Brantford. The Lake Erie counties in the southern Grand watershed are the most fortunate with seasonal weather with only four months of winter (December to March), four months of summer (June to September), and spring and fall both two months in length (Sanderson, 1998). The average annual temperature is about seven to seven and a half degrees Celsius. Average annual precipitation ranges from 850 to 900 millimetres.

2.5.4 Precipitation Trends

Precipitation in the Grand River watershed ranges from 800 to 1,025 millimetres per year (climate normals between 1971-2000; Environment Canada, 2005). Precipitation patterns in the watershed show a slight north to south trend, but the general precipitation patterns of south-western Ontario show slightly decreasing depths moving eastward. **Map 2.11** shows the pattern of precipitation across the Grand River watershed.

Map 2.11: Annual Precipitation across the Grand River Watershed



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Precipitation characteristics in the Grand River watershed are quite varied, including short intense rainfalls and thunderstorms in the summer due to convection, to steady gentle rainfalls in the autumn, to heavy snowfalls that can last for days in the winter, and flashy spring downpours.

Precipitation is fairly uniform throughout the year, as opposed to wet and dry seasons as seen in other regions such as the tropics. There are some months which have higher and lower precipitation values, for example February records the lowest precipitation depths and August has the highest precipitation value. Although it seems that winter and spring have the majority of the precipitation, it is actually August that has the highest average precipitation in this region. The warmer temperatures in the summer months enable the air to hold more moisture than in the winter months, giving us more precipitation. Following on this rule across the watershed, the driest months are February and January.

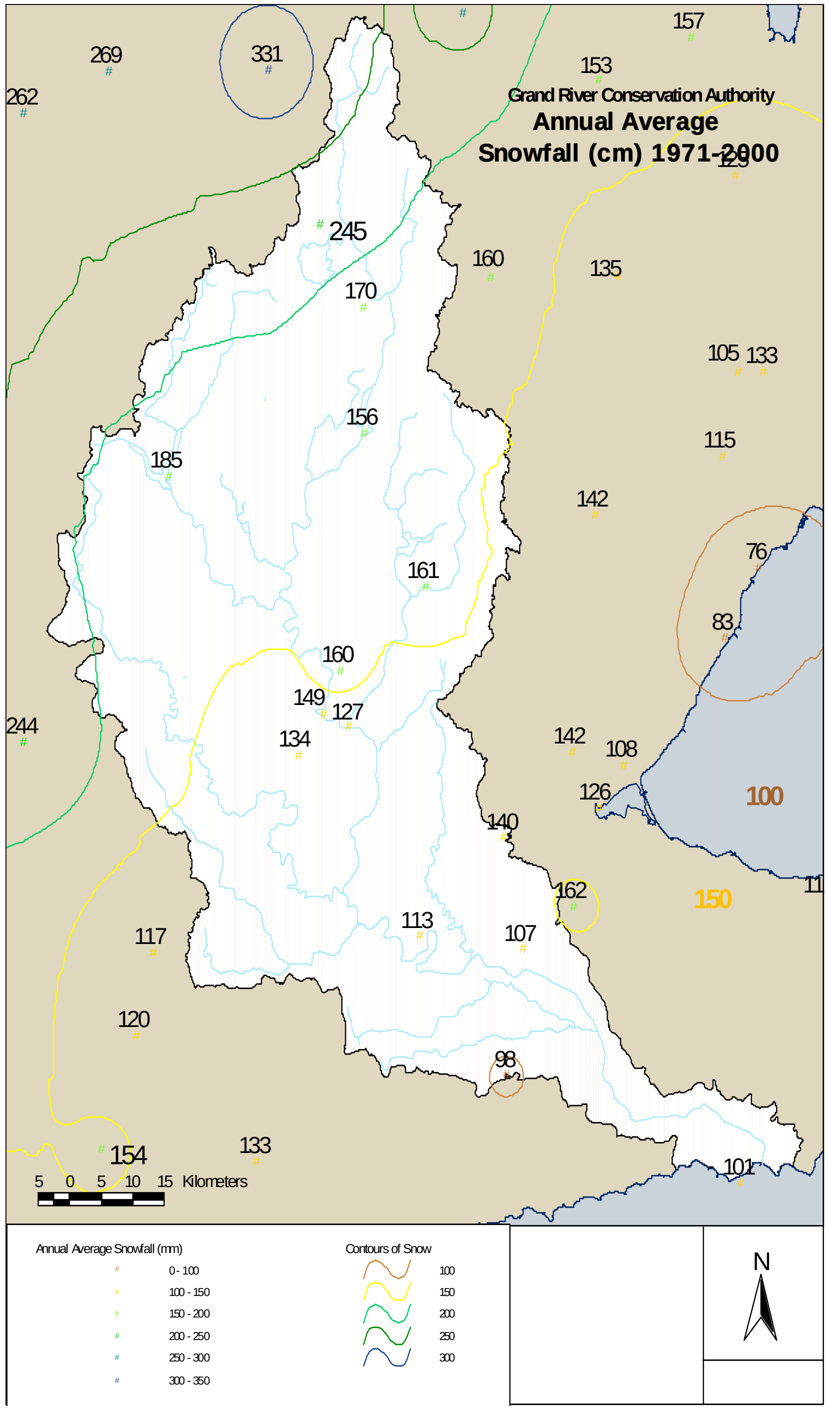
Snowfall generally begins in the month of October or November and ends around April, with traces of snow sometimes occurring in May and September. As previously mentioned, there are differences in the duration of the winter season from the headwaters to the mouth of the watershed at Lake Erie. Snowfall in the Grand River watershed has a trend of decreasing as you move southeast from the northwest (see **Map 2.12**). Lake Huron, to the west of the watershed, provides much moisture and the northwestern edge if the watershed is influenced by lake effects snow. The Dundalk Uplands will also have snow later into the spring and earlier in the fall than the southern portion due to the higher altitude.

2.5.5 Extreme Weather

Extreme weather is not uncommon in the Grand River watershed. This region experiences tornadoes, extreme snow days, droughts and other unpredictable weather events such as remnants of hurricanes. Summer is the time when most droughts occur because of the high water demands and high evapotranspiration rates. The summer can also see extreme thunderstorms due to convection or weather fronts, which can result in high amounts of rainfall in short durations, and thus, it is not uncommon that the summer experiences short stints of heavy rainfall followed by longer stretches of little to no rainfall. The winter months contend with various kinds of precipitation from rain to snow, including sleet, freezing rain, heavy wet snow, blizzards with extreme wind storms and ice conditions.

In summary, climatic patterns in the Grand River watershed, as well as the rest of southern Ontario, are constantly changing. The four seasons experienced here have typical weather patterns but are also coupled with unpredictable weather patterns due to its geographic location. Many things influence the weather from wind patterns bringing in Arctic cold from the north, or Gulf of Mexico weather from the south, to jet streams bringing weather patterns eastward across the continent from the Pacific. Daily weather within each of the seasons could be typical of the current season, or of the previous or following season, such as having a snowy day in October followed the next week by an Indian summer heat wave.

Map 2.12: Average Annual Snow Depths across the Grand River Watershed



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2.6 Hydrology and Hydrogeology

2.6.1 Hydrology

The Grand River drains approximately 6,800 square kilometres from its headwaters in the Dundalk Highlands to where it empties into Lake Erie at Port Maitland. Total elevation change along its 300 kilometres length is approximately 180 metres. The major tributaries of the Grand River include: the Conestogo and Nith Rivers, draining the western half of the watershed; and the Speed and Eramosa Rivers, which drains the north-east. Several smaller tributaries drain the southern half of the watershed. The largest of these include Fairchild, Whiteman's and McKenzie creeks. Portions of the Grand River and some of its tributaries are regulated for flood control and low flow augmentation using several water control structures and an extensive stream gauge network.

The geology of the watershed is not uniform, creating different hydrologic conditions throughout the watershed. The northern portion of the watershed is largely comprised of till plain characterized by high surface runoff and very little ground infiltration. Watercourses in this area respond quickly to precipitation events, with little to no flow during sustained dry periods. The topography is relatively flat; this has driven the need for extensive agricultural drainage works. The central portion contains the majority of the watershed's moraines and sand/gravel deposits left by glaciation. Because of the significant amount of pervious material, and the lack of a well defined drainage network, this area is characterized by extremely high infiltration and relatively low surface runoff. High infiltration sustains the areas' rich groundwater aquifers that support the high concentration of cold water fisheries found in this area. Urbanization in this part of the watershed has led to an increase in surface runoff from impervious areas and localized flooding issues. The southern portion of the watershed is dominated by the Haldimand Clay Plain. This geology produces extremely high surface runoff with little to no infiltration. Much like the northern till plain area, the southern portion of the watershed responds very quickly to precipitation events, with very little flow during dry periods. Due to the geology's inability to infiltrate water, the density of the drainage network is very high.

There are thirty-four water control structures operated by the Grand River Conservation Authority throughout the watershed. These structures range from simple overflow weirs to large multi-purpose dams and reservoirs. **Map 2.13** shows the location of control structures throughout the watershed.

There are also approximately 103 private and municipally-owned dams located throughout the watershed. Small mill ponds and overflow weirs are remnants of the valley's early industrial heritage. These structures are often a community focal point and recreational area. While they back water up and deepen the river channel locally, they do not provide flood control or improve river flow.

A Dam Inventory listing all known dams in the watershed is maintained by the GRCA. The inventory describes what is known about the dams, and is available to the public.

A series of multi-purpose reservoirs were constructed in the mid 20th century to control flooding and for low flow augmentation. There are seven significant water control structures, summarized in **Table 2.1**, that are used for active river management by the GRCA. The current operating procedure for the large dams (Shand, Conestogo, Guelph, and Luther) was established as a recommendation of the 1982 Grand River Basin Water Management Study. At that time, reservoir system operation was optimized to meet downstream flow targets for the dual purpose of waste assimilation and drinking water takings, while still providing an adequate level of protection for flood control. The reservoirs are filled during the spring snowmelt, the most active flooding season, and then gradually drawn down over the summer and early fall, thereby supplying more flow in the river than would normally be. The current operating procedures for the reservoir system were modified in 2005 to provide more flexibility to respond to warmer winters and less accumulation of snow. The reservoir system has a very significant effect on the flows in the Grand, Conestogo, and Speed Rivers.

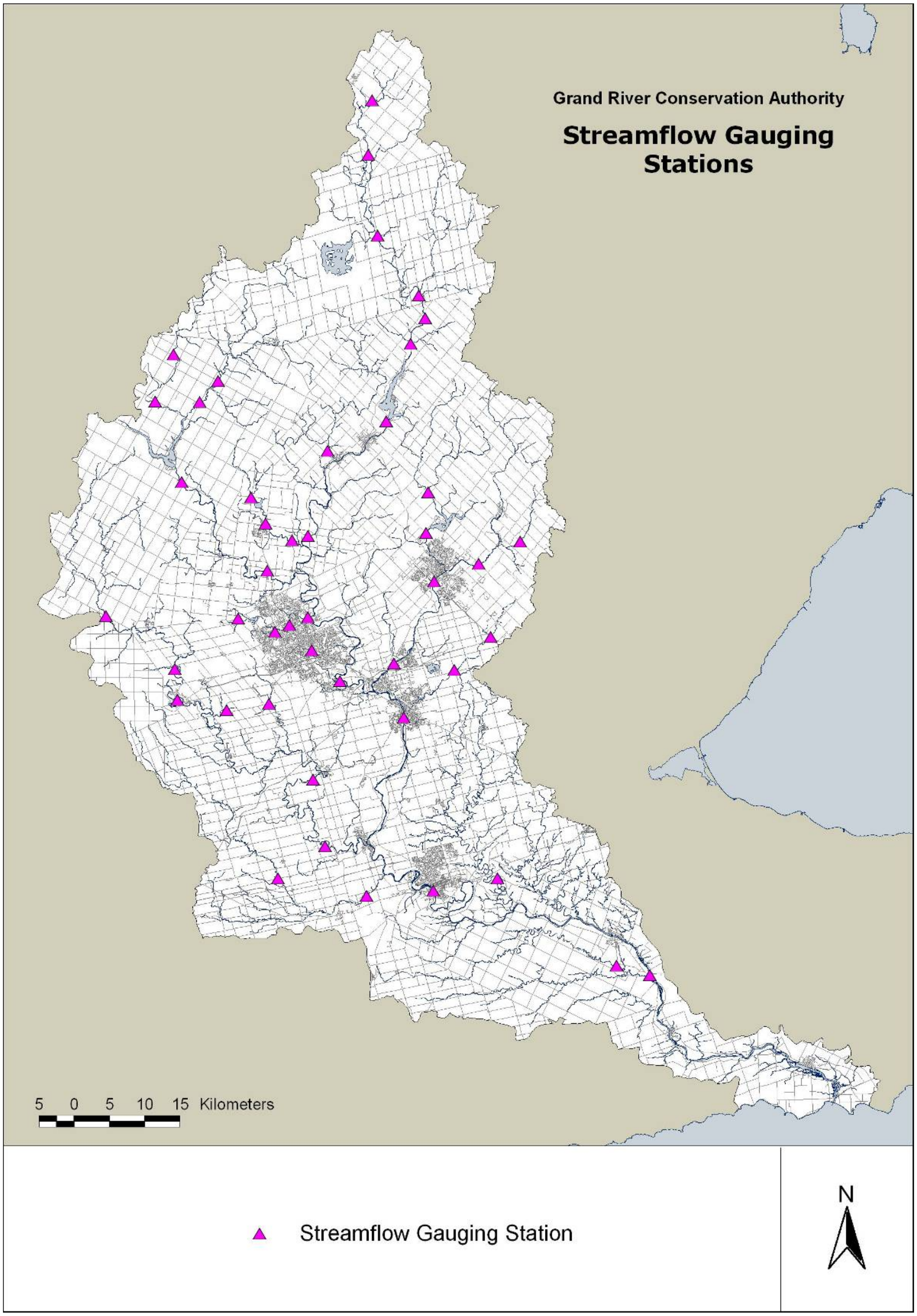
Table 2.1 Significant Water Control Structures in the Grand River Watershed

Dam	River	Purpose	Year Constructed	Dam Type	Max Storage (m^3)	Height (m)	Drainage Area (km^2)
Shand	Grand River	Flood Control, Low Flow Augmentation	1942	Earth Fill	63,745,000	25.9	800
Conestogo	Conestogo River	Flood Control, Low Flow Augmentation	1958	Earth Fill	59,445,000	24.4	570
Guelph	Speed River	Flood Control, Low Flow Augmentation	1976	Earth Fill	20,529,000	19.9	230
Luther	Grand River	Low Flow Augmentation and Conservation Area	1954	Earth Fill	23,325,000	7.0	64
Woolwich	Canagagigue Creek	Flood Control, Low Flow Augmentation	1974	Earth Fill	5,491,000	18.3	50
Laurel	Laurel Creek	Flood Control and Recreation	1966	Earth Fill	1,644,000	6.1	30
Shades Mills	Mill Creek	Storage and Recreation	1970	Earth Fill	2,419,000	7.8	105

The flow monitoring network in the Grand River watershed consists of a dense network of stream gauges as shown on **Map 2.13**. The network consists of gauges funded under the Federal/Provincial cost share agreement, gauges operated solely by the GRCA, and gauges operated in partnership between the GRCA and its member municipalities. The gauge network has been designed to support a number of water management activities such as flood management, low flow augmentation, water quality analysis, low water response, subwatershed planning, and basin reporting.

There are over 45 stream flow and level gauges currently in operation in the watershed. The gauge network covers both the regulated and the unregulated portions of the watershed, as well as inflow to major reservoirs and outflow from major dams. Many of the gauges record hourly flow, with flow data available in real-time. Some gauges are operated seasonally for specific purposes, while others are operated continuously for various water management activities. Flow records in the Grand River watershed date back to 1913 for some of the oldest gauges, predating the major dams and reservoirs.

Map 2.13: Streamflow Gauging Stations in the Grand River Watershed



The flow monitoring network continues to expand as water management activities require. Major stream flow gauge network evaluations were undertaken in 1991 and 2002.

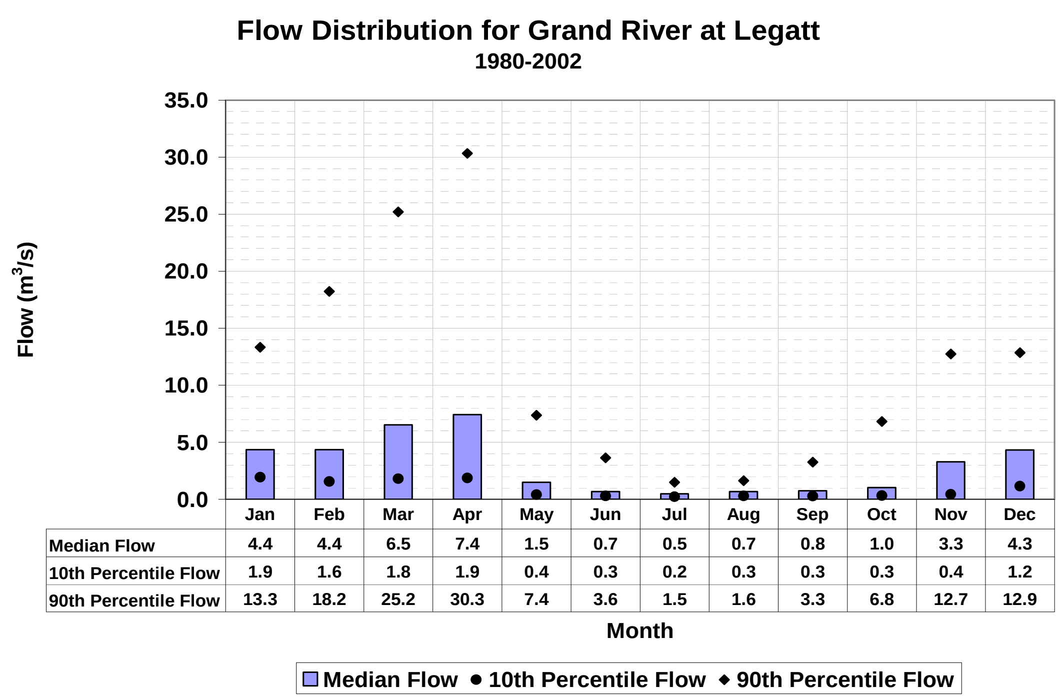
The flow regime for selected gauges is included in the following sections that describe the hydrology of various parts of the watershed.

2.6.1.1 Upper Grand River

The Upper Grand River watershed from the headwaters to the Conestogo River largely consists of Tavistock Till Plain, characterized by high surface runoff and low soil infiltration. The river valley is distinct through the region, with well defined banks and floodplains. Through part of its length the river has cut a steep sided gorge through exposed bedrock.

Upstream of the Belwood Lake (Shand Dam) Reservoir, the river is runoff dominated as shown by the flow distribution for the stream gauge at Legatt, **Figure 2.3**. Spring snowmelt is used to fill the large reservoirs, Luther Marsh and Belwood Lake, in the Upper Grand watershed to mitigate flooding and provide flow augmentation during low flow conditions. Downstream of the Shand Dam, the flow regime is modified by reservoir operations. Peak flows are smaller and base flows more stable as seen in the flow distribution for the stream gauge at West Montrose, **Figure 2.4**.

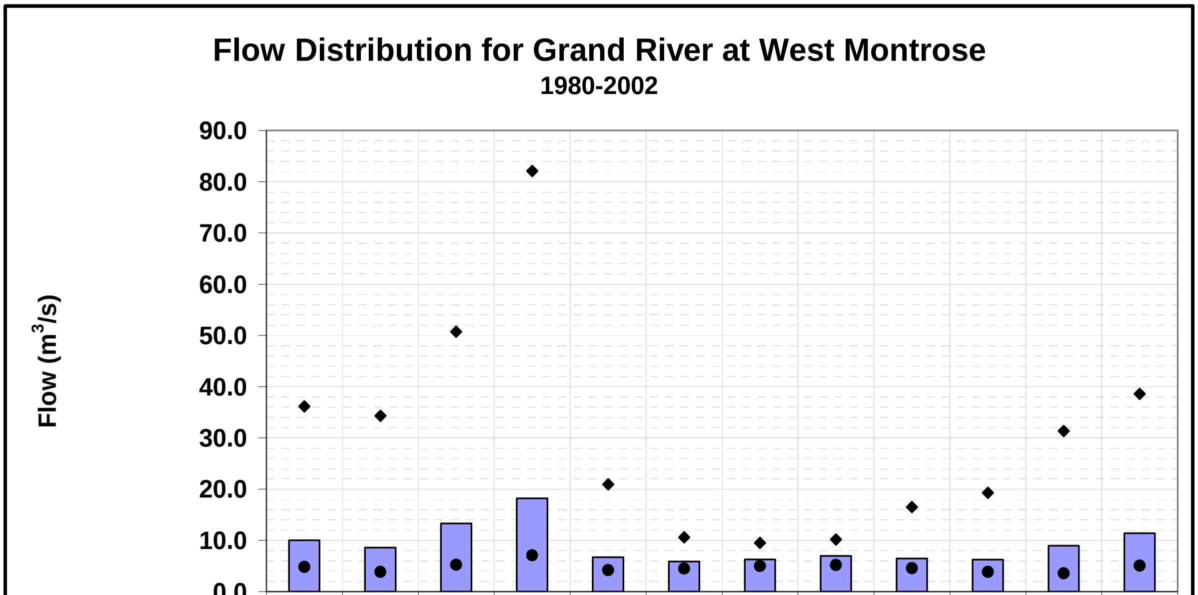
Figure 2.3: Flow Distribution for the Grand River at Legatt gauge showing median, 10th and 90th percentile flows



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Median Flow	4.4	4.4	6.5	7.4	1.5	0.7	0.5	0.7	0.8	1.0	3.3	4.3
10th Percentile Flow	1.9	1.6	1.8	1.9	0.4	0.3	0.2	0.3	0.3	0.3	0.4	1.2
90th Percentile Flow	13.3	18.2	25.2	30.3	7.4	3.6	1.5	1.6	3.3	6.8	12.7	12.9

The distribution shows a strong runoff component with high 90th percentile flows in the spring caused by the spring snowmelt. Base flow is low, as shown by low median and 10th percentile flows throughout the summer months.

Figure 2.4: Flow Distribution for the Grand River at West Montrose gauge showing median, 10th and 90th percentile flows



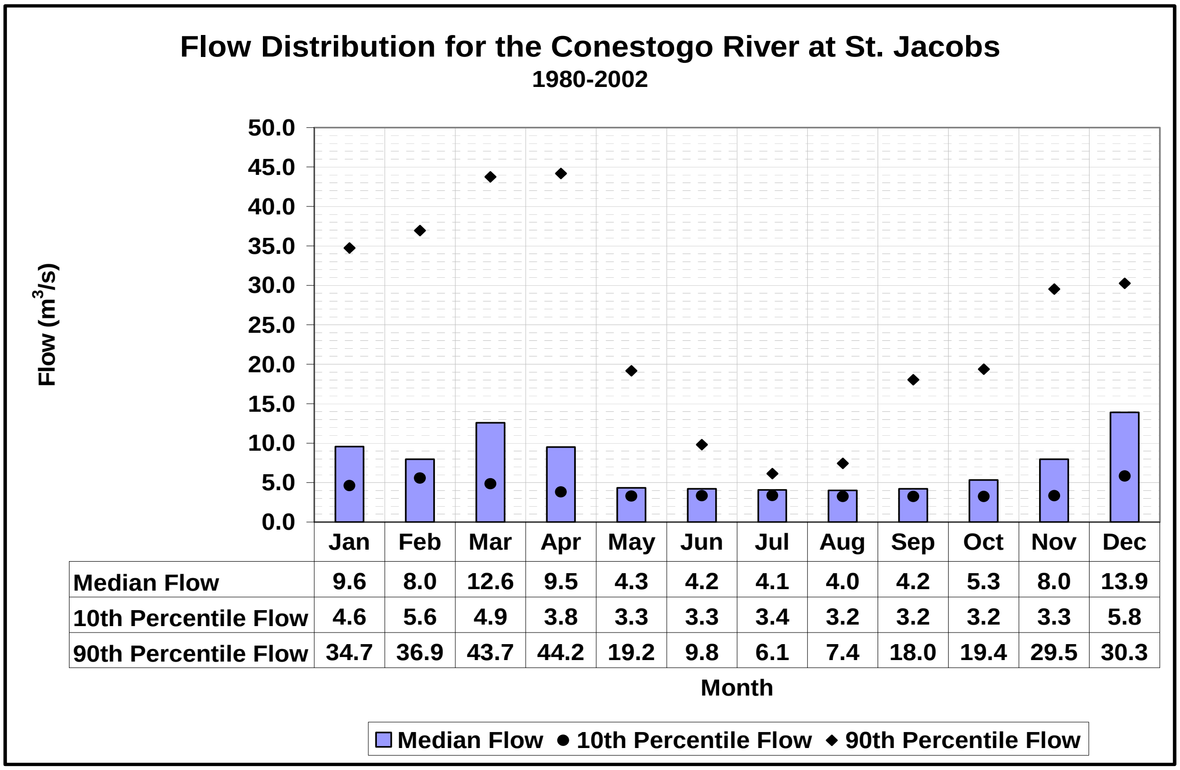
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Median Flow	10.0	8.6	13.3	18.2	6.7	5.8	6.3	6.9	6.4	6.2	8.9	11.4
10th Percentile Flow	4.8	3.9	5.2	7.1	4.2	4.5	5.0	5.2	4.6	3.9	3.6	5.0
90th Percentile Flow	36.2	34.3	50.7	82.1	20.9	10.6	9.5	10.2	16.5	19.3	31.3	38.6

The distribution shows the modifying effect of the upstream reservoir, with stable median and 10th percentile flows throughout the year.

2.6.1.2 Conestogo River

The Conestogo River watershed drains approximately 820 square kilometres. The watershed is a runoff dominated system, largely comprised of Tavistock Till Plain. The system generates extremely high runoff, however due to the efficient drainage system, peak flows rarely last long. The watershed contains one large reservoir, Conestogo Lake, which is used for flood control and low flow augmentation. Flow above Conestogo Dam during summer periods is quite low, with virtually no flow during extreme dry periods. Stream flow in the lower portion of the river is controlled by discharges from Conestogo Dam. The Dam controls flooding through the lower Conestogo and middle and lower Grand River, and adds significant flow augmentation during the summer dry period as shown in **Figure 2.5**. While the lower Conestogo does pick up some groundwater discharge from the northern flank of the Waterloo Moraine, most of the summer flows are solely from reservoir augmentation.

Figure 2.5: Flow Distribution for the Conestogo River at St. Jacobs gauge showing median, 10th and 90th percentile flows



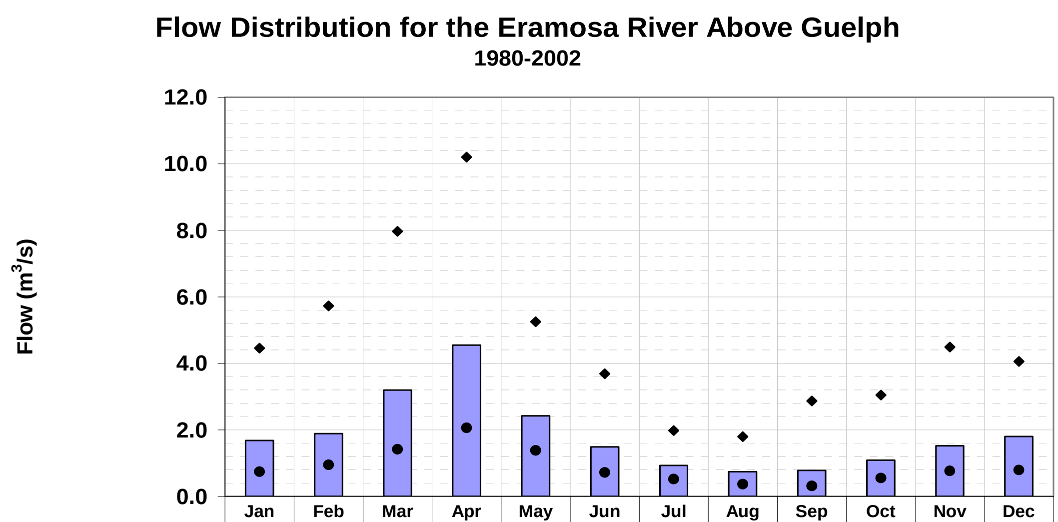
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Median Flow	9.6	8.0	12.6	9.5	4.3	4.2	4.1	4.0	4.2	5.3	8.0	13.9
10th Percentile Flow	4.6	5.6	4.9	3.8	3.3	3.3	3.4	3.2	3.2	3.2	3.3	5.8
90th Percentile Flow	34.7	36.9	43.7	44.2	19.2	9.8	6.1	7.4	18.0	19.4	29.5	30.3

The distribution shows the modifying effect of the upstream reservoir, with stable median and 10th percentile flows throughout the year.

2.6.1.3 Speed River

The Speed River, along with its tributary the Eramosa River, drains an area of approximately 780 square kilometres. The Eramosa River watershed is largely within the Galt/Paris moraines. It is characterized by low surface runoff, high soil infiltration, and disconnected drainage. The watershed also has a high percentage of forest cover. Because the drainage area includes a significant portion of moraines, the topography is also described as hummocky. In these areas, runoff, unable to reach a watercourse, collects in large scale depressions, and either evaporates or infiltrates. With pervious material, significant forest cover and hummocky topography, this watershed has very reliable baseflow as shown in **Figure 2.6**. The Eramosa River joins the Speed River in the City of Guelph below Guelph Dam.

Figure 2.6: Flow Distribution for the Eramosa River above Guelph gauge showing median, 10th and 90th percentile flows



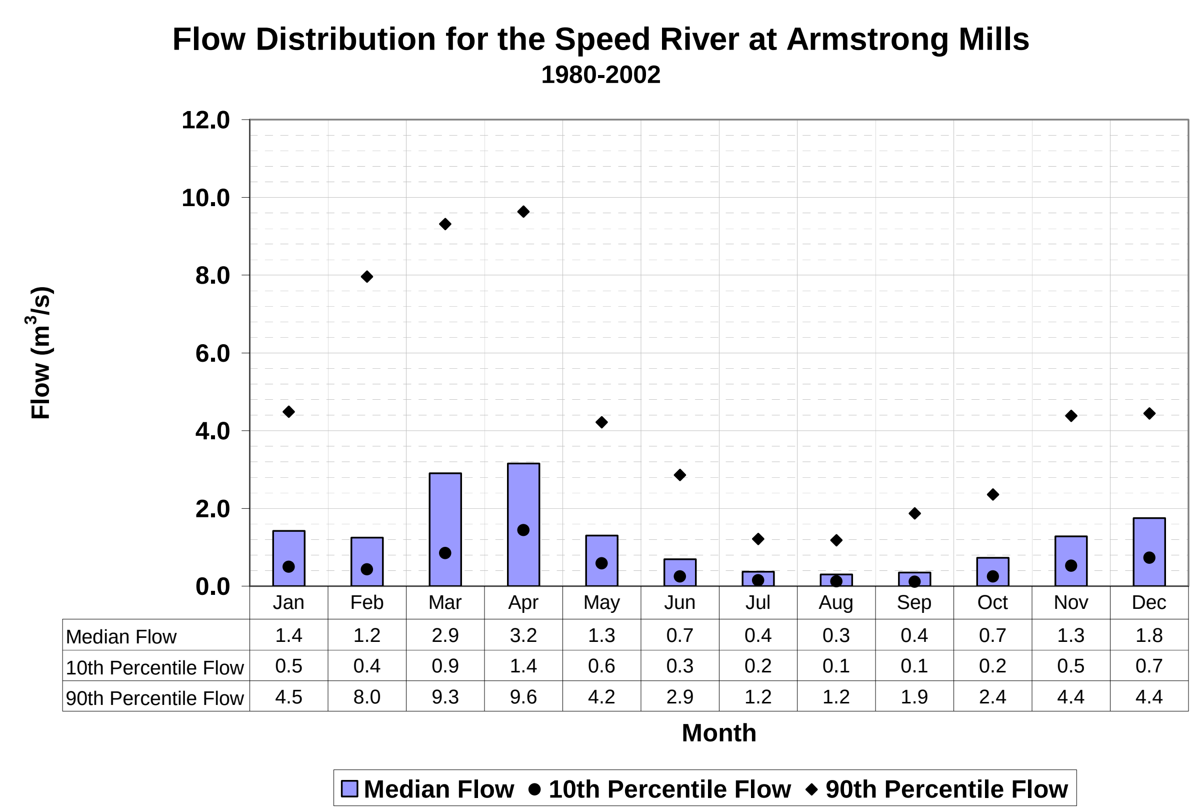
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Median Flow	1.7	1.9	3.2	4.5	2.4	1.5	0.9	0.7	0.8	1.1	1.5	1.8
10th Percentile Flow	0.7	1.0	1.4	2.1	1.4	0.7	0.5	0.4	0.3	0.6	0.8	0.8
90th Percentile Flow	4.5	5.7	8.0	10.2	5.2	3.7	2.0	1.8	2.9	3.0	4.5	4.1

The distribution shows a strong baseflow component with moderate median flows in the summer months.

The Upper Speed watershed is mainly within the Orangeville Moraine. Due to the eroded nature of the Orangeville Moraine the area has a well defined drainage network and therefore does not produce as much groundwater recharge as the Eramosa River watershed. This results in a more variable and often lower, groundwater discharge component of the flow regime as shown in **Figure 2.7**.

Guelph Dam was built for flood control and low flow augmentation. The Lower portions of the Speed River are regulated with discharge from Guelph Dam to augment low flow for waste assimilation purposes and to control flooding in the City of Guelph. The modifying effects of the Dam and the contribution of the Eramosa River can be seen in the flow distribution for the Speed River at Hanlon gauge, **Figure 2.8**. The Speed River joins the Grand River in the City of Cambridge.

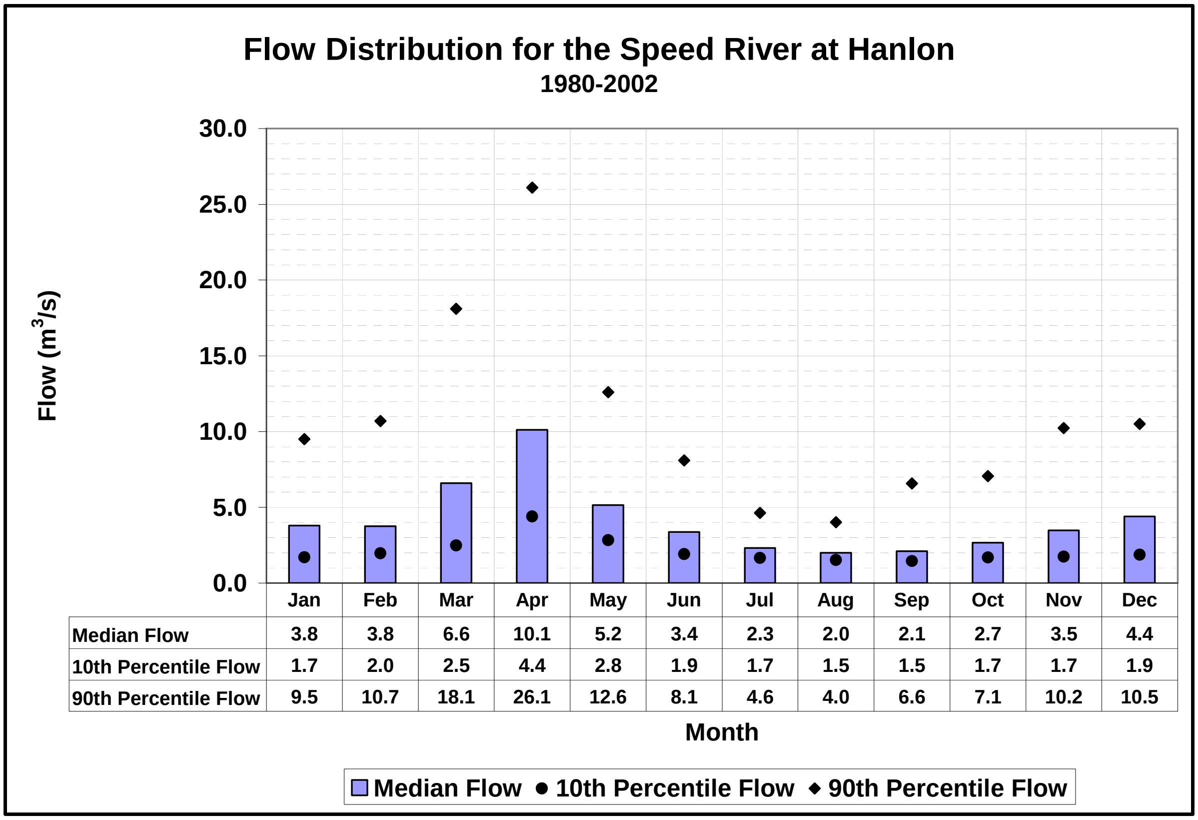
Figure 2.7: Flow Distribution for the Speed River at Armstrong Mills (above Guelph Dam) gauge showing median, 10th and 90th percentile flows



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Median Flow	1.4	1.2	2.9	3.2	1.3	0.7	0.4	0.3	0.4	0.7	1.3	1.8
10th Percentile Flow	0.5	0.4	0.9	1.4	0.6	0.3	0.2	0.1	0.1	0.2	0.5	0.7
90th Percentile Flow	4.5	8.0	9.3	9.6	4.2	2.9	1.2	1.2	1.9	2.4	4.4	4.4

The distribution shows a moderate baseflow component with low median flows in the summer months.

Figure 2.8: Flow Distribution for the Speed River at Hanlon gauge showing median, 10th and 90th percentile flows



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Median Flow	3.8	3.8	6.6	10.1	5.2	3.4	2.3	2.0	2.1	2.7	3.5	4.4
10th Percentile Flow	1.7	2.0	2.5	4.4	2.8	1.9	1.7	1.5	1.5	1.7	1.7	1.9
90th Percentile Flow	9.5	10.7	18.1	26.1	12.6	8.1	4.6	4.0	6.6	7.1	10.2	10.5

The distribution shows the modifying effect of the upstream reservoir, with stable median and 10th percentile flows during the summer months.

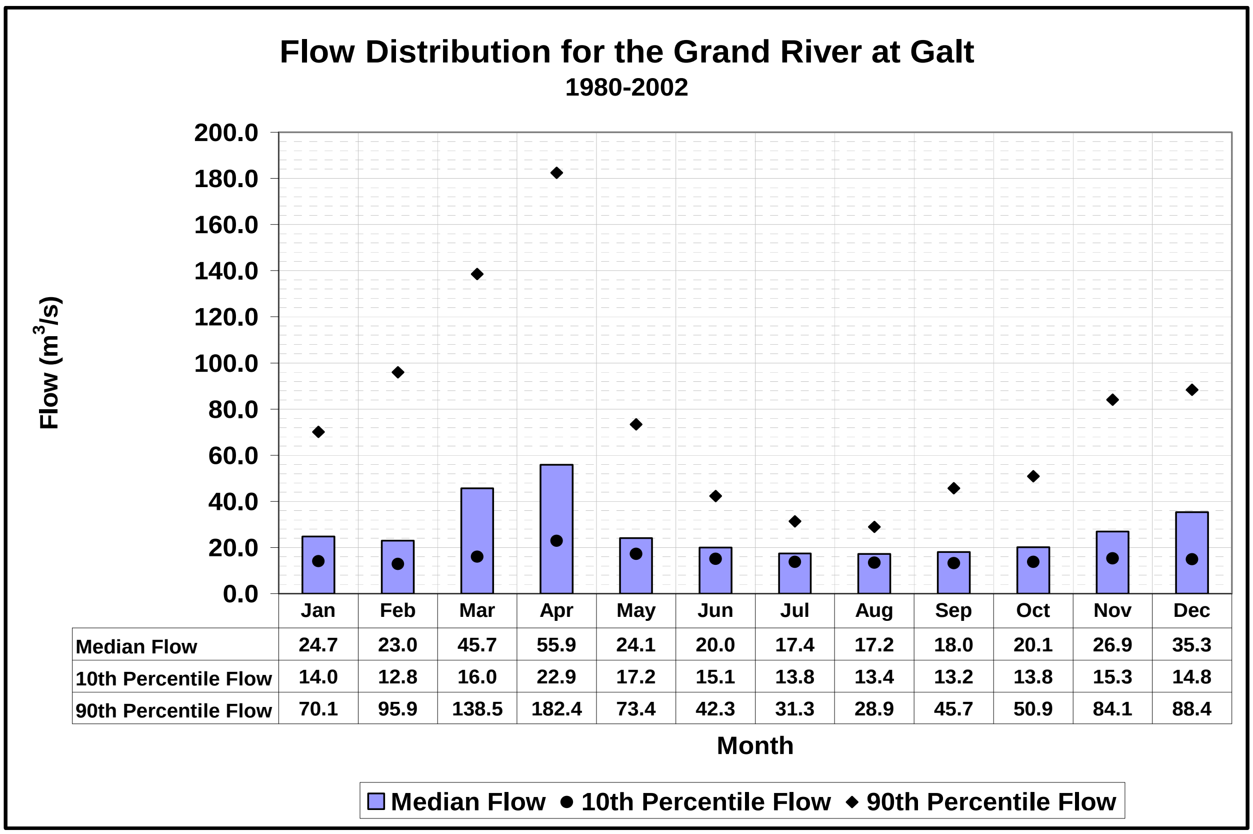
2.6.1.4 Central Grand

The central portion of the Grand River, from the confluence of the Conestogo River to the Nith River, is the most urbanized part of the watershed. It contains the Cities of Kitchener, Waterloo, and Cambridge. The natural river channel has been altered in places and increased impervious areas in the urban areas have led to some localized flooding. Within this central portion, the Grand is joined by the Speed River in Cambridge. There are also two reservoirs located in this section, Laurel Creek and Shades Mill.

Laurel Creek Reservoir is on Laurel Creek, a small creek that drains approximately 74 square kilometres. Upstream of the reservoir the watershed is largely agricultural on the Waterloo Moraine, while downstream the creek passes through the City of Waterloo. This makes for a variety of watercourse conditions including concrete channels, natural streams within wooded areas, regulated flow, and urban runoff. Shades Mill Reservoir is on Mill Creek, a small watercourse, draining 83 square kilometres, within Puslinch Township. Mill Creek flows through Cambridge before entering the Grand River, just upstream of the Grand at Galt gauge. Mill Creek flows through a glacial outwash, which is sandwiched between the Galt and Paris moraines. Due to the high amounts of hummocky topography in the moraines, and significant deposits of gravel within the outwash areas, the watercourse is a known coldwater stream, seeing considerable groundwater discharge and very little surface runoff. The largest anthropogenic impact along Mill Creek is the presence of numerous aggregate pits, many of which are extracting below the water table.

Flow is regulated through the central portion of the Grand River from upstream reservoirs. Spring flows are greatly reduced by the reservoirs which capture the spring snow melt. In combination with local dyke systems, this has reduced average annual flood damages through the urban centers in Waterloo, Kitchener, and Cambridge by 75 percent. Flows in the summer are augmented by the reservoirs to maintain flow for municipal water supply withdrawals and wastewater assimilation as shown in the flow distribution for the Galt gauge, **Figure 2.9**. South of Cambridge, the Grand River passes through a massive groundwater discharge zone, which adds as much flow as either Shand or Conestogo dams. This large amount of groundwater discharge allows the Grand River to recover downstream of the large urban and intensive agricultural regions of the upper watershed.

Figure 2.9: Flow Distribution for the Grand River at Galt gauge showing median, 10th and 90th percentile flows



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Median Flow	24.7	23.0	45.7	55.9	24.1	20.0	17.4	17.2	18.0	20.1	26.9	35.3
10th Percentile Flow	14.0	12.8	16.0	22.9	17.2	15.1	13.8	13.4	13.2	13.8	15.3	14.8
90th Percentile Flow	70.1	95.9	138.5	182.4	73.4	42.3	31.3	28.9	45.7	50.9	84.1	88.4

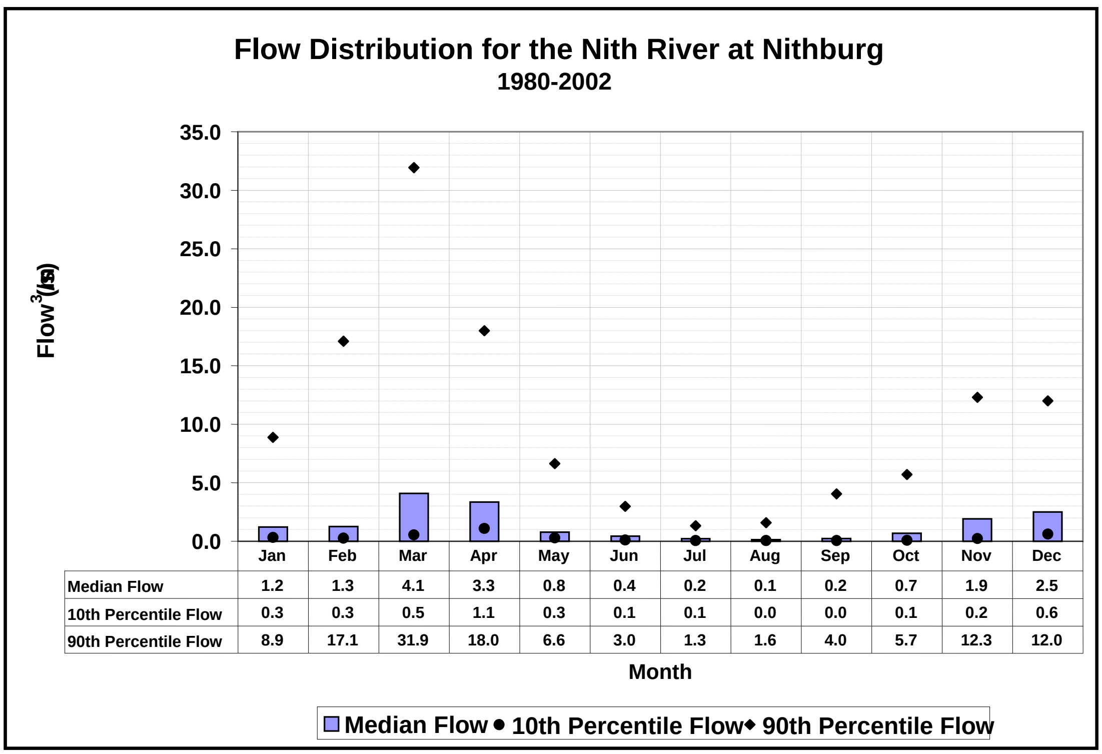
The distribution shows the modifying effect of the upstream reservoirs, with stable10th percentile flows and median flows removed from peak (90th percentile) flows.

2.6.1.5 Nith River

The Nith River drains approximately 1,030 square kilometres of the western portion of the watershed, and is the largest uncontrolled tributary in the Grand River watershed. It drains two vastly different portions of the watershed. The Upper Nith River drains the same geologic unit as the Upper Conestogo, and hence reacts similarly. The tight Tavistock Till generates large volumes of runoff, but very little infiltration, leading to little or no summer flows as shown in **Figure 2.10**.

As the Nith flows southward downstream of New Hamburg, it passes by the western and then southern flank of the Waterloo Moraine. In this area, the Nith River picks up substantial groundwater discharge, improving base flows as shown in the flow distribution for the gauge at Canning, **Figure 2.11**. In addition to the moraine, the geology changes in the southern portion of the watershed to more pervious materials, that produce large quantities of groundwater recharge. While there are significant groundwater takings occurring within the Nith River Basin, surface water takings are relatively insignificant. The Nith River joins the Grand River in the Town of Paris in Brant County.

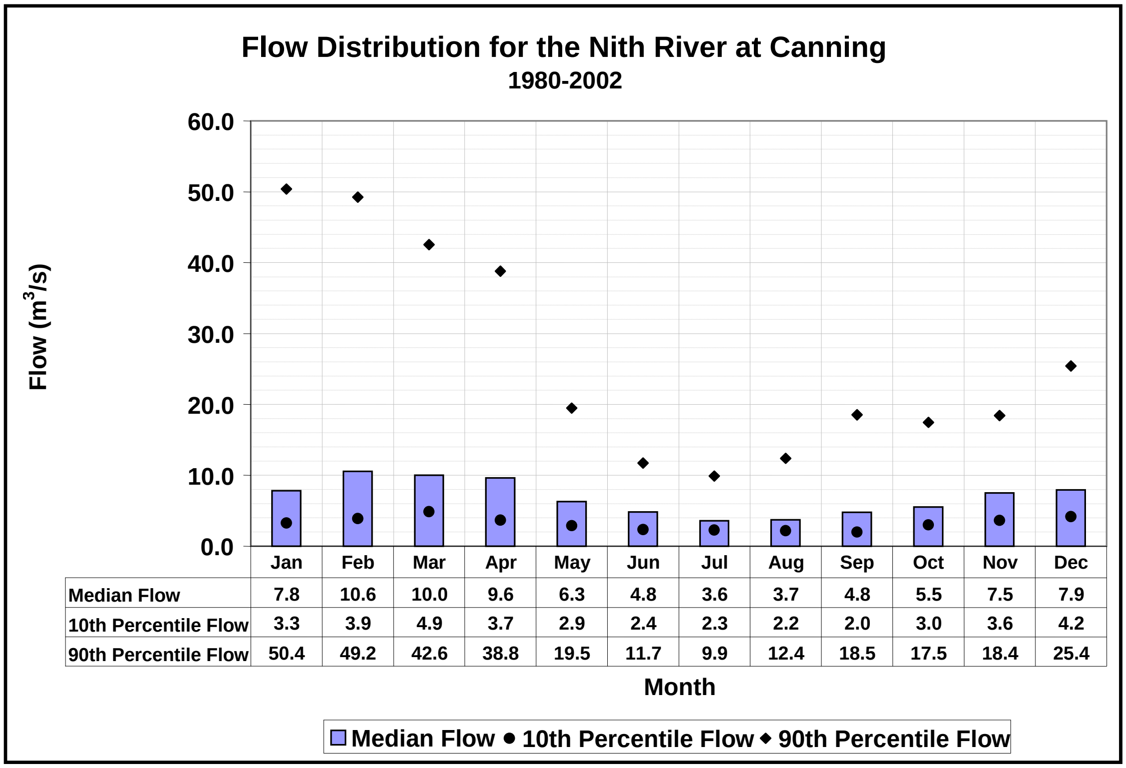
Figure 2.10: Flow Distribution for the Nith River at Nithburg gauge showing median, 10th and 90th percentile flows



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Median Flow	1.2	1.3	4.1	3.3	0.8	0.4	0.2	0.1	0.2	0.7	1.9	2.5
10th Percentile Flow	0.3	0.3	0.5	1.1	0.3	0.1	0.1	0.0	0.0	0.1	0.2	0.6
90th Percentile Flow	8.9	17.1	31.9	18.0	6.6	3.0	1.3	1.6	4.0	5.7	12.3	12.0

The distribution shows a runoff dominated system with very little baseflow, low median flow with very high peak flows.

Figure 2.11: Flow Distribution for the Nith River at Canning gauge showing median, 10th and 90th percentile flows



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Median Flow	7.8	10.6	10.0	9.6	6.3	4.8	3.6	3.7	4.8	5.5	7.5	7.9
10th Percentile Flow	3.3	3.9	4.9	3.7	2.9	2.4	2.3	2.2	2.0	3.0	3.6	4.2
90th Percentile Flow	50.4	49.2	42.6	38.8	19.5	11.7	9.9	12.4	18.5	17.5	18.4	25.4

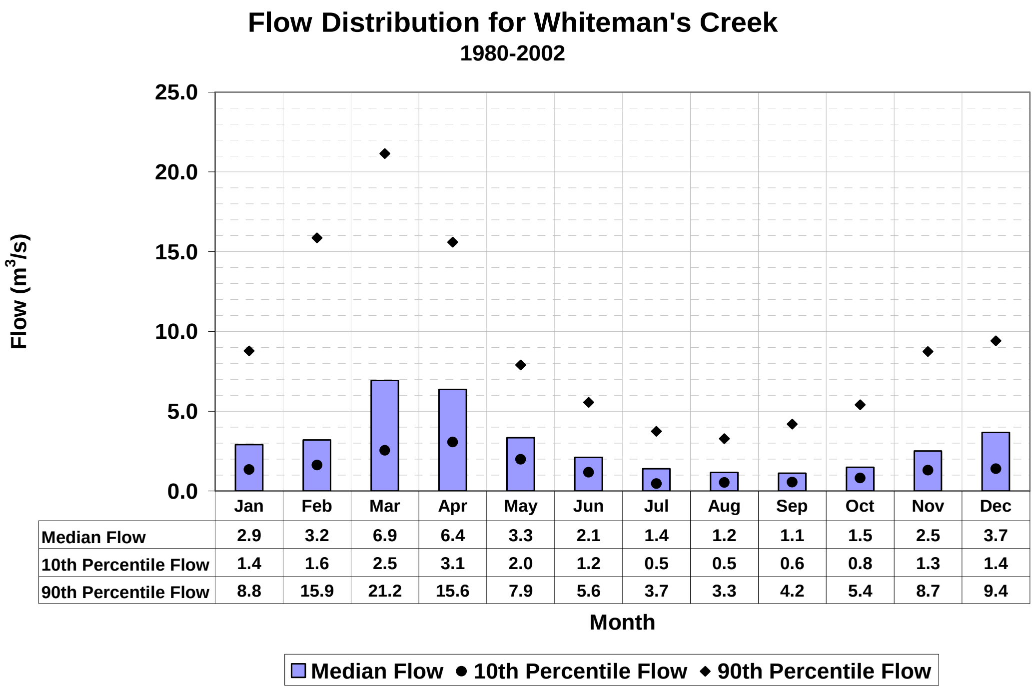
The distribution shows a significant component of groundwater discharge contributing to base flow with stable median flows and low flows.

2.6.1.6 Whiteman's, Fairchild and McKenzie Creeks

The watershed of Whiteman's Creek lies adjacent to the Nith River and has two main tributaries, Horner and Kenny creeks. Much like the Nith River, Whiteman's Creek has two distinct geologic areas. Furthest upstream, Horner Creek flows over the Tavistock Till Plain, then as it flows south, drains an area characterized by granular, more pervious material. The watershed of Kenny Creek is dominated by Port Stanley Till, another relatively impervious material. At the Kenny and Horner confluence, where Whiteman's Creek is formed, the watershed becomes largely comprised of Norfolk Sand Plain. The sands of the area produce large amounts of groundwater recharge (Figure 2.12), although because of the well drained nature of the area, substantial irrigation is required to sustain viable crops. Water takings for irrigation can affect the flow series lowering summer base flows, which can impact the creek's cold water fishery. Whiteman's Creek flows into the Grand River just upstream of Brantford.

Fairchild Creek drains an area of approximately 360 square kilometres just west of the City of Brantford, and enters into the Grand River near the community of Onondaga. The watershed's geology is a mixture of Haldimand Clay, Rockton Bedrock Plain, Norfolk Sand Plain, and portions of the Paris Moraine. Due to the influence of the sand deposits and the Paris Moraine, this watershed can have a substantial low flow component. The drainage density in this portion of the Grand River watershed is extremely high in comparison to other areas, pointing to very high runoff rates, and low groundwater recharge (**Figure 2.13**).

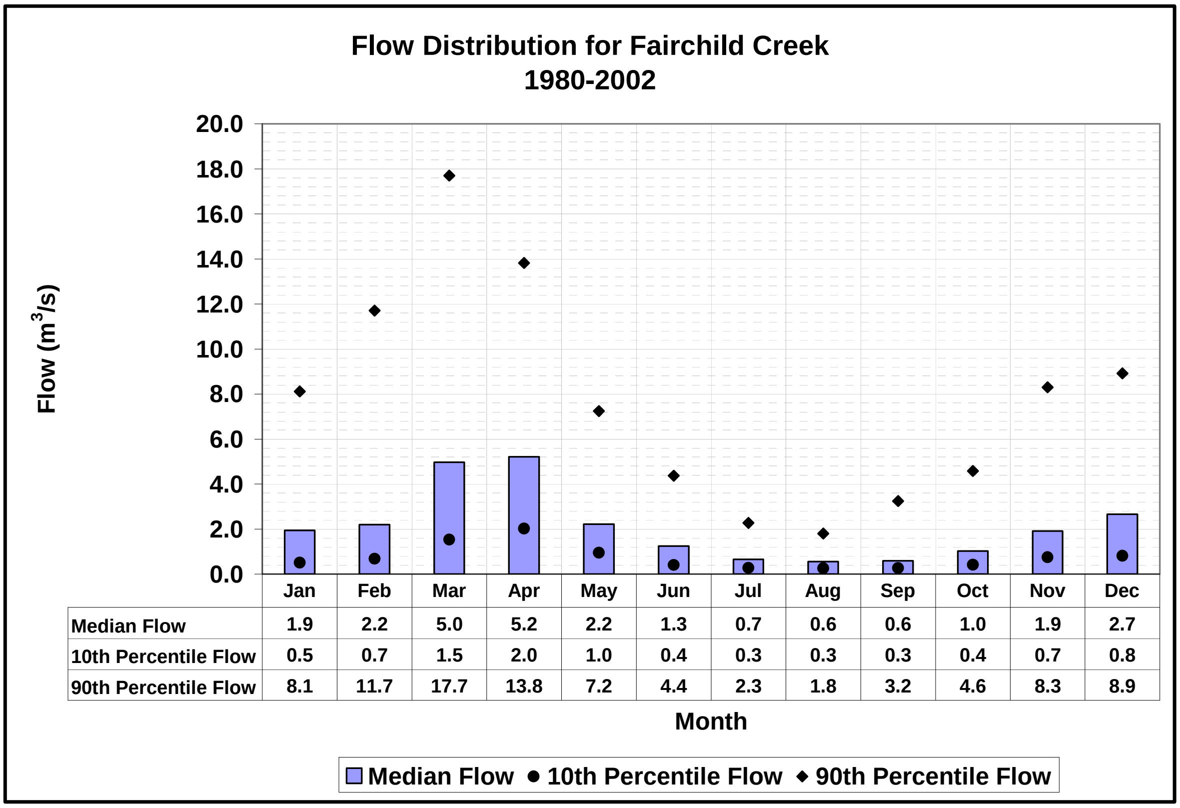
Figure 2.12: Flow Distribution for Whiteman's Creek showing median, 10th and 90th percentile flows



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Median Flow	2.9	3.2	6.9	6.4	3.3	2.1	1.4	1.2	1.1	1.5	2.5	3.7
10th Percentile Flow	1.4	1.6	2.5	3.1	2.0	1.2	0.5	0.5	0.6	0.8	1.3	1.4
90th Percentile Flow	8.8	15.9	21.2	15.6	7.9	5.6	3.7	3.3	4.2	5.4	8.7	9.4

The distribution shows a significant base flow component with stable median flows during the summer months.

Figure 2.13: Flow Distribution for the Fairchild Creek gauge showing median, 10th and 90th percentile flows

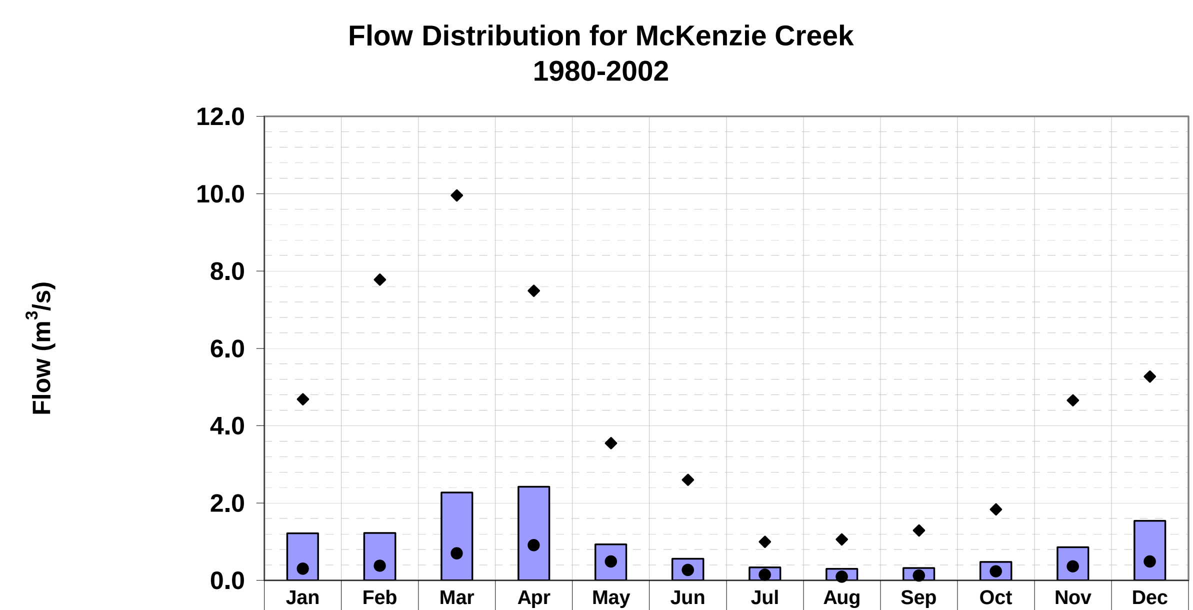


	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Median Flow	1.9	2.2	5.0	5.2	2.2	1.3	0.7	0.6	0.6	1.0	1.9	2.7
10th Percentile Flow	0.5	0.7	1.5	2.0	1.0	0.4	0.3	0.3	0.3	0.4	0.7	0.8
90th Percentile Flow	8.1	11.7	17.7	13.8	7.2	4.4	2.3	1.8	3.2	4.6	8.3	8.9

The distribution shows a low and stable baseflow component during the summer months and a runoff component with high median flows during the spring snow melt.

McKenzie Creek drains 171 square kilometres, including portions of the Six Nations Territory and Haldimand County. The watershed is largely comprised of Haldimand Clay, with the upper portion draining an area of the Norfolk Sand Plain. With the majority of the watershed being clay, this is predictably, a runoff dominated system (**Figure 2.14**). The upper portions of the watershed can produce a reliable low flow component, however, irrigation within the Norfolk Sand Plain causes this to be variable.

Figure 2.14: Flow Distribution for the McKenzie Creek gauge showing median, 10th and 90th percentile flows



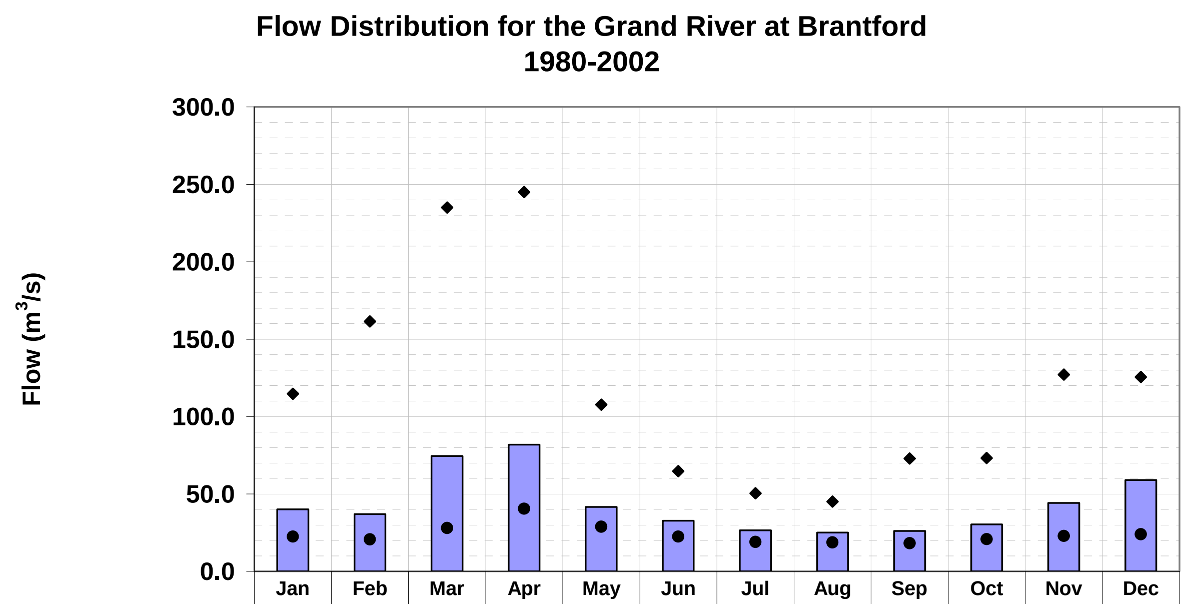
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Median Flow	1.2	1.2	2.3	2.4	0.9	0.6	0.3	0.3	0.3	0.5	0.9	1.5
10th Percentile Flow	0.3	0.4	0.7	0.9	0.5	0.3	0.1	0.1	0.1	0.2	0.4	0.5
90th Percentile Flow	4.7	7.8	10.0	7.5	3.6	2.6	1.0	1.1	1.3	1.8	4.7	5.3

The distribution shows a low and stable baseflow component during the summer months and a runoff component with high median flows during the spring snow melt.

2.6.1.7 Lower Grand River

The Lower Grand River from the Nith River confluence to Lake Erie is largely influenced by upstream flow conditions. Contributions to the flow regime from Whiteman's, Fairchild and McKenzie creeks have little influence on the flow regime of the Grand River compared to the watershed upstream of the Nith River confluence. At Brantford the flow distribution, **Figure 2.15**, shows a stable base flow component which is influenced by both upstream reservoir operations and groundwater discharge upstream of the gauge. Peak flows occur in April, a reflection of the influence of the later snowmelt in the northern portion of the watershed on this flow distribution.

Figure 2.15: Flow Distribution for the Grand River at Brantford gauge showing median, 10th and 90th percentile flows

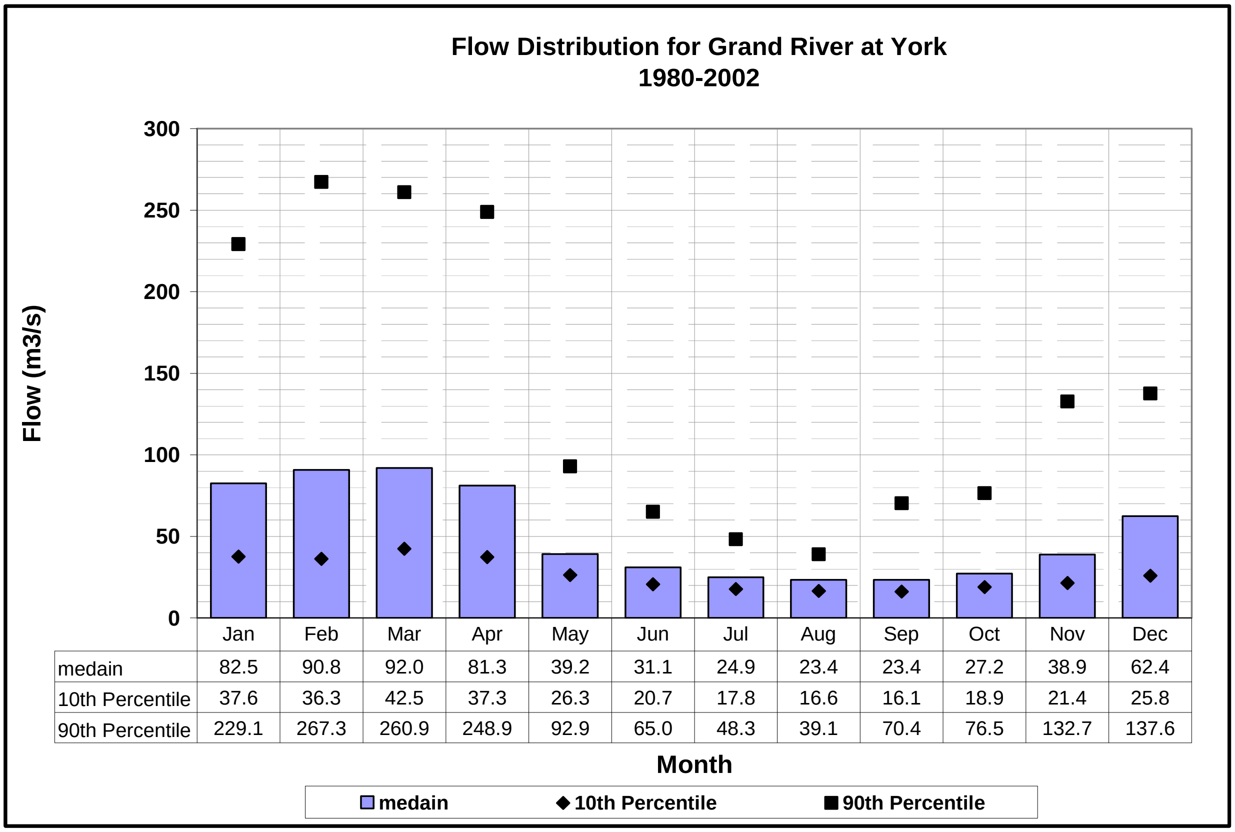


	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Median Flow	40.0	37.0	74.6	82.0	41.6	32.7	26.4	25.1	26.0	30.3	44.2	59.0
10th Percentile Flow	22.5	20.7	28.0	40.5	28.8	22.4	19.0	18.7	18.2	20.8	22.8	23.9
90th Percentile Flow	114.8	161.4	235.0	245.0	107.6	64.8	50.5	45.0	72.9	73.2	127.1	125.6

The distribution shows a stable baseflow component and moderate peak flows.

Downstream of Brantford the watershed is fairly flat and comprised of Haldimand Clay Plain. The drainage area produces high runoff and little groundwater recharge. Tributaries in this area form a dense drainage network that quickly conveys water to the river. The main river channel itself is very wide and it meanders as it travels south to Lake Erie. Water is slow moving, but flow rates can be significant. The last stream gauge on the Grand River is at the community of York. The York gauge is operated by the GRCA and its flow distribution is given in **Figure 2.16**. Following York the Grand River continues its southward path past the communities of Cayuga and Dunnville before it joins Lake Erie at Port Maitland.

Figure 2.16: Flow Distribution for the Grand River at York gauge showing median, 10th and 90th percentile flows



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
medain	82.5	90.8	92.0	81.3	39.2	31.1	24.9	23.4	23.4	27.2	38.9	62.4
10th Percentile	37.6	36.3	42.5	37.3	26.3	20.7	17.8	16.6	16.1	18.9	21.4	25.8
90th Percentile	229.1	267.3	260.9	248.9	92.9	65.0	48.3	39.1	70.4	76.5	132.7	137.6

The distribution shows a fairly high stable baseflow component and moderate sustained peak flows.

2.6.2 Hydrogeology

Approximately 82% of the population of the Grand River watershed relies on groundwater as a clean, safe, domestic water supply. In addition to providing the Grand River Watershed's population with a safe source of water, groundwater is used in agriculture, industry, and commercial production of bottled water for export. Groundwater also plays a pivotal role in sustaining sensitive natural features and aquatic habitats such as streams and wetlands. It has long been recognized that groundwater within the Grand River Watershed has a vital role in the hydrologic function of the watershed. Groundwater provides critical baseflow to many parts of the watershed, thereby supporting many of the watershed's aquatic and wetland ecosystems.

Numerous municipalities and communities within the watershed are dependent on groundwater as their principal drinking water source. Groundwater resources are found within both bedrock and overburden aquifers. Both the quality and quantity of groundwater are strongly influenced by the bedrock and overburden geology within the watershed.

2.6.2.1 Bedrock Aquifers

Within the Grand River watershed, several bedrock units have the ability to transmit significant quantities of groundwater making them potentially important for municipal or private use. These units, shown on **Map 2.1**, include the Lockport-Amabel Formation, the Guelph Formation and the Salina Formation.

The Lockport-Amabel Formation underlies the Guelph Formation throughout the Grand River Watershed with the exception of where it subcrops in the far eastern extents of the watershed. The formation, which is predominantly comprised of limestone and dolostone, ranges in thickness from 10 to 45 metres. Portions of the Amabel Formation have been subjected to varying degrees of solution enhancement (karstification), resulting in areas of higher porosity, which have enhanced the ability of the rock to transmit groundwater. A key example has been documented through recent work in the City of Guelph (Golder, 2006). Here, the Amabel Formation is a highly productive aquifer where significant groundwater yields are derived from the middle section of the Formation, which is often termed the ‘Production Zone’. The Production Zone exhibits a higher secondary porosity relative to the less fractured upper and lower zones. To date, the exact lateral extents of the production zone are unknown.

In the vicinity of the Production Zone and near the community of Rockwood, the Amabel Formation includes the Eramosa Member. In this area, the Eramosa Member, which can be up to 20 m thick, overlays the Amabel Formation. This member, which is characterized by its black, shale-rich nature, behaves as an aquitard. The underlying Amabel Formation is therefore, where the Eramosa Member is present, not highly influenced by shallow groundwater recharge and discharge.

Overlying the Amabel Formation, the Guelph Formation, which generally consists of brown or tan dolostone, has a maximum thickness of 55 metres to the west and forms a moderately productive aquifer. The largest groundwater yields from this formation are from the upper portion of the bedrock which exhibits a higher secondary porosity (typically more weathered and fractured) than lower sections of the Formation.

The Salina Formation, which consists of evaporites (salts, gypsum, anhydrite), shales, and interbeds of carbonate rock, overlies the Guelph Formation in the western and southern portion of the watershed. This formation is considered a moderately productive regional aquifer, supplying groundwater for both municipal and private use. Higher transmissivity values are a result of mineral dissolution and fractures which have developed in the upper bedrock. As a groundwater resource however, many wells are not completed in this aquifer because of water quality concerns, as water quality is often poor

2.6.2.2 Overburden Aquifers

Several major moraine systems are found in the Grand River Watershed, including the Orangeville and Waterloo interlobate moraines, and the Paris and Galt recessional moraines. These moraines, made up of extensive sand and gravel units, provide significant amounts of groundwater for municipal and private use across the watershed. **Map 2.4** and **Map 2.5** show the location of moraines in the watershed. Additional significant groundwater resources are found within the Norfolk Sand Plain, which is located to the southwest of the City of Brantford.

The Orangeville interlobate moraine, located in the northern portion of the Grand River Watershed, is situated on the east side of Belwood Lake, and extends up to the west side of Orangeville. Groundwater maps produced for areas throughout the Orangeville Moraine have shown that a high water table elevation is associated with the feature. A portion of the groundwater within the moraine tends to flow to the northwest towards the Grand River, while the remainder flows to the southwest towards the Credit River Watershed (Burnside Environmental, 2001). Although not used for municipal supplies, the Orangeville Moraine is a highly permeable feature and has been identified as an area of significant recharge (AquaResource, 2006).

Located to the south of the Orangeville Moraine, the Waterloo Moraine is one of the largest moraines within the Grand River Watershed. A number of aquifers situated within the moraine are used by the Region of Waterloo for drinking water supply. The moraine is situated within the west-central part of Waterloo Region in the central portion of the watershed. A significant till unit within the moraine is the Lower Maryhill Till, an ice-deposited clay till which acts as a major aquitard for the aquifers utilized by the Waterloo Region municipal supply wells. Large aquifers within the moraine discharge to and maintain baseflow within the Grand River and the Nith River and many of their tributaries (AquaResource, 2006). Three major overburden aquifer units, the Mannheim, Greenbrook, and Parkway, are found within the Waterloo Moraine and supply 50% of the municipal groundwater supplies for the Region of Waterloo (AquaResource, 2006). The Mannheim aquifer, composed of extensive thick sand and gravel layers is the primary aquifer within the moraine. Most of the Mannheim aquifer is unconfined and recharged by surface waters. The Greenbrook aquifer is located beneath the Lower Maryhill Till and generally within or above the Catfish Creek Till. This aquifer consists of layered gravels, sands and silts and is found on the flanks of the moraine. The Parkway aquifer, which is comprised of layered sands and gravel, generally overlays the Catfish Creek Till. It is found on the eastern flank of the moraine but is discontinuous and not laterally extensive.

In the St. George area, just north of Brantford, the Galt Moraine yields two local aquifers; a deeper aquifer which consists of 3 to 5 m of gravel deposits and a shallow sand and gravel aquifer (AquaResource, 2006).

Another significant groundwater resource is within the Norfolk Sand Plain, located in the southwest portion of the Grand River watershed. The sand plain is composed of coarsely textured glaciolacustrine sand and silt deposits laid down as a delta in glacial Lakes Whittlesey and Warren (Waterloo Hydrogeologic, 2003). The deposits consist of fine- to medium-grained, cross-bedded sand up to 25 m thick. The permeable sand and gravel deposits associated with the Norfolk Sand Plain yield good water supplies; however, they are particularly vulnerable to impacts from land use activities.

2.6.2.3 Regional Groundwater Static Water Levels and Flow Directions

The Grand River Conservation Authority has produced two static water level surfaces using the Ministry of the Environment’s water well database; one surface was developed using deeper wells, and a second water table surface was created using shallower wells. The mapping of static water levels on a regional scale does not follow aquifer units and the resulting surfaces are therefore not considered to be locally representative, however these surfaces can be used to represent regional groundwater flow conditions.

On a watershed scale, groundwater flow directions can be interpreted from potentiometric surfaces that have been developed from static groundwater levels. In the case of the

Grand River watershed, a ‘deep’ potentiometric surface was developed from hydraulic head values collected from wells greater than 40 m deep. These values were then interpolated to develop a continuous potentiometric surface as shown on **Map 2.14**. The direction of groundwater flow within the bedrock and deep overburden sediments can then be inferred from the potentiometric surface. From Map 15, the highest potentiometric elevations are found in the northern part of the watershed, whereas lower hydraulic head values are found in the southern part of the watershed; this implies a general north to south flow direction, as might be expected. The major river systems, as well as the Dundas Valley, are observed to influence groundwater movement in the deeper subsurface units within the watershed.

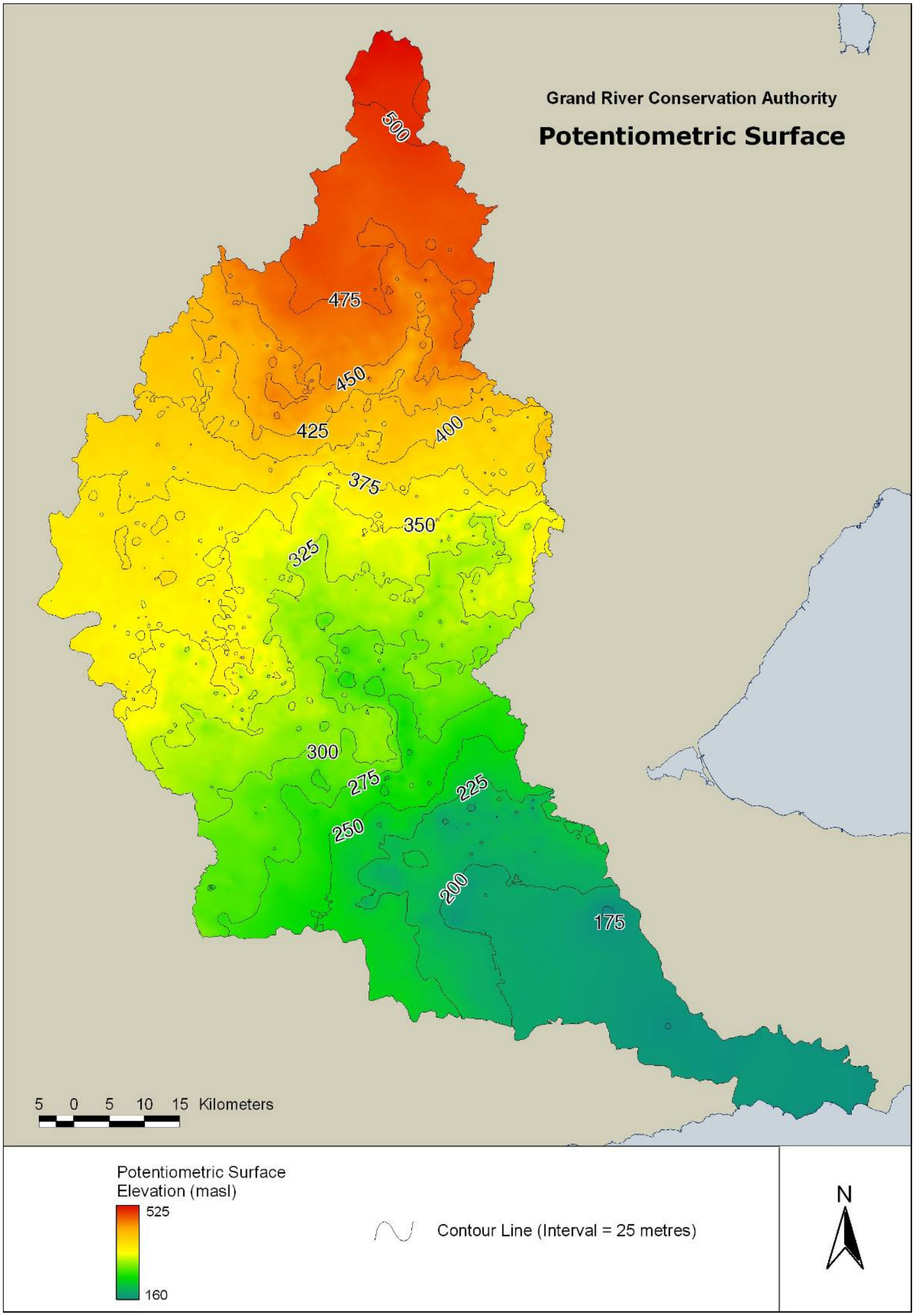
The regional water table surface, shown on **Map 2.15**, was developed from an interpolation of the reported static water levels in wells less than 25 m deep. In general, from this map, groundwater is interpreted to flow from the topographically higher elevations in the north towards the topographically lower elevations in the south. It can be observed from **Map 2.15** that the present day Grand River and the most significant tributaries have an influence on shallow groundwater movement across the watershed. Also illustrated on **Map 2.15** is the interpreted water table divide across the watershed. Where the interpreted water table divide is located inside the boundaries of the surface watershed, the Grand River watershed is likely losing water via shallow groundwater movement to the adjacent watershed. However, where the water table divide is located outside the surface watershed, it is likely that the Grand River watershed is receiving via shallow groundwater movement from the adjoining watershed.

2.6.2.4 Specific Capacity

The specific capacity of a well is defined as its yield of groundwater per unit of drawdown. It is a function of the properties of the aquifer, pumping time, and well construction characteristics and is calculated by dividing the pumping rate by the water level drawdown that occurred in the water well. This measure therefore provides an estimate of the productivity of the aquifer in which the well is completed. In general, high specific capacities in water wells are indicative of high transmissivities and consequently, high productivity in the associated aquifer. However, the results may be skewed to indicate the aquifer is more productive than it really is, as wells with low productivity are immediately abandoned.

Map 2.17, Map 2.18, Map 2.19 and Map 2.20 shows the specific capacity of domestic and non-domestic wells completed in the bedrock and overburden, respectively. **Map 2.17** shows the bedrock specific capacity for domestic wells and Map 2.18 shows the specific capacity for other non-domestic wells. Similarly, **Map 2.19** shows the overburden specific capacity for domestic wells where Map 20 shows the overburden specific capacity for non-domestic wells.

Map 2.14: Potentiometric Surface of the Grand River Watershed



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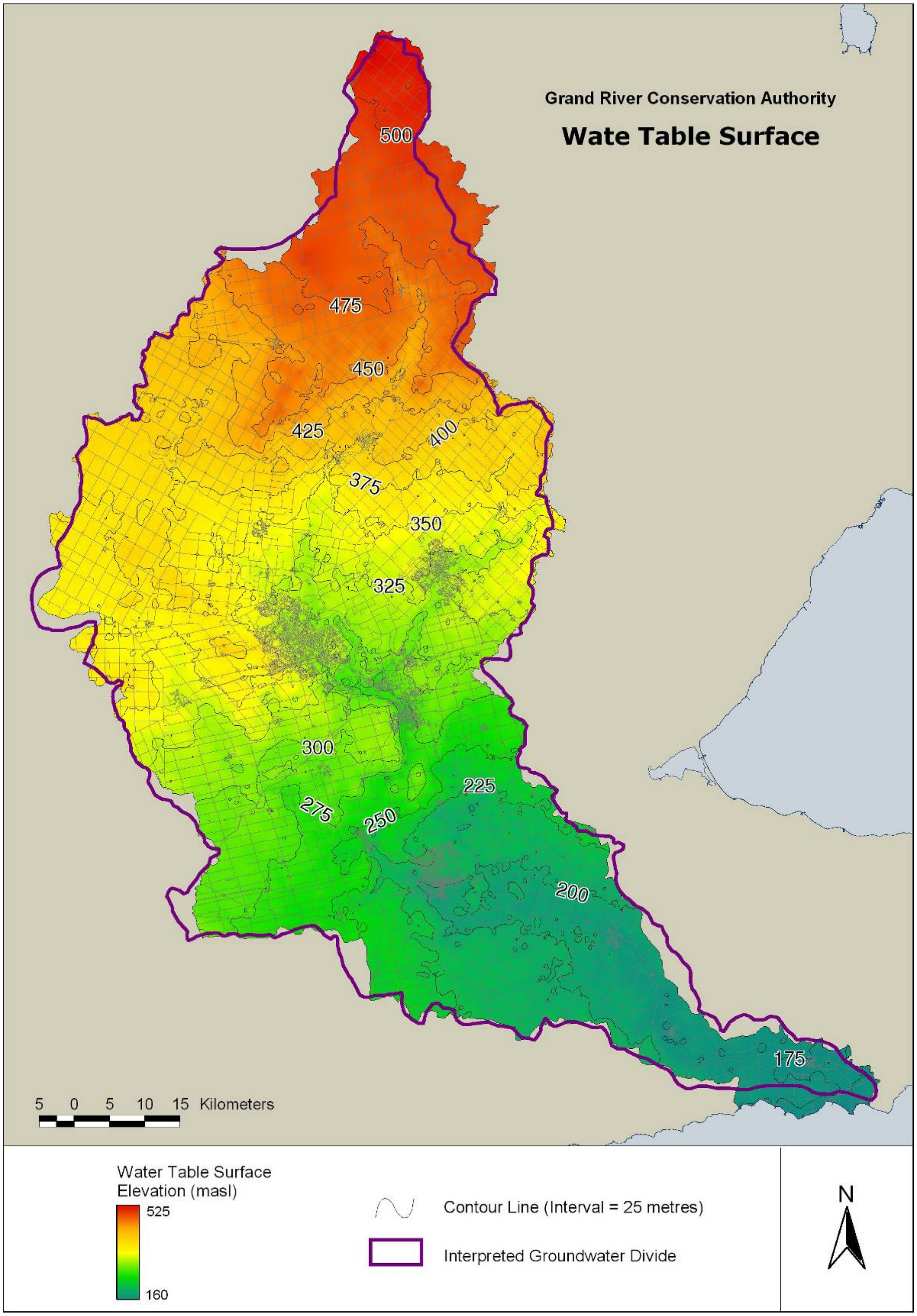
Map 2.15: Water Table Surface of the Grand River Watershed



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Map 2.16 shows the greatest concentration of high specific capacity domestic wells to be found in the eastern half of the watershed, generally coincident with the Amabel Formation. High specific capacity wells are also found to be coincident with the Guelph Formation, which is also known to be a highly productive aquifer. High capacity wells occur in the western half of the watershed less frequently. Other bedrock aquifers that show limited high specific capacity include the Salina Formation in the vicinity of Caledonia, and the Bois Blanc Formation near Drayton in the northwest of the watershed (Holysh et al., 2001). **Map 2.17** indicates similar patterns to domestic bedrock wells, where high values are found in both the Amabel and Guelph Formations. The Salina Formation only shows geographically limited areas as having higher specific capacity values.

Domestic overburden wells with a high specific capacity are generally found throughout the central portion of the watershed, as illustrated on **Map 2.18**. In particular, wells with a high specific capacity tend to coincide with the Paris and Galt Moraines as well as the Waterloo Moraine. **Map 2.19** indicates a similar pattern, where high specific capacity, non-domestic overburden wells are generally located along parts of the Paris and Waterloo moraines. In addition, high specific capacity wells are located within the Norfolk sand plain where many irrigation wells have high specific capacity values (Holysh et al., 2001).

2.6.2.5 Major Groundwater Recharge Areas

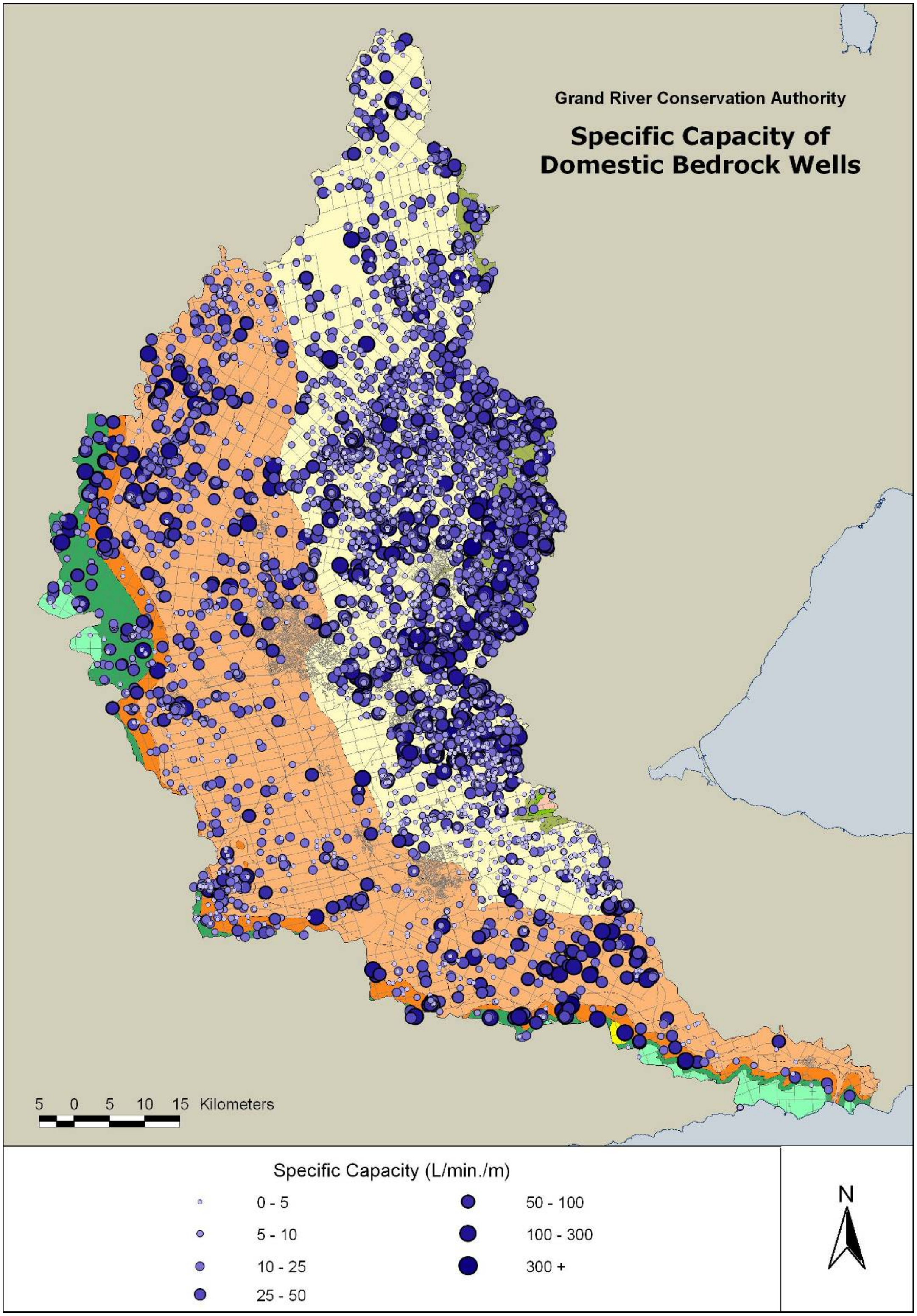
Groundwater recharge occurs throughout the Grand River watershed, as indicated on **Map 2.20**. The rate of recharge is dependent on slope of the ground surface, soil moisture, grain size and stratification (Waterloo Hydrogeologic, 2005).

The areas of highest recharge tend to coincide with the moraine features within the watershed (shown on **Map 2.4** and **Map 2.5**). These include the Galt, Paris and Waterloo Moraines in the central portion of the watershed and the Orangeville Moraine located in the northern portion of the watershed. These moraines are commonly comprised of permeable, coarse-grained deposits and consist of areas of hummocky topography (disconnected drainage), allowing for extensive infiltration and recharge. These moraine areas represent very significant recharge zones for the watershed’s major aquifers.

Where recharge in the areas of the Galt, Paris and Waterloo Moraines contributes to the groundwater system in the overburden deposits, the Orangeville Moraine is a major recharge area that contributes to the bedrock aquifers in the region. In addition to the moraine features, areas within the Upper Grand watershed contain isolated, interspersed pockets of coarse-grained glaciofluvial outwash deposits which allow for high recharge rates.

To the southwest, the Norfolk Sand Plain is an area characterized by thick deposits of highly permeable, coarse-grained sands. High recharge supports an extensive unconfined overburden aquifer throughout the Norfolk Sand Plain. Potentially a large quantity of recharge from this area leaves the watershed as subsurface flow across the watershed boundary.

Map 2.16: Specific Capacity of Domestic Bedrock Wells in the Grand River Watershed



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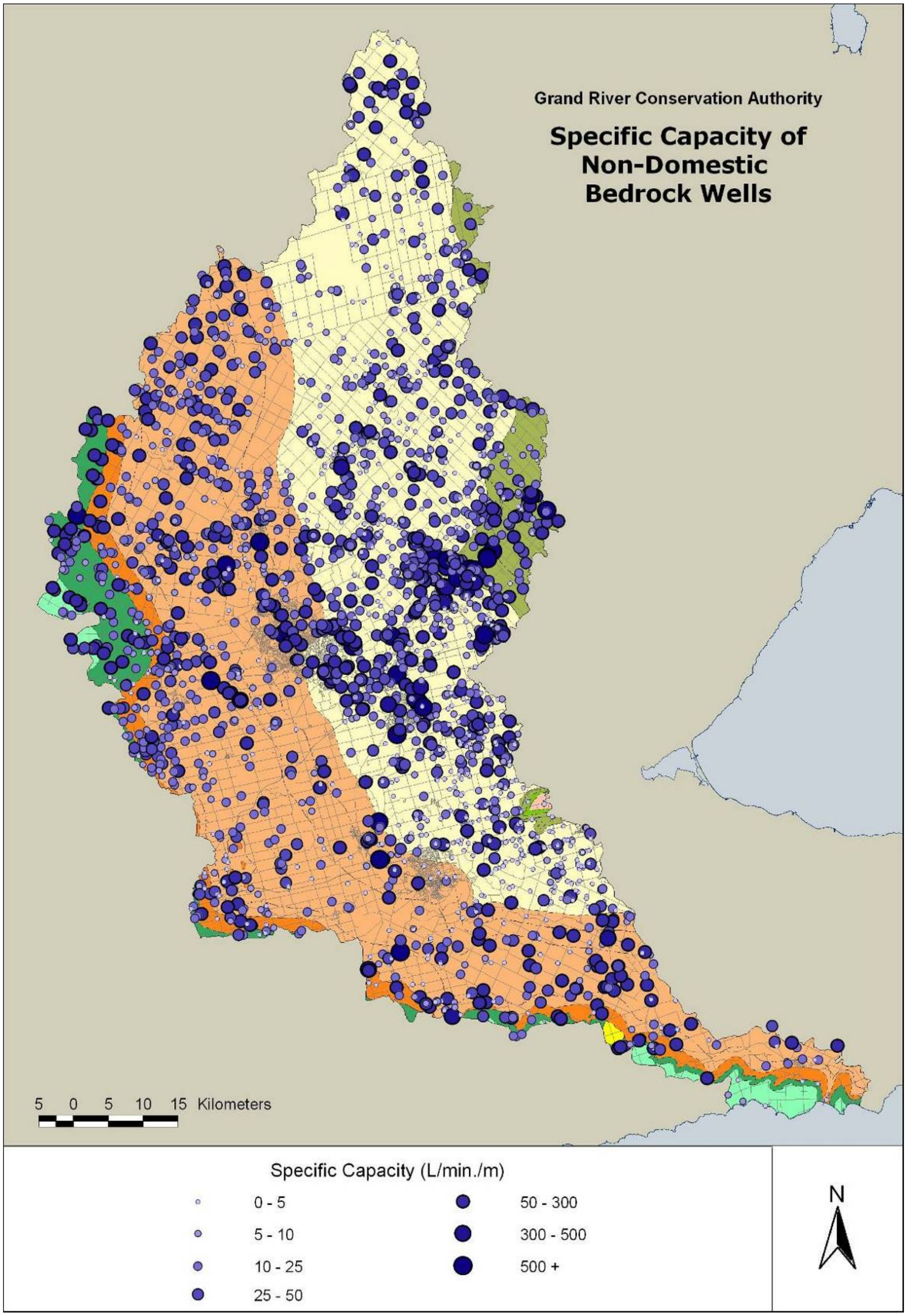
Map 2.17: Specific Capacity of Non-Domestic Bedrock Wells in the Grand River Watershed



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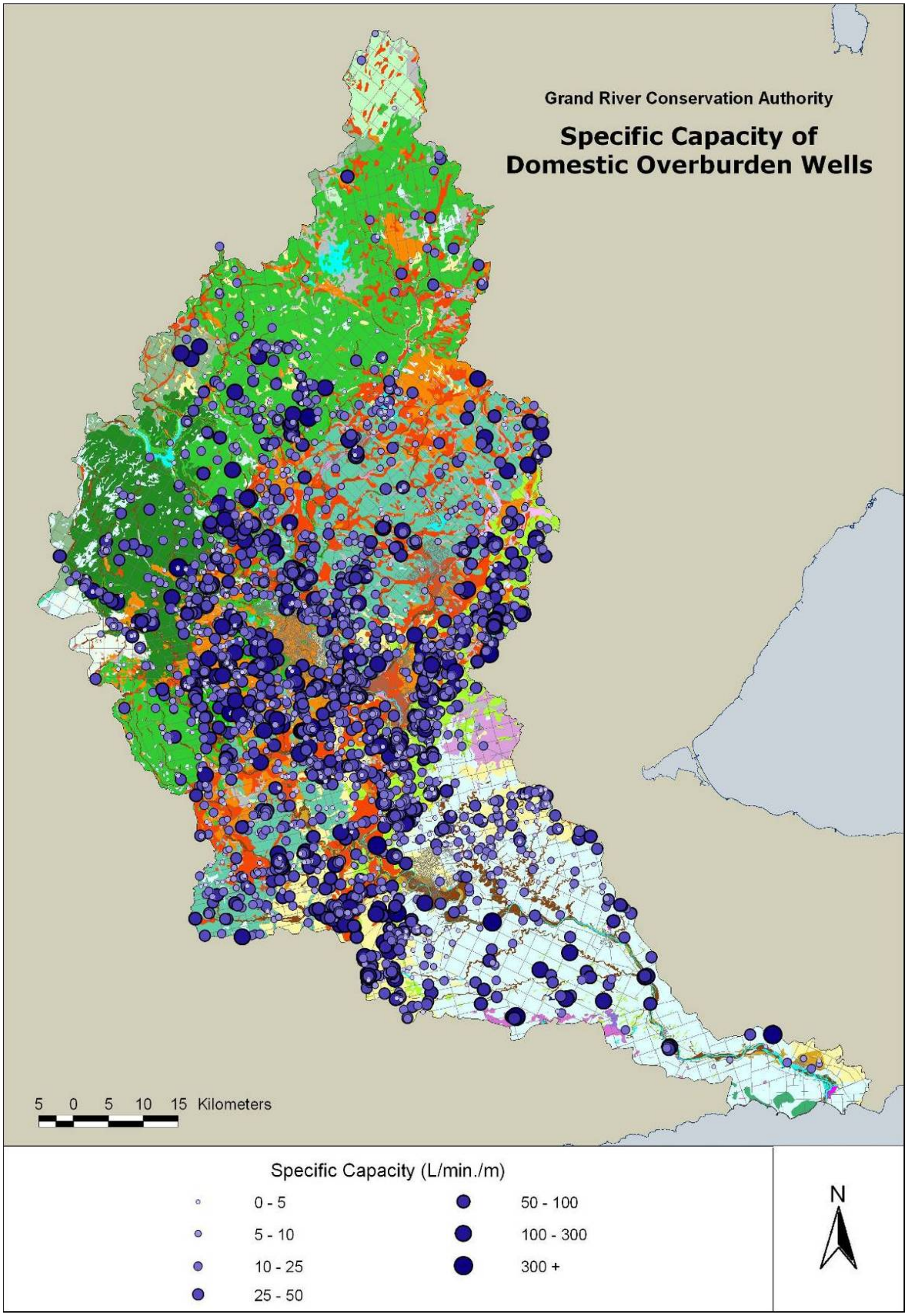
Map 2.18: Specific Capacity of Domestic Overburden Wells in the Grand River Watershed



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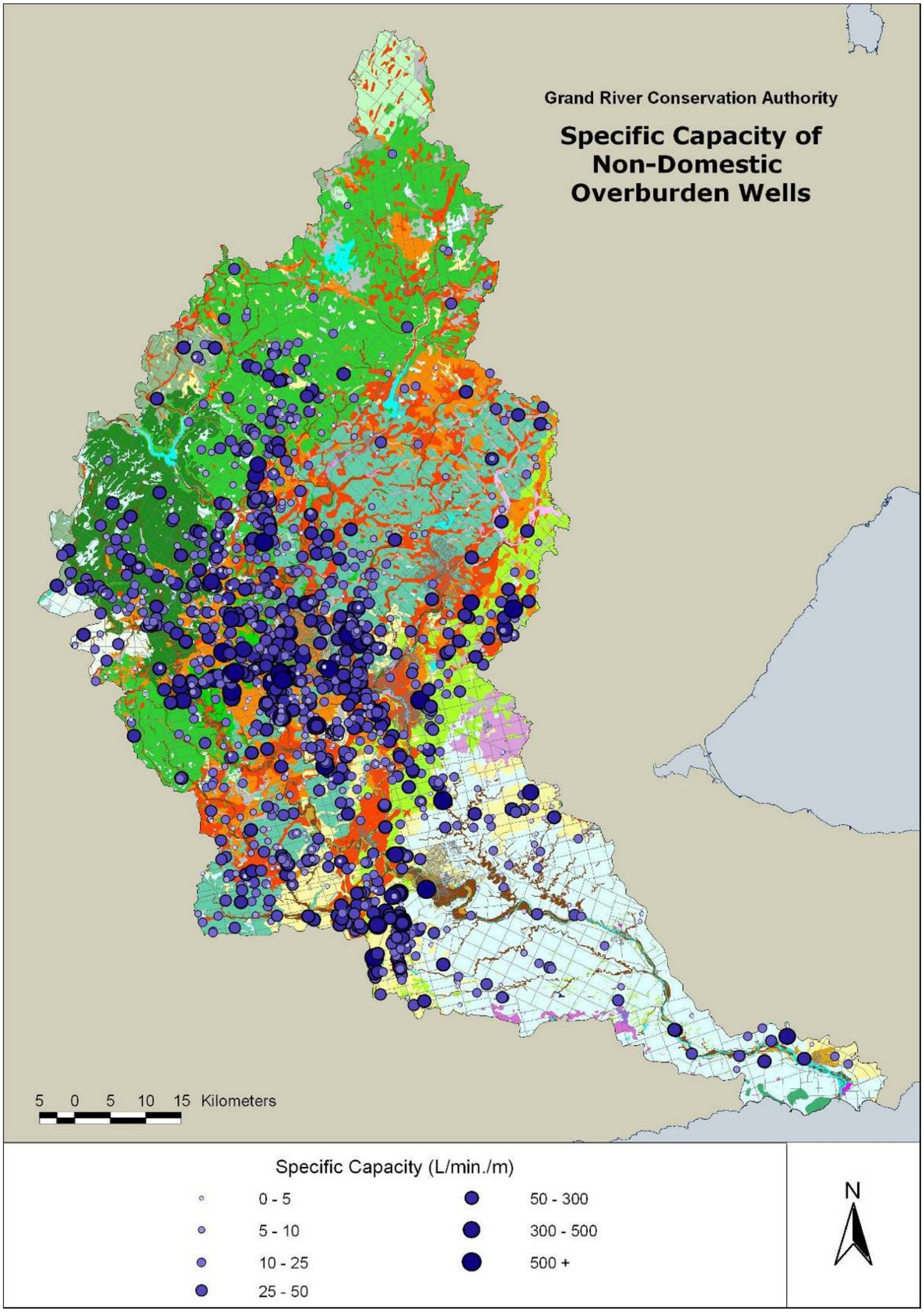
Map 2.19: Specific Capacity of Non-Domestic Overburden Wells in the Grand River Watershed



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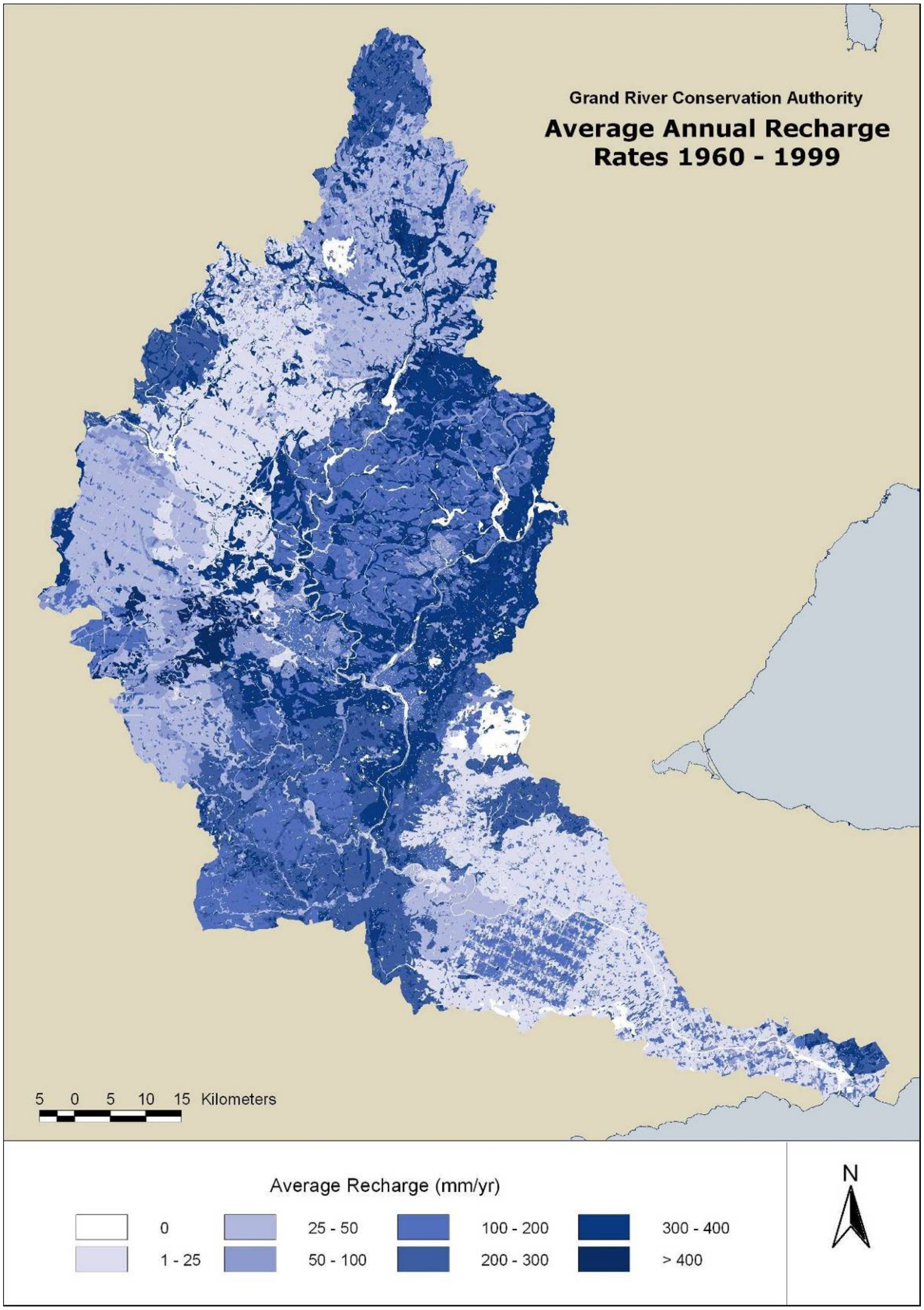
Map 2.20: Significant Groundwater Recharge Areas in the Grand River Watershed



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The northern portions of the watershed, including the Upper Conestogo River, Upper Nith River and the Irvine River, generally consist of consolidated till deposits with low permeability that inhibit water movement through to the subsurface. Towards the south of the watershed, the fine-grained clay-rich deposits characteristic of the Haldimand Clay Plain inhibit recharge in this area.

2.6.2.6 Major Groundwater Discharge Areas

As indicated on **Map 2.21**, major discharge areas within the Grand River watershed are associated with the major river corridors, especially along the lower Nith River and the Grand River south of Cambridge (Waterloo Hydrogeologic Inc., 2005). In addition, Luther Marsh, Belwood Lake and the Orangeville Reservoir are examples of significant wetland areas that are indicated as being groundwater discharge areas (Holysh et al., 2001). Groundwater discharge areas within the watershed have resulted in significant ecological habitat for cold water aquatic species, such as rainbow trout. Particularly, the stretch of the main Grand River from Paris to Brantford is known for significant groundwater discharge, and has spurred resurgence in trout populations within the last decade as water quality has improved.

Of additional note, the clay plain located in the southern portion of the watershed is a very limited discharge area due to the low permeability of both the surficial materials and soils in the area.

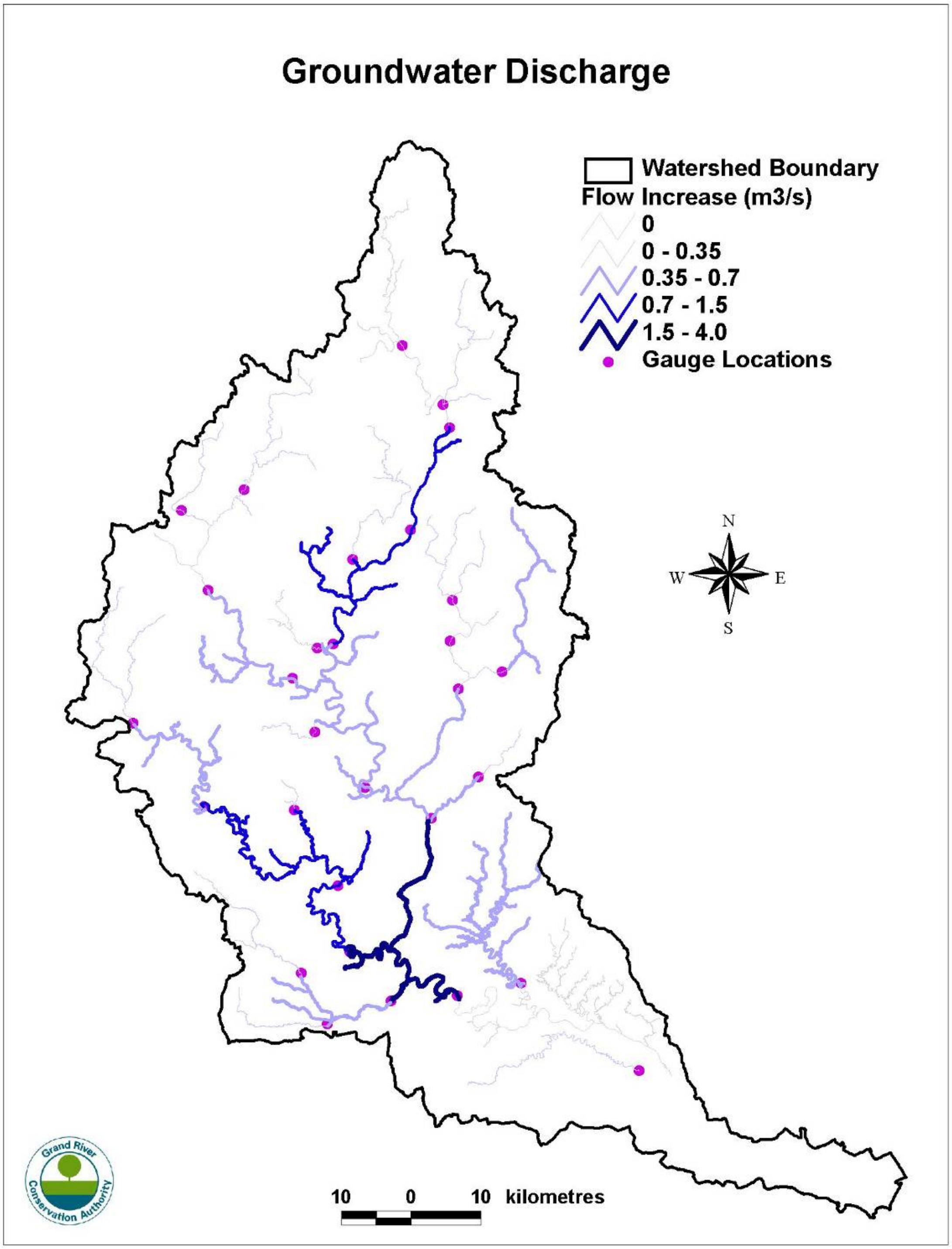
2.6.3 Surface and Groundwater Interactions

Interactions between groundwater and surface water systems in the Grand River Watershed are very important. Groundwater discharge sustains many watercourses through dry periods resulting in significant ecological habitat and improved water quality. On the other hand, recharge from surface waters supports groundwater aquifers which are a significant source of drinking water in the watershed.

Within the Grand River Watershed, groundwater recharge occurs over much of the landscape. However the rate at which recharge occurs is dependant on the nature of the overburden material, where highest rates of recharge occur on coarse-grained moraine deposits with disconnected drainage. Groundwater discharge occurs in many of the watercourses in the watershed where stream beds intersect the water table or upward hydrologic gradients drive water through permeable material. This is shown by sustained baseflows in many watercourses and the abundance of cold water aquatic ecosystems. Areas that have been identified with high rates of groundwater discharge include the middle portions of the Grand River, in particular the reach between Cambridge and Brantford, the Nith River below New Hamburg, the Lower Eramosa River including Blue Springs Creek, the Speed River below Guelph, and Whiteman’s Creek.

Major areas of potential discharge to the Grand River include the reach between Legatt and Shand Dam, the reach below Elora through Kitchener, and the reach from Cambridge to Brantford (AquaResource 2006 draft). The massive discharge zone downstream of Cambridge is most likely produced from a combination of the Galt Moraine to the east and the presence of large overburden aquifers to the west. Discharge in this area adds as much flow to the river as either Shand or Conestogo dams, allowing water quality to recover after large urban influences upstream.

Map 2.21: Groundwater Discharge Areas in the Grand River Watershed



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The lower Nith River and some of its tributaries including Cedar Creek receive large quantities of groundwater discharge from moraines and other coarse-grained deposits. This area of the Nith River watershed is characterized by thick deposits of coarse-grained sand and gravel which support extensive overburden aquifers. Both local and regional groundwater flow systems may contribute to groundwater discharges through this subwatershed.

The lower Eramosa River including Blue Springs Creek and the Speed River below Guelph pass though areas receiving groundwater discharge. The Lower Eramosa River receives discharge from both bedrock aquifers and overburden sediments (Gartner Lee 2004). Unconfined aquifers are located along much of the river's length in this area. Groundwater discharge contributes to healthy cold water aquatic ecosystems in this subwatershed.

Whiteman's Creek flows through a large groundwater discharge zone. Springs and seeps can be found along parts of the creek, which also supports a cold water fishery. Whiteman's Creek flows through the upper part of the Norfolk Sand Plain, an area characterized by thick deposits of coarse-grained and highly permeable sand. High recharge in this subwatershed supports an unconfined overburden aquifer, which in turn discharges to the creek.

There are also areas with little groundwater - surface water interaction. These areas often are characterized by fine-grained, silt- and clay-rich surficial deposits which results in a decreased permeability that inhibits water movement between the surface and sub-surface systems. Areas within the Grand River Watershed with these characteristics include the Haldimand Clay Plain in the south and tight, consolidated tills in the north.

2.7 Water Quality Summary

2.7.1 Water Quality Monitoring

2.7.1.1 Surface Water Quality Monitoring

Surface water quality monitoring has historically focused on characterizing the chemical and physical attributes of the creeks and rivers within a watershed. The Provincial Water Quality Monitoring Network (PWQMN) is an important long-term monitoring program for Ontario which facilitates the characterization of the chemical and physical aspects of water quality. However, financial cutbacks by the province over the last decade, along with limited capacity at Conservation Authorities, have resulted in a decrease in the number of sites monitored and the frequency at which they are sampled.

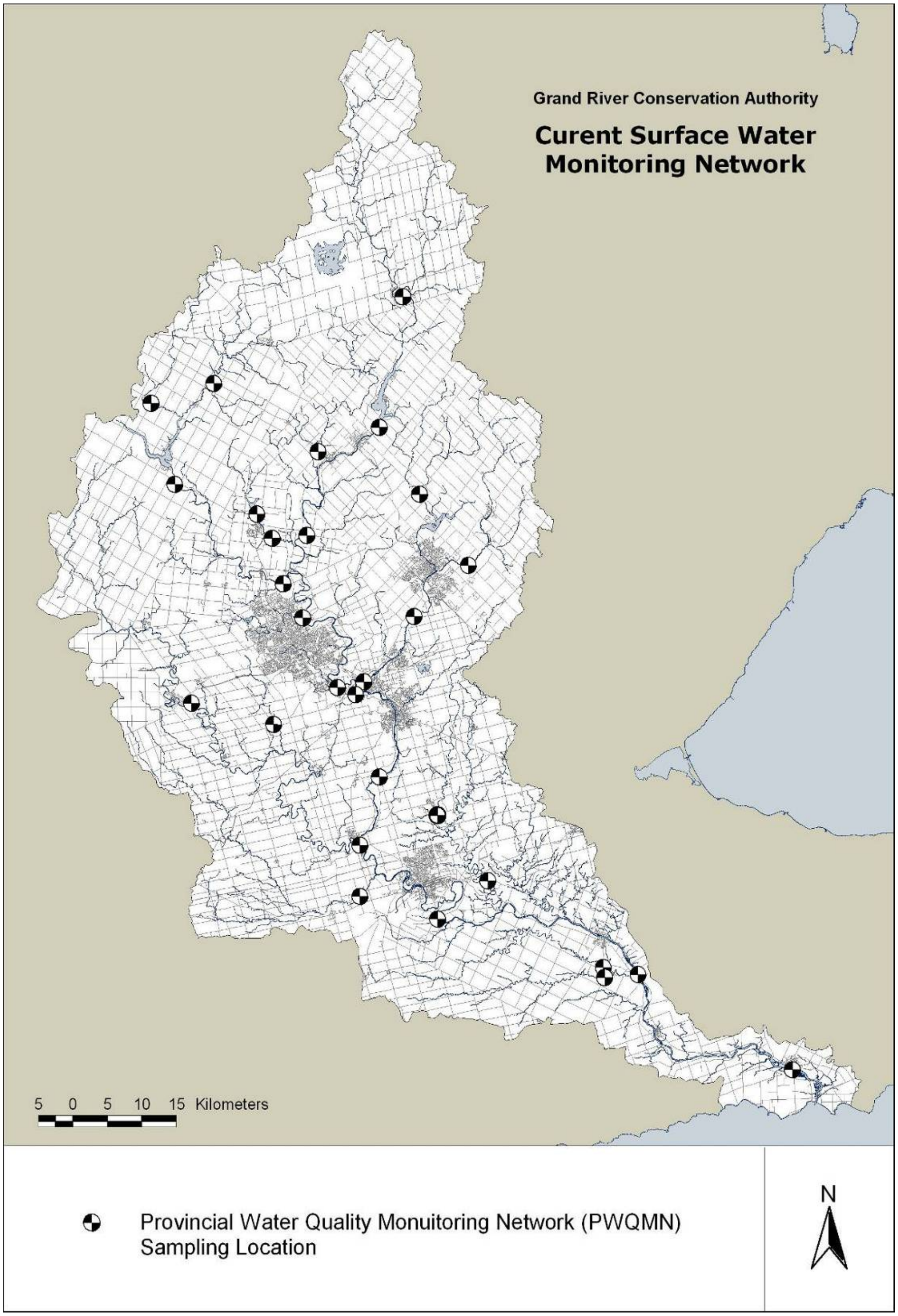
As part of the partnership in the PWQMN program the Ontario Ministry of the Environment (MOE) is responsible for the laboratory analysis while the Conservation Authorities are responsible for collecting the samples. In the Grand River watershed, the number of monitoring sites fell from a high of 45 in 1975 to a low of 28 in 1996. In 1996 when the MOE cut funding to the PWQMN program, the Grand River Conservation Authority's watershed wide monitoring program was scaled back to 28 sites, for which the MOE and the Grand River Conservation Authority (GRCA) both had the capacity to support.

The number of annual samples taken per site has also declined over the years. Currently the MOE allows for eight samples per year to be taken at each of the PWQMN sites; however, historically a total of 12 samples per year were taken at each of the sites. Water quality is highly variable and is sensitive to season, time of day, temperature, flow-stage, spills, soil types, basin topography and many other factors. Due to this, water quality samples must be collected over the range of stream-flows that are representative of the stream at the sample-collection site (Environmental Commissioner of Ontario, 2002; Painter et al., 2000). Consequently, many samples are required to adequately characterize water quality over a range of environmental conditions. Painter et al. (2000) recommends that at least ten samples be taken per year to adequately characterize ambient surface water quality in streams, while Maybeck et al. (1996) suggest 12 samples per year for a multipurpose monitoring program, such as the PWQMN. The current eight samples per year per site limits the network's ability to characterize water quality over a full range of environmental conditions such as low and high flows or the effects of seasonality (e.g. under ice conditions). Therefore, any interpretation of the PWQMN data must be in context of the flow and seasonal conditions represented by the data.

Historically, water quality samples collected at sites in the Grand River watershed were generally collected during low to moderate flows (**Figure 2.17**). This was likely a result of limited manpower and logistical challenges associated with sampling high flow events. However, starting in 2003 there has been a concerted effort to characterize high flow events.

Under the current PWQMN program, the Grand River Conservation Authority (GRCA) monitors 28 sites, which have all been historically sampled (**Map 2.22**). In addition to the PWQMN sites, nine monitoring sites were added as part of the Grand River Conservation Authority's enhanced monitoring program, in 2004, to increase the spatial coverage of the water quality monitoring network (**Map 2.23**). This program is entirely funded by the GRCA and samples are analysed by a private laboratory. Each of the 37 sites within the current monitoring network are sampled between eight and ten times per year to be consistent with the PWQMN program.

Map 2.22: Provincial Water Quality Monitoring Network in the Grand River Watershed



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Map 2.23: Enhanced Water Quality Monitoring Stations in the Grand River Watershed

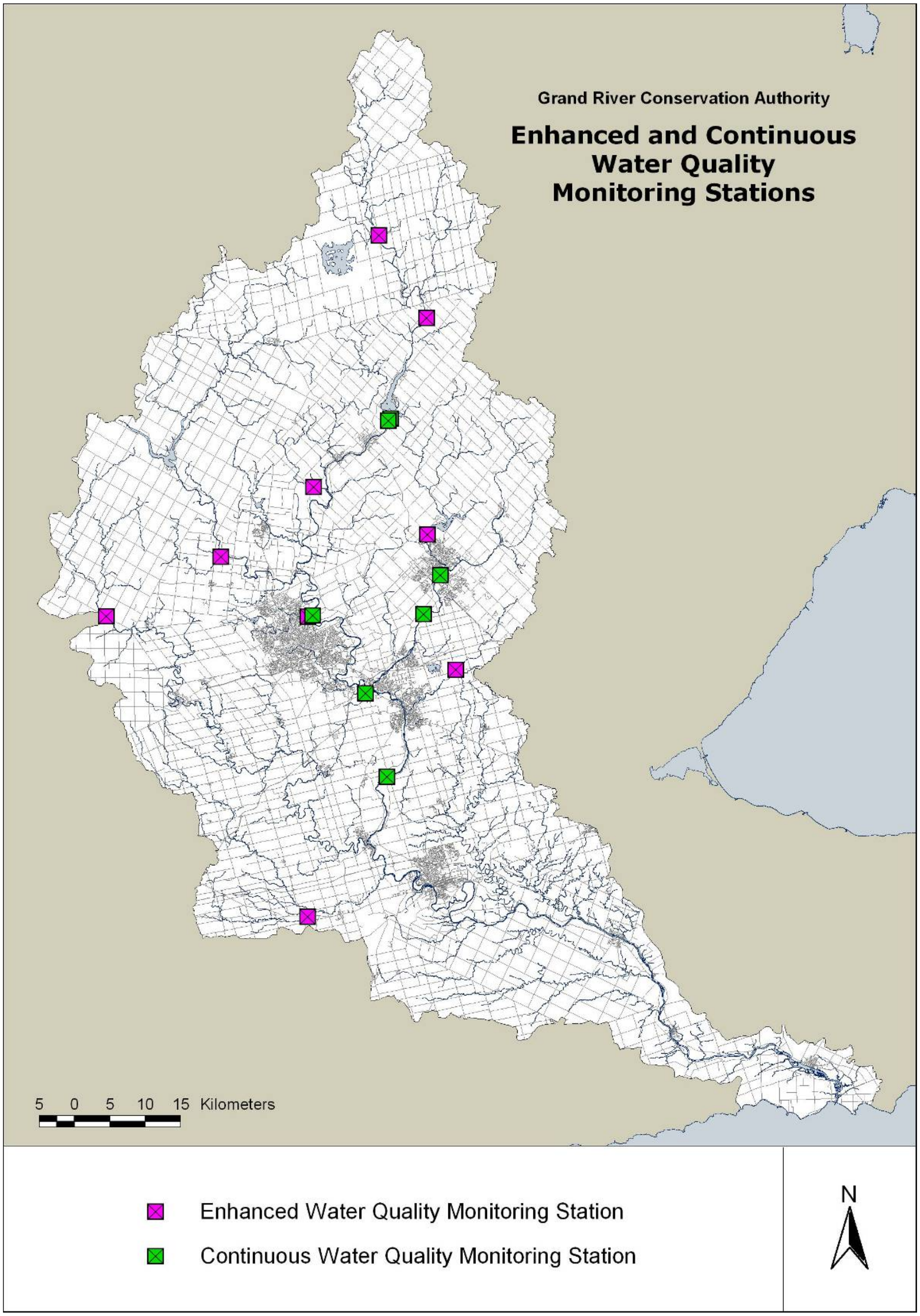
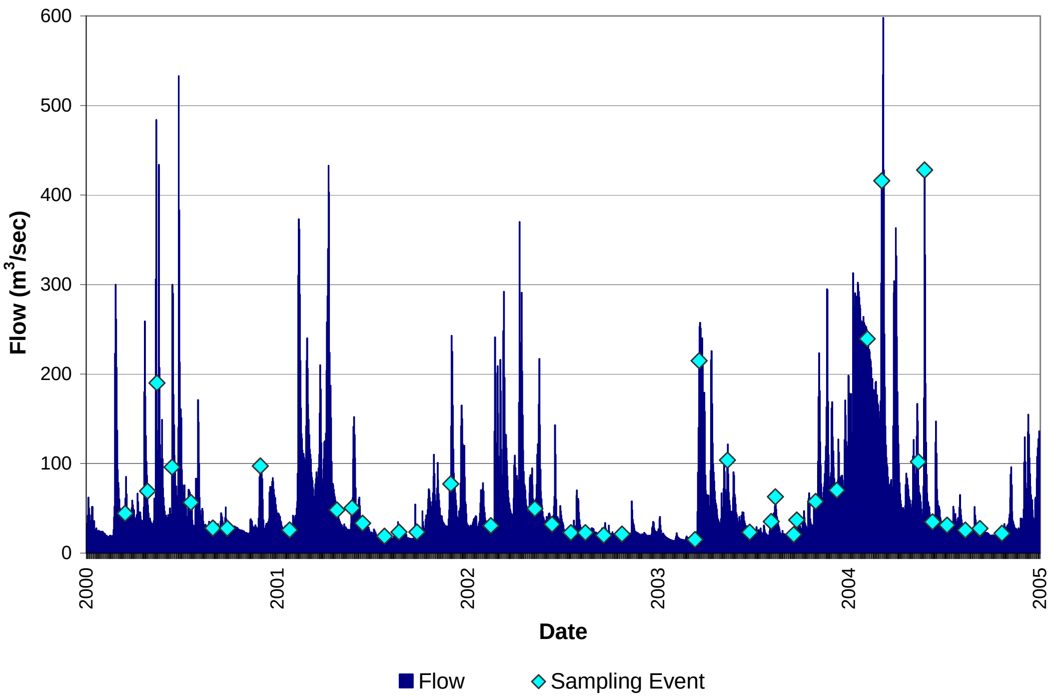


Figure 2.17: Water Quality Sampling Events as they Relate to River Flow at Brantford from 2000-2004



Current water quality samples are analyzed for routine chemistry, nutrients and metals (**Table 2.2**). For more information on laboratory methods and detection limits refer to Ontario Ministry of the Environment (1994). Water samples were collected using standard bridge-sampling techniques as set out by the Ministry of the Environment (MOE) (Aaron Todd pers. comm.). A stainless steel pail is used to collect water samples. Water is poured into bottles, preserved if necessary, stored on ice and couriered to the laboratory.

PWQMN site 16018403502 (Dunnville Bridge) has been targeted to take in excess of 30 samples to help characterize river flow and provide an estimate of the loading to Lake Erie. River samples collected at this site are also routinely analyzed for pesticides and other contaminants of concern. This enhanced tributary monitoring is part of an MOE initiative and is carried out by a private consultant.

Pesticides were also collected from 18 sites in 2003 and 2004 in partnership with the MOE and the Ontario Ministry of Agriculture and Food (OMAF). These pesticide monitoring sites were chosen to represent smaller subwatersheds that had either agricultural or urban land uses (Cooke, 2006). Surveys were completed twice a year from 2003 to present to capture high and low flow periods. The purpose of the June survey was to target a pre-application period while the August survey was targeted as a post application period. Effort was made to also sample wet weather events.

Table 2.2: List of Water Quality Variables Analyzed in PWQMN Stream/River Samples

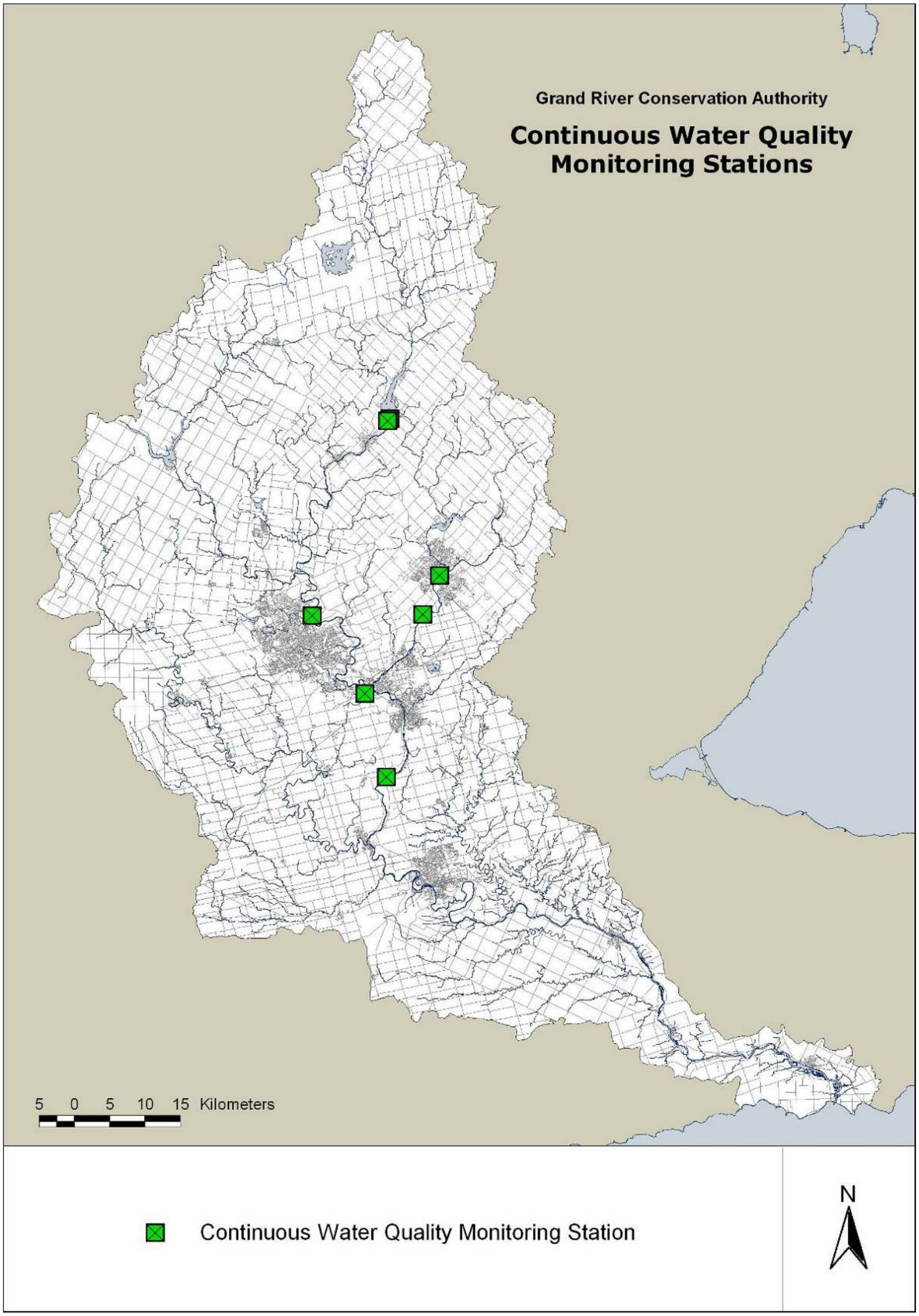
Water Quality Variable Category	Water Quality Variables
Nutrients	Dissolved Nutrients: ammonia, nitrate+nitrite; phosphate
	Total Nutrients: Total phosphorus, Total Kjeldahl nitrogen
Solids	Total Suspended solids; Total dissolved solids
Major Ions/Anions	Calcium; Magnesium, Sodium, Potassium; Hardness; Chloride
Routine Chemistry	pH; Alkalinity; Conductivity
Metals	Aluminum; Barium, Beryllium; Cadmium; Chromium, Copper; Iron; Manganese; Molybdenum; Nickel; Lead; Strontium; Titanium; Vanadium; Zinc
Routine Physical	Turbidity; Temperature
Pesticides*^	Phenoxy Acid Herbicides°; Triazine Herbicides°; Organophosphorus insecticides°

* only sampled at one site: 16018403502 (at Bridge in Dunnville) as part of MOE's Enhanced Tributary Monitoring Program
° includes currently registered and phased out products
^ for a complete list of pesticide products, see Cooke, (2006).

Dissolved oxygen, conductivity, pH and temperature are collected in the field at each PWQMN and GRCA Enhanced site using a handheld YSI™ data sonde. These parameters are also monitored continuously at seven monitoring stations (separate from the PWQMN) in the Grand River watershed using Hydrolab™ or YSI™ data sondes (**Map 2.24**). The data are primarily collected to support the Grand River Simulation Model (GRSM), which models the dissolved oxygen levels within the Grand and Speed Rivers for the purpose of assessing their assimilative capacity, as well as to provide information on the state of the river with respect to the protection of aquatic health. Two additional continuous monitoring stations are currently under construction. The first is situated on the Grand River upstream of the Holmedale drinking water intake in Brantford, and the second is situated at Victoria Street in Kitchener between the Waterloo wastewater treatment plant and the Kitchener (Mannheim) drinking water intake. Information from the continuous stations is also used for reporting and operational purposes (e.g. the two stations at Shand Dam).

River water samples are not routinely collected at the 28 long term river monitoring sites for bacteria or pathogens. Significant variability in sampling and analysis methodologies provides for some hesitation when including these parameters as part of a long term monitoring program. However, river water samples are collected weekly from the Grand River through the Elora Gorge Conservation Area during the summer months (May – August) and analyzed for *E. coli*. The water samples are submitted to an accredited laboratory for analysis. Although these data are from one location in the Grand River, they do provide some insight into the range of *E. coli* concentrations found in the upper-middle Grand River.

Map 2.24: Continuous Water Quality Monitoring Stations in the Grand River Watershed



There are other programs carried out by the GRCA which include some form of surface water quality sampling but tend to be on a subwatershed or site specific scale and for a relatively short period of time. These include monitoring of benthic macroinvertebrates (see **Section 2.8.2**), water quality sampling as part of the subwatershed or rural water quality programs, and short term projects such as the exceptional waters program.

2.7.1.2 Groundwater Quality Monitoring

Groundwater is primarily monitored in Grand River Watershed through the Provincial Groundwater Monitoring Network (PGMN), a network of wells distributed throughout the province that provide insight on long-term ambient trends and conditions. The monitors are typically sited so that they are reflective of broad hydrogeologic conditions, away from areas where pumping or contamination may impact those data collected. The MOE owns the monitoring infrastructure and manages the data gathered through the program, but in many cases the program is locally administered by Conservation Authorities.

There are currently 24 PGMN wells at 18 locations within the Grand River Watershed. The wells are distributed throughout the watershed, with the most number of wells located throughout the Region of Waterloo (see **Map 2.25**). Eleven wells are completed within the overburden deposits of the Waterloo Moraine, 1 well is within the Paris Moraine, and another overburden well is located within the Norfolk Sand Plain. A total of 8 wells are completed within the Guelph Formation and another 1 well each within the Amabel Formation, Salina Formation and Oriskany Formation. Water levels in the wells are monitored through a combination of manual and electronic means. Where electronic dataloggers are in place, water levels are recorded hourly and uploaded to the MOE on a prescribed basis. Manual measurements are made in all wells on a quarterly basis. An annual water quality sampling program commenced in 2006.

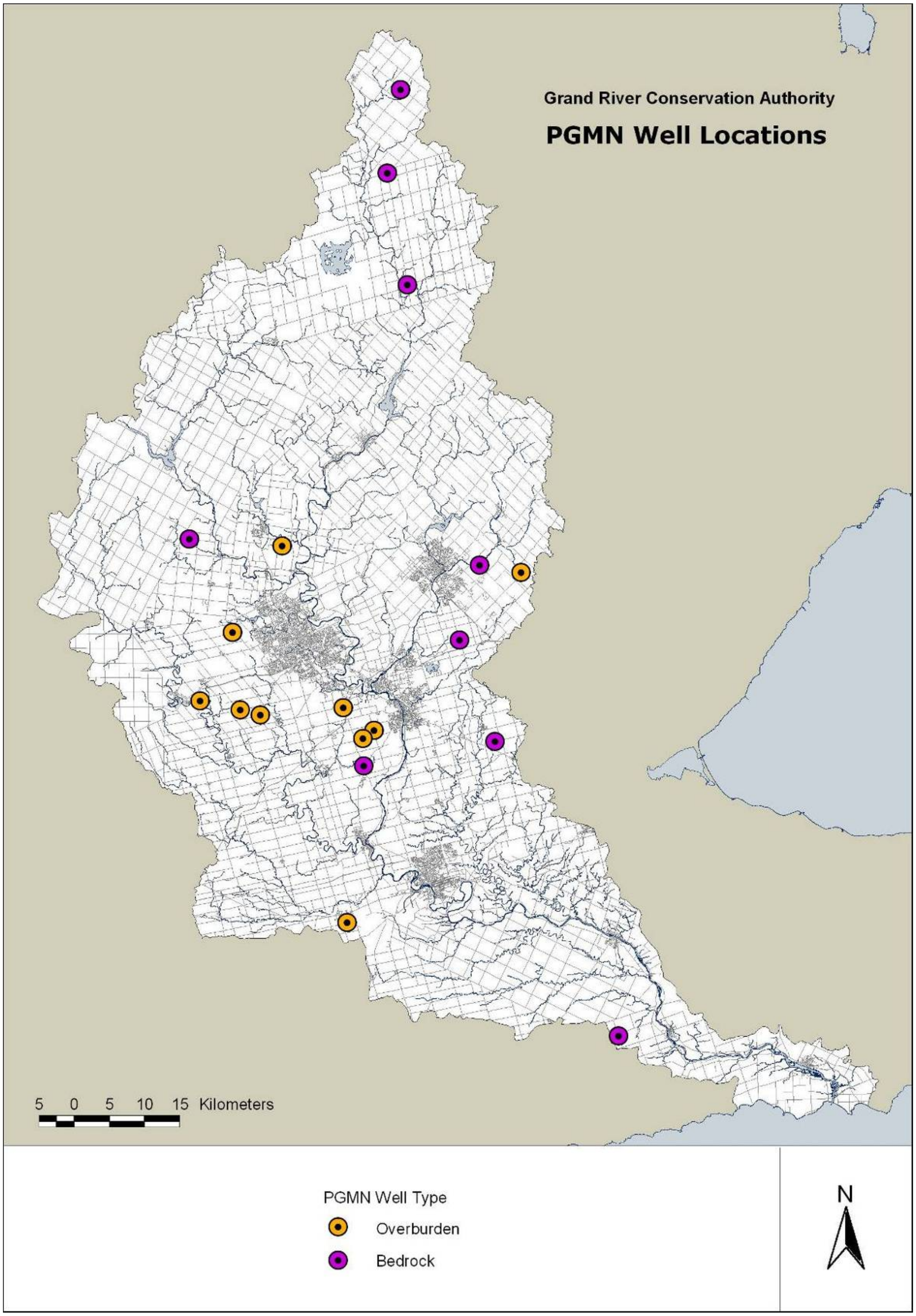
2.7.2 Surface Water Quality Conditions and Trends

The following summary is based on findings from *the Water Quality Technical Assessment Report for the Grand River Watershed*, which examined the most recent contiguous five year set of data (2000-2004) in an attempt to identify the water quality conditions and trends found within the watershed (Cooke, 2006). A list of the 28 long-term water quality monitoring sites with their PWQMN site identification number, short identification number and site description can be found in **Table 2.3**.

Water quality sampling within the Grand River watershed occurred on a routine basis whereby flow was not always considered. This is evident when dates of sampling events are graphed against stream flow (see **Section 2.7.1**, **Figure 2.17**). Generally, sampling was performed across a range of flows; however, peak events were missed for some years. This potential bias towards sampling at low to moderate flows indicates that the results from the monitoring data presented here has mainly characterized base-flow and likely has not captured the changes in water quality which occur during high flow events.

In general, nutrient concentrations within the Grand River tend to be high where as metal concentrations usually comply with guidelines.

Map 2.25: Provincial Groundwater Monitoring Network Well Locations in the Grand River Watershed



The inherent geology and current land use practices appear to drive some of the chronic surface water quality issues within the Grand River watershed. For example, subwatersheds draining the clay and till plains tend to have the highest non-filterable residue and nutrient concentrations (e.g. Nith River, Fairchild Creek). Subwatersheds with intensive agricultural production or urban development also contribute to the overall high nutrient levels within the Grand. Water quality in the lower reaches of the Grand River reflects the cumulative impact of the upstream watershed (e.g. effluent from the 27 sewage treatment plants in the watershed) and the underlying geology as it tends to progressively deteriorate as it travels from the Shand Dam (upper middle Grand) towards Brantford (lower Grand).

The central portion of the Grand River, including the major tributaries draining into this reach such as the Canagagigue Creek, Conestogo River and lower Speed River, tends to be the area within the watershed where water quality is most impaired. Land use including intensive agricultural production, urban development and wastewater treatment plant effluents in this area likely contribute to the degradation in water quality. Sites experiencing nutrient enrichment tend to be downstream of the major urban areas with the exception of the intensive agricultural areas in the Canagagigue Creek. High levels of phosphorus and nitrogen contribute to prolific aquatic plant growth in locations where conditions are right (e.g. good substrate, shallow, low flows etc) which can lead to depletion of dissolved oxygen levels.

Dissolved oxygen is an important indicator of the river's ability to sustain aquatic life. Certain reaches in the Grand River watershed experience stress with low dissolved oxygen levels (e.g. Grand River at Blair, Speed River at Road 32). However, in 2004 temperatures were cooler and dissolved oxygen levels tended to remain above the four milligrams per litre target.

The impact of the urban development on the Grand River is reflected by the significant increase in the concentrations of phosphorus, total ammonium and chloride as the river flows through the Region of Waterloo from Bridgeport to Blair (**Figure 2.18, Figure 2.19 and Figure 2.20**). Similar impacts are also found within the Speed River below Guelph.

Table 2.3: List of the 28 Long Term Water Quality Monitoring Sites with their PWQMN Site Identification Number, Short Identification Number and Site Descriptions

PWQMN Identification Number	Short ID Number	Site Description
Grand River		
16018403902	39	Downstream of Grand Valley
16018403702	37	Below Shand Dam
16018410302	103	West Montrose
16018401502	15	Bridgeport
16018401202	12	Blair
16018401002	10	Glen Morris
16018402702	27	Brantford
16018409202	92	York
16018403502	35	Dunnville

Table 2.3: List of the 28 Long Term Water Quality Monitoring Sites with their PWQMN Site Identification Number, Short Identification Number and Site Descriptions

PWQMN Identification Number	Short ID Number	Site Description
Irvine River		
16018410402	104	Irvine River
Canagagigue Creek		
16018405102	51	Upper Canagagigue Creek
16018401602	16	Lower Canagagigue Creek
Conestogo River		
16018409102	91	Moorefield Creek
16018410002	100	Upper Conestogo River
16018407702	77	Conestogo River below Reservoir
16018402902	29	Conestogo River near mouth
Speed River		
16018410202	102	Eramosa River
16018409902	99	Upper Speed River
16018403602	36	Speed River at Road 32
16018410102	101	Speed River at Preston
Nith River		
16018403802	38	Alder Creek
16018403202	32	Upper Nith River below New Hamburg
16018400902	9	Nith River at mouth
Fairchild's Creek		
16018404402	44	Upper Fairchild's Creek
16018409302	93	Fairchild’s Creek near mouth
Whitemans Creek		
16018410602	106	Whitemans Creek
Boston/McKenzie Creek		
16018409502	95	Boston Creek
16018409602	96	McKenzie Creek

Figure 2.18: Total Phosphorus Concentrations between 2000-2004 at 28 Long-Term Monitoring Sites in the Grand River Watershed

(Note Log Scale)

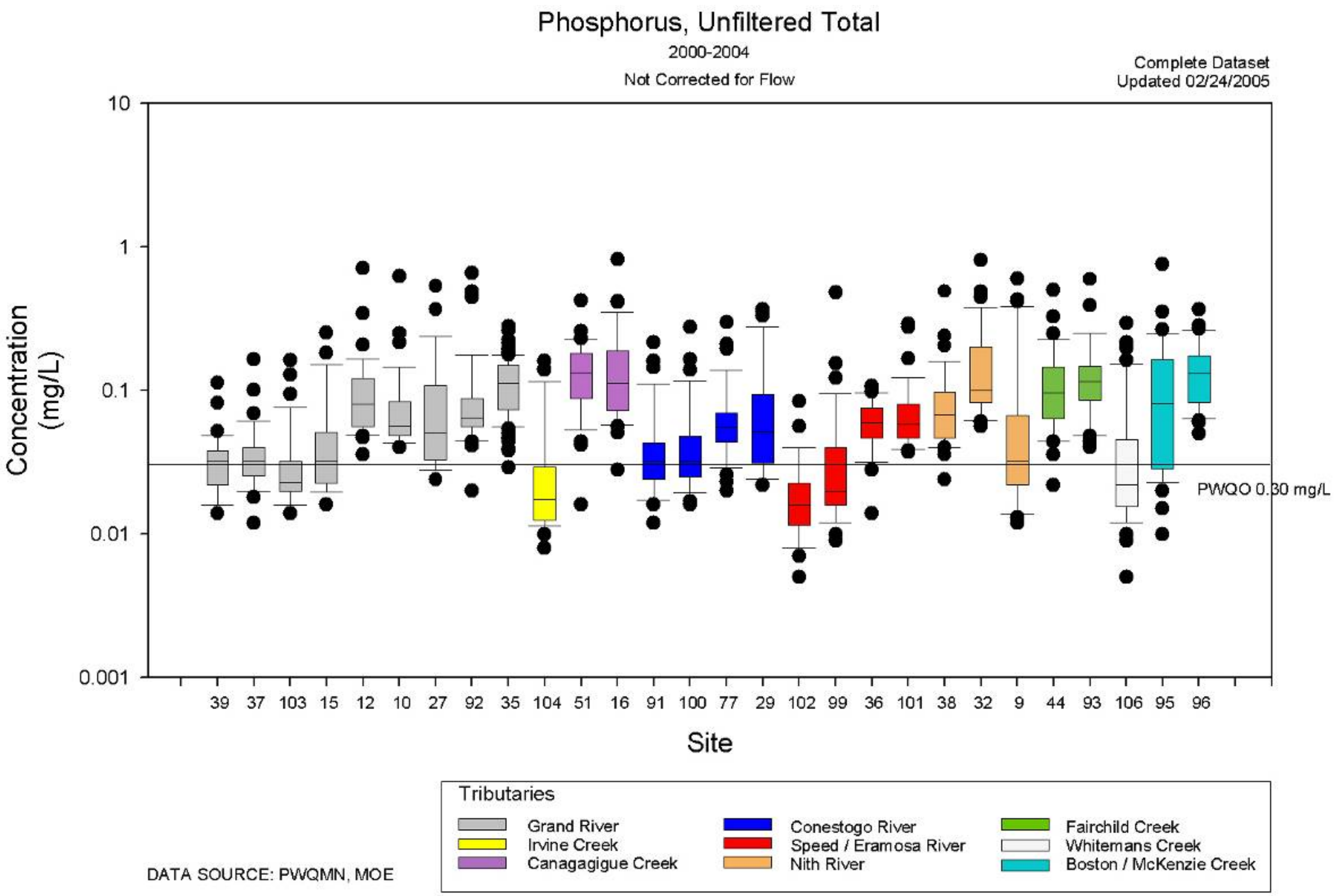


Figure 2.19: Range of Unionized Ammonia Concentrations between 2000-2004 at 28 Long-Term Sampling Sites in the Grand River Watershed

(Note Log Scale)

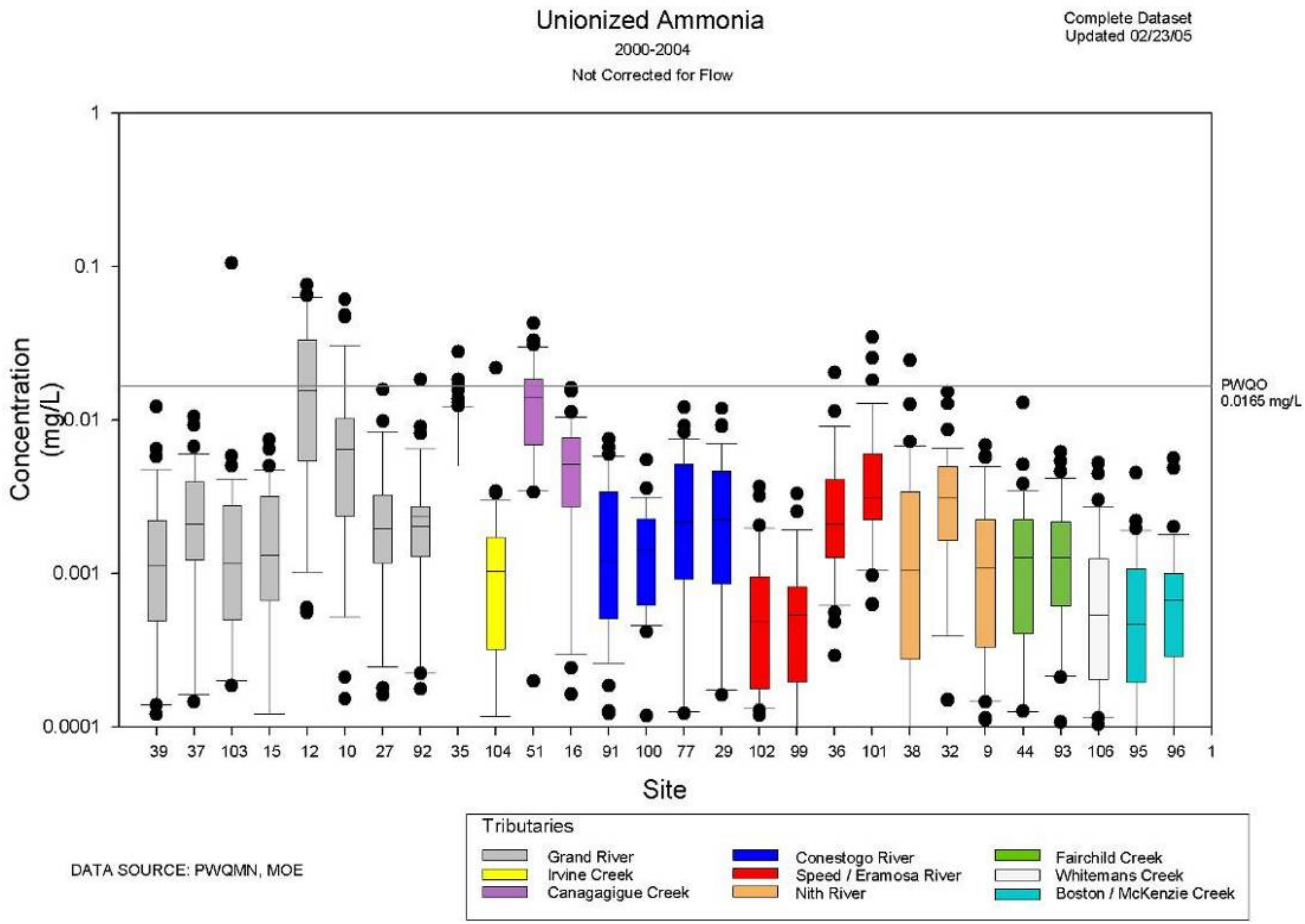
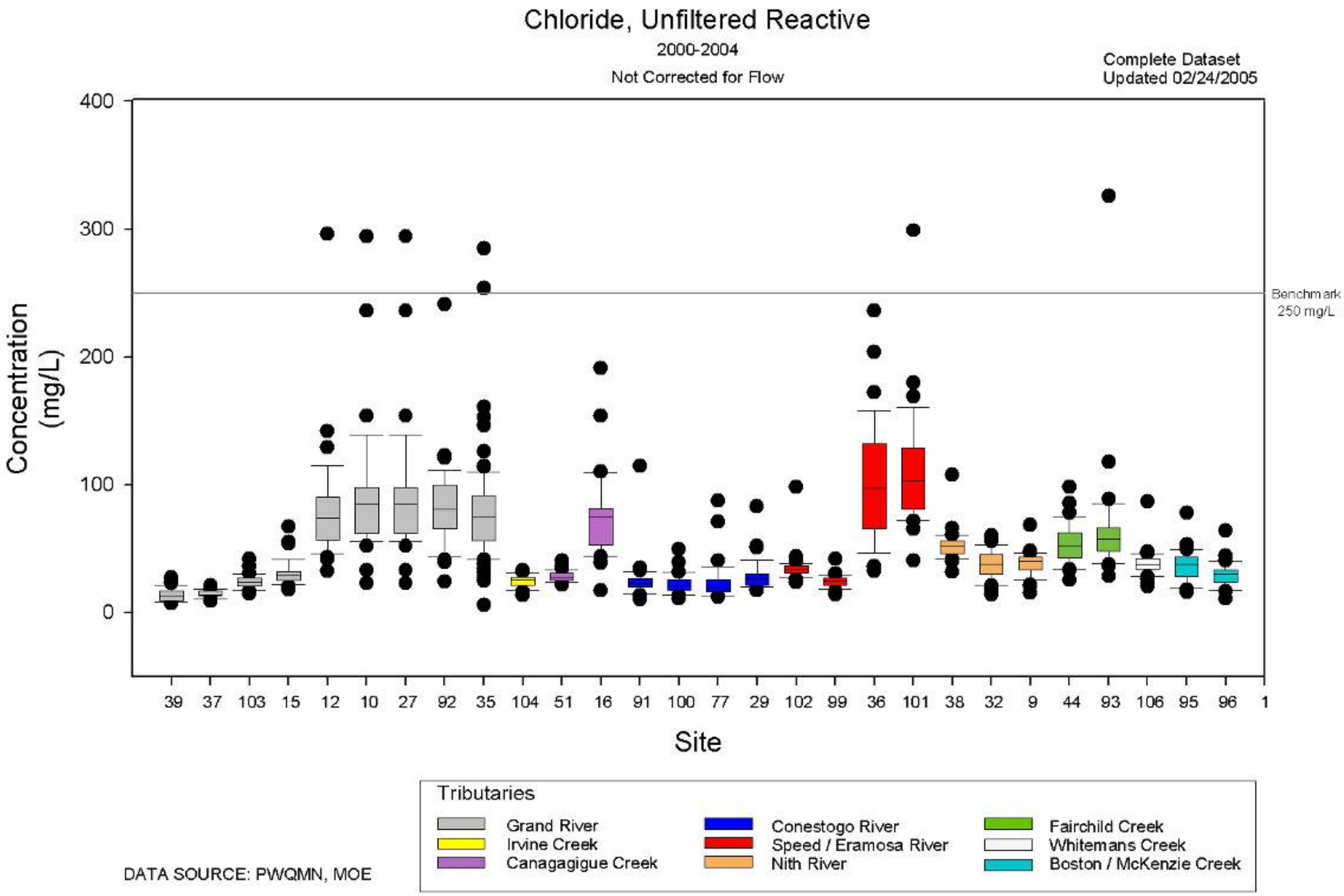


Figure 2.20: Box and Whisker Plots Showing the Range of Chloride Concentrations at 28 Long-Term Monitoring Sites between 2000-2004



In general, non-filterable residue appears to be low throughout the upper and middle Grand River reaches when compared to the lower Grand River (**Figure 2.21**). A distinct change in water quality is evident below Brantford as significantly higher levels of non-filterable residue are seen in the river at York. This is due in part to the high non-filterable residue contributions from the Nith River, but is mainly as a result of the Grand River traversing into the southern clay plain, where it picks up colloidal clay particles that virtually always remain in suspension (GRBWMS, 1979) making it highly turbid. Non-filterable residue and phosphorus increase again in the river at Dunnville likely due to the significant contributions from Fairchild's and McKenzie creeks and river impoundments which makes the river almost lake-like.

Most of the nitrate in the Grand River originates in the upper middle region of the watershed, likely from high concentrations found in Irvine Creek, Canagagigue Creek and Conestogo River (**Figure 2.22**). However, it is evident that contributions from other sources such as shallow groundwater high in nitrates (likely the source of elevated levels in both Whitemans and Alder creeks) and wastewater treatment plant effluent are also impacting the nitrate concentration within the watershed.

Chloride levels in the lower Speed River are among the highest in the Grand River watershed (**Figure 2.20**). Sources include road deicing and likely water softener discharges in the municipal wastewater effluent.

Two surveys conducted on the river for pesticides and other trace organics in 2003 and 2004 reveal that pesticides may not be a widespread issue in the watershed. Pesticides were detected in one intensive agricultural watershed and two urban watersheds. However, two surveys likely do not adequately characterize this issue and additional, targeted surveys are required to understand the breadth of this issue in the watershed.

Very little current information exists on the three major reservoirs in the Grand River watershed. Historic monitoring data suggest that the Guelph and Conestoga Lake reservoirs are eutrophic with very high phosphorus levels in the euphotic zone while the Belwood Lake Reservoir is meso-eutrophic with moderately high phosphorus levels.

Bacteria and pathogen monitoring is not done on a regular basis. Research indicates that bacteria and pathogens are common in the Grand River which is not surprising and generally decrease in concentrations from the upper middle Grand River to the lower reaches of the River.

Some spills and wastewater treatment plant bypasses can be a risk to downstream water users. Of greatest concern are incidents involving industrial chemicals, such as gasoline or diesel and untreated (raw) sewage, since these can contribute chemicals or high levels of pathogens to the river that may impact downstream water users. Typically, raw sewage spills occur at sewage system pumping stations which lose their power or otherwise fail. Incidents of raw manure spills into water courses are also a concern.

Tertiary or secondary bypasses at wastewater treatment plants are likely not a risk to downstream users as the effluent has still received some level of treatment such as nutrient removal and chlorination that kills pathogens before the effluent reaches the river

Figure 2.21: Box and Whisker Plots Showing the Range of Non-Filterable Residue Concentrations at 28 Long-Term Sampling Sites in the Grand River Watershed between 2000-2004

(Note Log Scale)

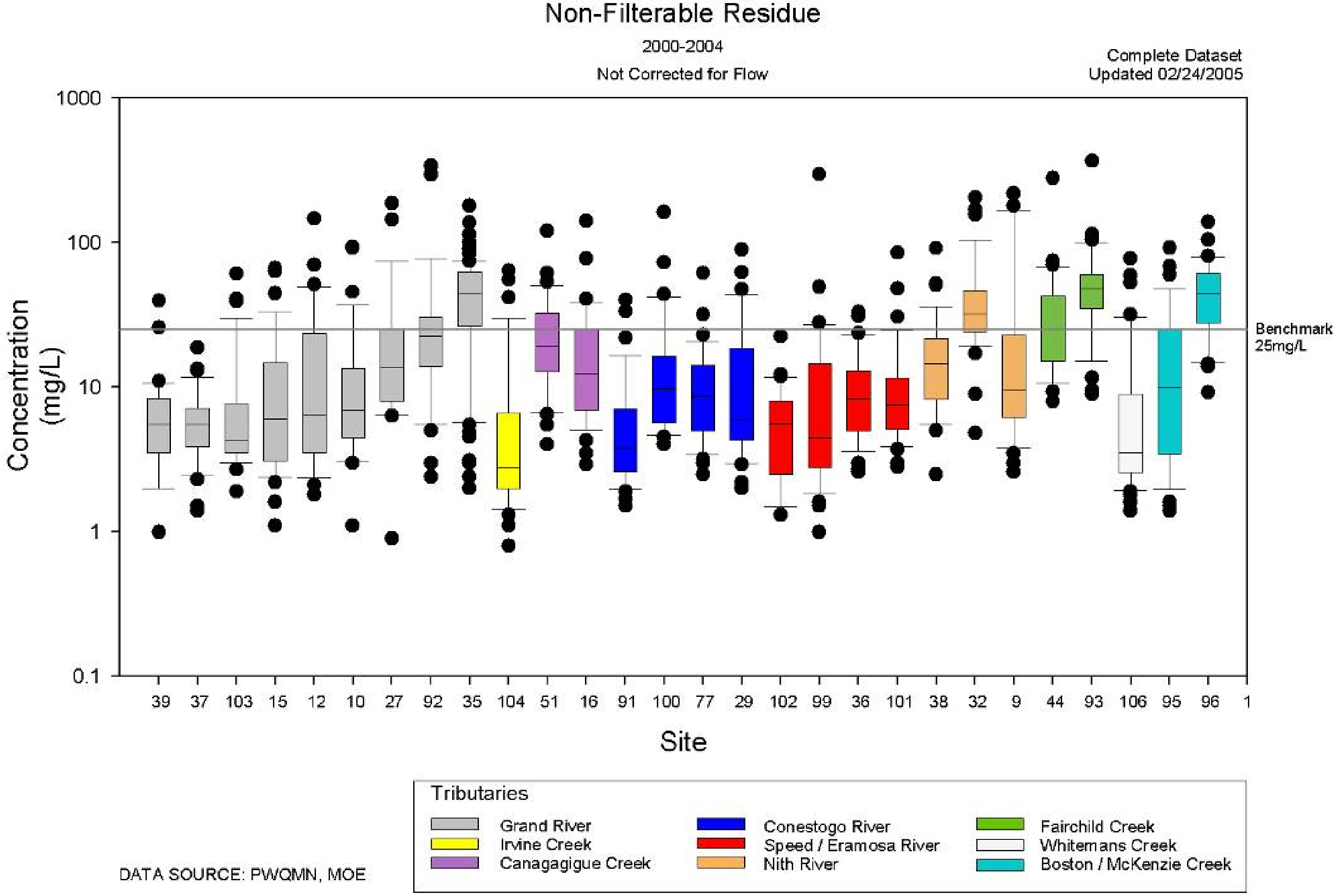
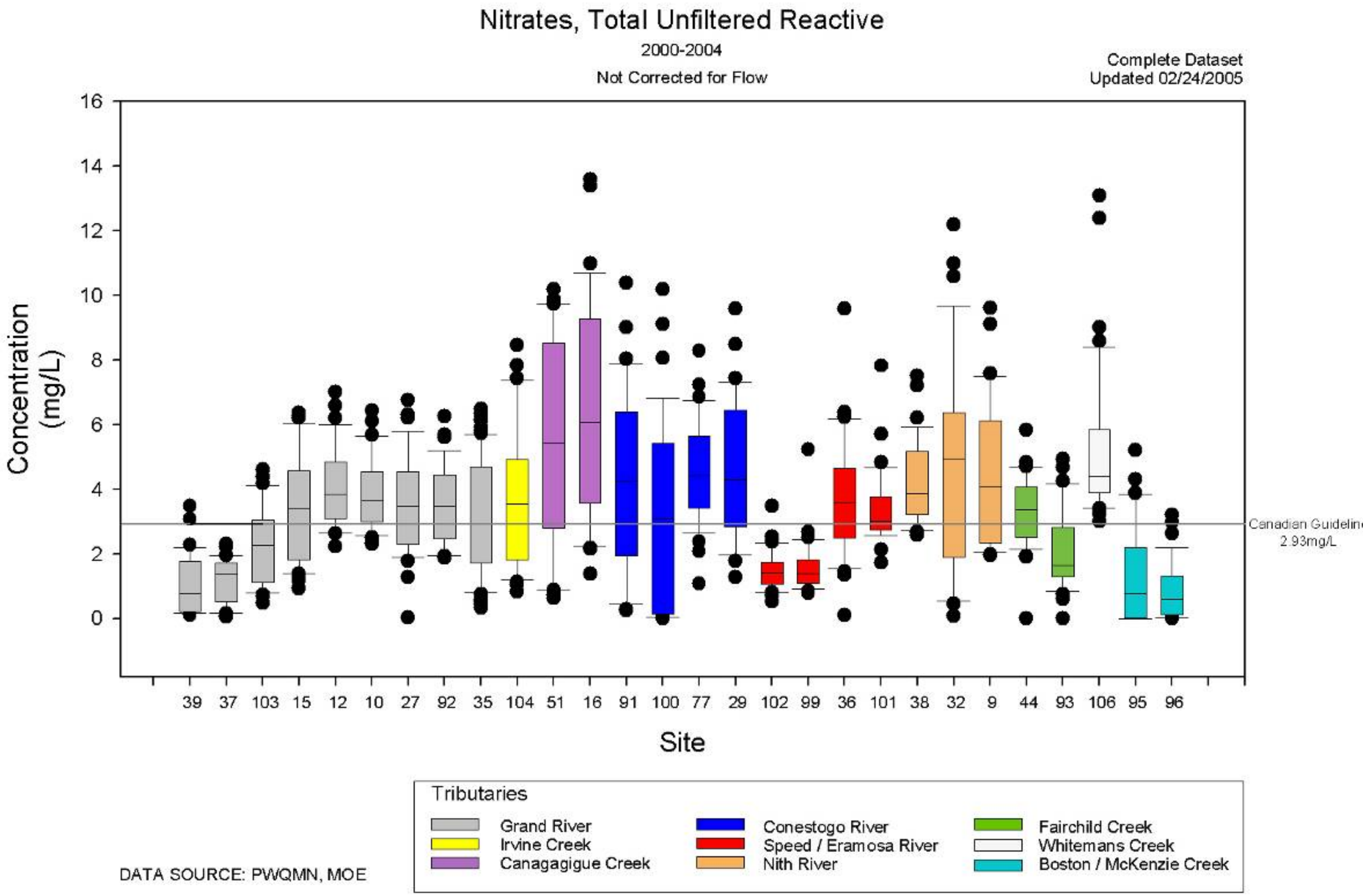


Figure 2.22: Box and Whisker Plots Showing the Range of Total Nitrate Concentrations between 2000-2004 at 28 Long-Term Sampling Sites in the Grand River Watershed



A summary of three years of incidents (2003-05) showed that about 22 spills or bypasses out of a total of 134 (16 per cent) involved raw sewage. (Report on Spills and Bypasses in Grand River Watershed 2003-2005)

In the event of a spill or wastewater treatment bypass, downstream water users, including the Grand River Conservation Authority, are notified by the provincial Spills Action Centre (SAC). The Grand River Conservation Authority works with downstream users and provides necessary information on the time it would take a spill at a particular location to reach downstream drinking water intakes.

Water quality conditions have greatly improved in the watershed since the 1930's and 40's when minimally treated sewage was dumped into the river. In the 1970's many parts of the Grand River and its tributaries were considerably stressed from wastewater treatment plant effluent. A preliminary analysis of temporal trends in nutrient concentrations from 1981-2001 illustrates that total phosphorus concentrations are decreasing however nitrate concentrations are increasing at selected sites (**Table 2.4**). Therefore, continued pro-active planning and implementation by municipal water managers, agricultural producers and watershed residents will help to speed up improvements and slow down further deterioration of water quality in the river so that watershed residents can continue to enjoy the Grand River.

Table 2.4: Summary of Results Seasonal Mann Kendall Trend Analysis for Nutrients, Suspended Sediment and Chloride

Site	Total Phosphorus	Total Ammonium	Total Nitrates	Chloride	Total Suspended Sediment
	Concentrations				
Grand River					
16018403902	↔	↔	↔	↑	↓
16018403702	↔	↔	↔	↑	↔
16018410302	↓	↔	↔	↑	↔
16018401502	↓	↓	↔	↔	↓
16018401202	↓	↑	↔	↑	↔
16018401002	↓	↔	↔	↑	↓
16018402702	↓	↔	↑	↑	↔
16018409202	↓	↔	↑	↑	↓
16018403502	↔	↔	↑	↑	↔
Irvine River					
16018410402	↓	↔	↔	↑	↓
Canagagigue Creek					
16018405102	↔	↔	↔	↑	n/a
16018401602	↓	↔	↔	↔	↔
Conestogo River					
16018409102	↓	↔	n/a	↔	↓
16018410002	↓	↔	↔	↑	↔
16018407702	↔	↔	↔	↔	↓
16018402902	↓	↔	↔	↑	↓
Speed River					

Table 2.4: Summary of Results Seasonal Mann Kendall Trend Analysis for Nutrients, Suspended Sediment and Chloride

Site	Total Phosphorus	Total Ammonium	Total Nitrates	Chloride	Total Suspended Sediment
	Concentrations				
16018410202	↔	↓	↑	↑	↔
16018409902	↑	↔	↔	↑	↑
16018403602	↓	↑	↑	↑	↔
16018410102	↓	↑	↑	↑	↔
Nith River					
16018403802	n/a	n/a	n/a	n/a	n/a
16018403202	↓	↔	↑	↔	↓
16018400902	↓	↔	↔	↑	↔
Fairchild's Creek					
16018404402	n/a	n/a	n/a	n/a	n/a
16018409302	↓	↔	↑	↑	↓
Whitemans Creek					
16018410602	↔	↔	↑	↑	↔
Boston/McKenzie Creek					
16018409502	↔	↓	↔	↑	↓
16018409602	↔	↔	↔	↑	↔

↑ Concentrations are increasing (deteriorating trend); ↓ Concentrations are decreasing (improving trend); ↔ no change

(Cooke 2006).

2.7.2.1 Water Quality Data Gaps

The current sampling frequency does not allow for the characterization of flow events which limits the ability to properly calculate loads or statistically analyze for trends.

There are certain water quality parameters for which there is a lack of data such as pesticides, metals and persistent chemicals and emerging contaminants (e.g. pharmaceuticals), which limits our ability to characterize their spatial and temporal traits across the watershed.

The spatial coverage of the current continuous water quality monitoring network should be expanded to include sites downstream of Brantford.

There is a lack of current water quality data for the reservoirs within the Grand River watershed. Future monitoring within and upstream of the reservoirs will be necessary to fully identify any water quality concerns associated with the reservoirs and the potential sources.

Designing an integrated monitoring and reporting plan would capitalize on data resulting from other stream and biological monitoring as well as subwatershed planning programs within the Grand River Conservation Authority and increase our understanding of the water quality issues and the associated ecological processes being impacted.

The current Provincial Water Quality Objectives and the Canadian Water Quality Guidelines may not be appropriate for all watersheds across Ontario. However, identifying useful sub-watershed or basin specific targets within the Grand River watershed has not been thoroughly investigated. Further exploration into identifying local benchmarks or targets will likely require further academic investigation and monitoring.

2.7.3 Regional Groundwater Quality Conditions and Trends

The characterization of groundwater chemistry is an important consideration in hydrogeological studies. In addition to being available in sufficient quantities, the geochemical properties of groundwater must be compatible with the intended use (e.g., potable, agricultural, industrial).

The geochemical composition of groundwater is a result of many processes, including interaction with atmospheric gases, reaction with minerals, bacteriological processes, anthropogenic effects, and other subsurface reactions and processes. Although there is a public perception that all instances of undesired compounds in groundwater are a result of anthropogenic contamination, groundwater may be rendered unusable due entirely to natural geochemical processes. For instance, some industrial processes are very sensitive to scaling issues, which may eliminate groundwater high in hardness from use. Groundwater may have naturally attained high concentrations of arsenic or total dissolved solids which eliminates it from use as a source of potable water. Consequently, there is a need to better understand the ambient quality of groundwater and its controlling processes. This in turn allows for a stronger understanding of the impacts other contaminants may have on groundwater and provides insight into pollution trends and their effects on the aquifer system.

Ambient groundwater geochemistry generally evolves as it moves along its flowpath. Typically, groundwater originates as precipitation and is generally low in total dissolved solids, is slightly acidic, and somewhat oxidizing (Freeze and Cherry, 1979). Upon infiltration into the ground, the recent precipitation tends to increase in acidity and begins reacting with the geologic material it encounters. As groundwater continues along its flowpath, it may evolve from being dominated by the anion bicarbonate and having relatively low total dissolved solids to sulphate domination and finally domination by the anion chloride and having relatively high total dissolved solids (Freeze and Cherry, 1979). This sequence is commonly referred to as the Chebotarev sequence and can account for the spatial variations in geochemistry that are often observed. The process of geochemical mapping and the recognition of geochemical trends can assist in distinguishing provenance and source identification (i.e. natural versus anthropogenic).

Although there have been no regional, long-term groundwater quality monitoring programs within the Grand River Watershed, some inferences can be made with observations collected at the time of drilling or through the results of sampling of ambient groundwater conducted through the Provincial Groundwater Monitoring Network (PGMN).

Some basic observations of groundwater type are made by drillers at the time of drilling and submitted to the MOE water well information system. Groundwater type is classified through odour and taste as fresh, salty, sulphur or mineral. This method of classification provides a crude indication of groundwater quality at the time the well is drilled and, when mapped, can provide insight into the general geochemical conditions in a particular location and within a particular hydrogeologic unit. **Map 2.26** and **Map 2.27** show the spatial distribution of these observations in the overburden and bedrock, respectively.

Examination of the distribution of the water types reported indicates that there is a general bias towards the sulphur classification in bedrock wells, likely because the sulphur odour is such a strong distinguishing feature.

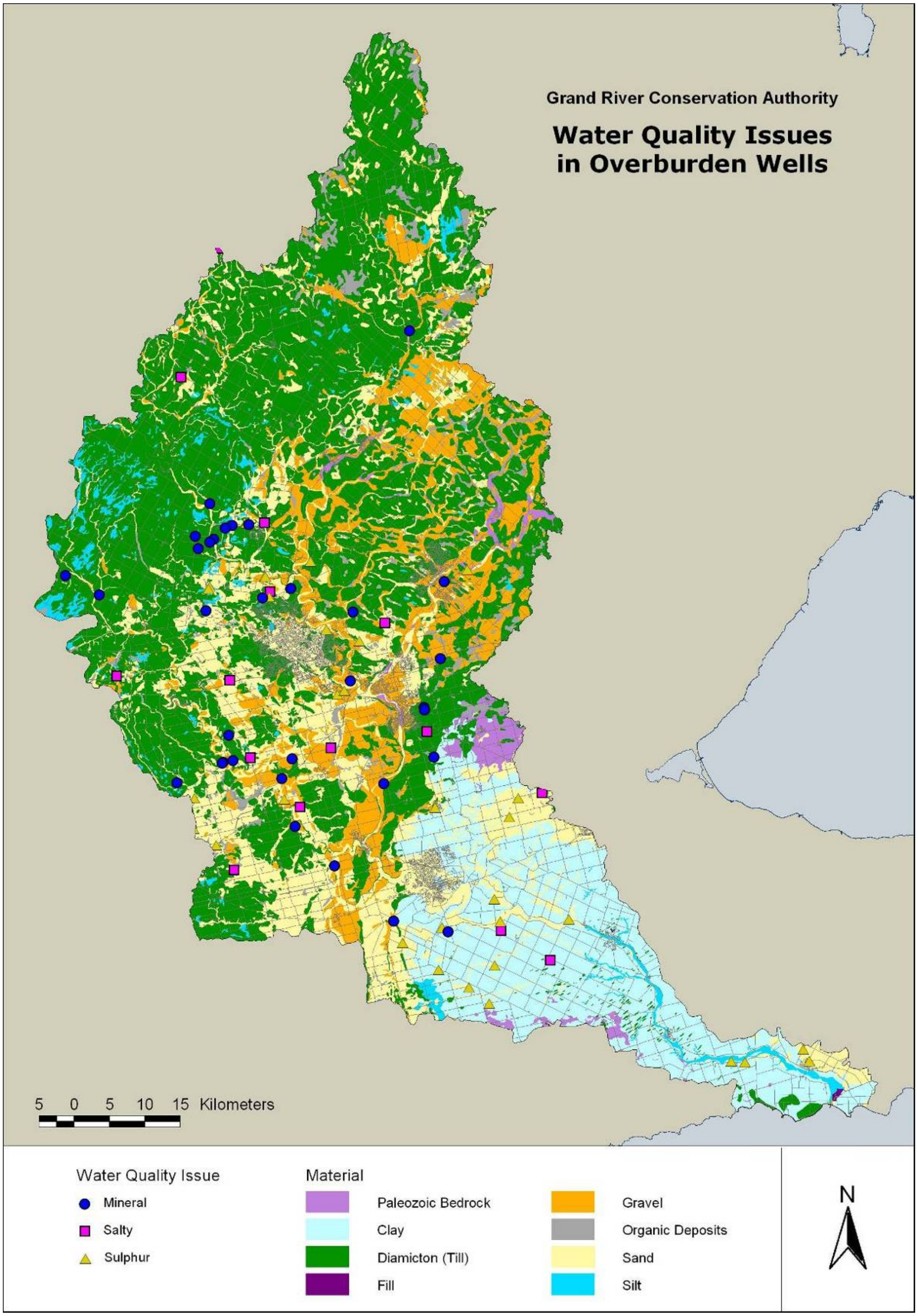
Overall water quality problems of one type or another exist throughout the watershed regardless of the geological unit into which they have been drilled. However, some geological units, especially bedrock units, have a higher tendency to produce water with certain types of water quality problems.

Holysh et al. (2001) found that high sulphur content was the most common water quality problem associated with bedrock throughout the watershed. Three bedrock formations contain the bulk of the high sulphur wells: the Guelph Formation; the Salina Formation; and the Onondaga–Amherstburg Formation. Within these three formations, the wells classified as having high sulphur content were clustered, indicating that there might be some other control on the water quality in addition to the bedrock geology. These clusters did not correspond to any known submembers, however the elevated sulphur content may be related to the presence of common sulphur bearing minerals such as gypsum or pyrite (Holysh et al., 2001).

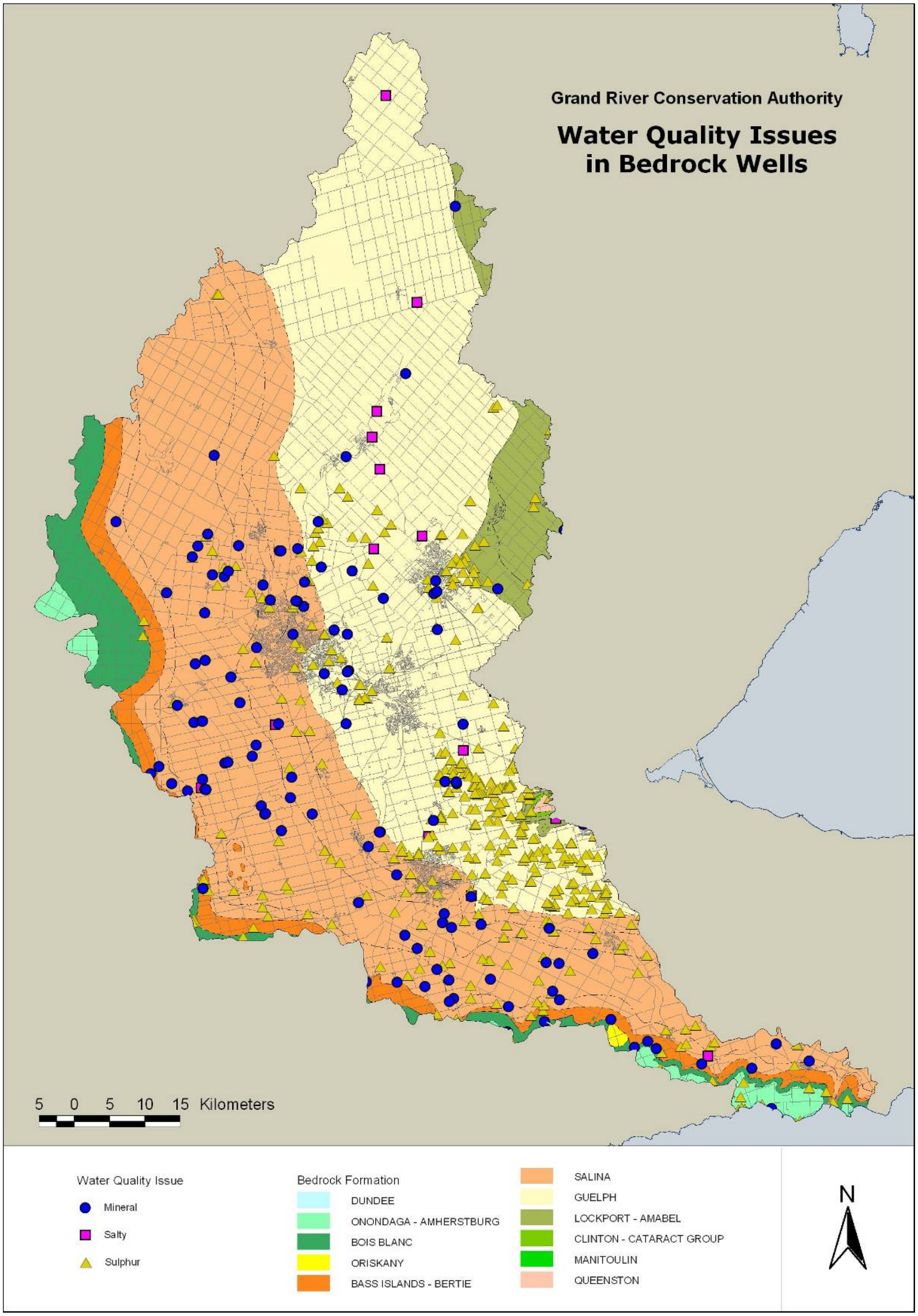
Several bedrock wells were also reported as having a high salt content. Of these, almost half were located in the Guelph Formation, suggesting a source of salts associated with this formation. High salt content is also reported in wells completed in the Salina Formation. Wells with high concentrations of salt could be indicative of groundwater discharge from deeper, more regional groundwater flow systems. Generally, the longer groundwater remains in the subsurface the greater the concentration of dissolved ions.

Water quality problems associated with overburden aquifers can be found throughout the watershed. However, no obvious geographic patterns could be deciphered. One exception to this is a small cluster of wells with a mineral water quality problem found to the west of Elmira in Waterloo Region. Little explanation for this grouping is obvious as some wells have been drilled into tills while others have been drilled into sands and gravels (Holysh et al., 2001).

Map 2.26: Groundwater Quality Issues for Overburden Wells in the Grand River Watershed



Map 2.27: Groundwater Quality Issues for Bedrock Wells in the Grand River Watershed



Wells that are a part of the PGMN were sampled once between 2003 and 2006. The data from these samples provides a baseline for these wells. It is important to note that due to the small number of sample points, it is not possible to complete any statistical analyses and these samples are not indicative of groundwater quality within the entire aquifer. **Table 2.5** provides selected parameters for each of the PGMN wells sampled and also indicates in which aquifer the well is completed.

Of the 11 PGMN wells sampled within the Waterloo Moraine, 4 samples exceeded the Ontario Drinking Water Objective's Aesthetic Objective (AO) of 500 mg/L for sulphate (MOE, 2006). Seven of the 11 wells exceeded the AO of 500 mg/L for Total Dissolved Solids (TDS) and 7 wells exceeded the AO of 300 ug/L for iron (MOE, 2006).

The only PGMN well completed within the Norfolk Sand Plain exceeded the AO of 500 mg/L for TDS. The PGMN well completed with in the Oriskany Formation exceeded the AO of 500 mg/L for both sulphate and TDS. Within the Salina Formation, the PGMN well sample exceeded the AO of 500 mg/L for both sulphate and TDS and the AO of 300 ug/L for iron.

Eight PGMN wells are completed within the Guelph Formation. Two of the samples from these wells had fluoride concentrations exceeding the Ontario Drinking Water Objectives Maximum Acceptable Concentration (MAC) of 1.5 mg/L. One of the 8 wells exceeded the MAC of 10 mg/L for nitrate. Two wells exceeded the AO of 500 mg/L for sulphate and an additional 4 wells exceeded the AO of 300 ug/L for iron.

Table 2.5: Summary of selected groundwater quality parameters from the PGMN within the Grand River Watershed

Sample ID	Aquifer	F	SO_4	Na	Cl	NO_3	TDS	As	Fe
		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	µg/L	µg/L
W022-1	Waterloo Moraine	0.03	104	32.4	49.2	1.365	669	0.8	645
W036-1	Waterloo Moraine	1.04	1290	23.4	2	0.045	2110	4.8	2190
W037-1	Waterloo Moraine	0.04	30.1	5.8	5.1	3.485	519	0.2	4
W427-1	Waterloo Moraine	0.88	751	20	9.4	0.045	1480	11.2	1530
W428	Waterloo Moraine	0.2	41	7.4	7	0.24	339	0.2	121
W309-2	Waterloo Moraine - Likely southern extension of Mannheim aquifer and possibly Greenbrook Aquifer	0.13	34.6	11.6	24.3	0.795	388	0.4	4
W309-3	Waterloo Moraine - Likely southern extension of Mannheim aquifer and possibly Greenbrook Aquifer	0.25	23.7	6.4	1.6	0.045	304	6.1	183
W423	Waterloo Moraine	1.2	1420	18	8	0.1	1550	0.5	1210
W425-1	Waterloo Moraine - Likely southern extension of Mannheim aquifer and possibly Greenbrook Aquifer	0.27	45.6	19	1.2	0.045	365	4.2	634
W429	Located near wetland to investigate gw/sw interactions	0.42	1400	51.8	2.5	0.038	2410	4.2	786
W430	Located near wetland to investigate gw/sw interactions	0.53	346	58.8	104	0.045	1120	2.8	454
W024-2	Paris Moraine	0.12	39.2	4.8	7.8	0.04	361	0.8	129
W065-4	Norfolk Sand Plain	0.1	99.3	14.6	44.9	0.39	501	0.3	22
W178-1	Oriskany Formation	0.4	1150	6.8	19.2	2.105	2050	0.2	1
W424	Salina Formation	1.3	1630	42	6	0.1	1730	2.5	847
W023-1	Guelph Formation	0.22	10	34.4	71.1	0.045	464	3.2	2610
W024-4	Guelph Formation	0.16	22.8	4.2	6.2	0.037	374	0.6	1610
W035-5	Guelph Formation	1.05	443	4.8	5.5	10.349	933	3	117
W306-1	Guelph Formation	0.09	19	8.2	17.8	0.045	372	0.3	51
W307-1	Guelph Formation/Flamborough Plain	1.98	49.4	1.4	2.1	0.045	401	1.1	65
W347-2	Guelph Formation	0.54	19.2	25.8	231	0.515	900	7.7	389
W347-3	Guelph Formation	1.69	3.7	1	1.1	0.045	254	0	8
W421	Guelph Formation	1.22	9.5	15.2	0.5	0.045	267	5	24
W046-1	Lockport-Amabel Formation	1.13	34.8	7.6	18.9	0.045	359	10.9	35

2.8 Aquatic Ecology

The health and diversity of aquatic species in a watershed is a good indicator of water quality conditions. Over the past few decades, water quality throughout the Grand River watershed has improved, and this has helped spur a resurgence of native aquatic species.

2.8.1 Fisheries

The Grand River watershed holds a diverse mix of fish species found throughout three main fish communities (coldwater, mixed water, and warm water). As of 1999, 83 species of fish have been confirmed in the watershed, along with another 13 unconfirmed species, two extirpated species (Blue Pike, Lake Sturgeon), two occasional escapees from aquaculture facilities (Atlantic Salmon, Arctic Char), and two occasional migrant species (Pink and Coho Salmon).

The most prevalent species within each community include:

- Coldwater – brook trout and mottled sculpin.
- Mixed Water – brook trout, northern pike and small mouth bass.
- Warm Water – smallmouth bass, largemouth bass and walleye.

For a detailed listing of species found in the Grand River watershed, consult the *Technical Background Report for the Grand River Fisheries Management Plan* (Wright and Imhoff, 2001).

This range of diversity is impressive when considering the historical water quality issues in the watershed during the past 150 years. Only recently, during the last 30 to 40 years, has the quality of the watershed improved through major initiatives to clean up the river and its tributaries.

As discussed in **Section 2.2** (Surficial Geology), the Grand River watershed can be divided into three geologic zones from north to south, including:

- Upper Zone – predominantly clay and till plain;

- Middle Zone – outwash gravel and sand intermixed with till (Catfish and Wentworth);

- Lower Zone – predominantly glacio-lacustrine clay and silts.

These zones have a major influence on the type of fish species found throughout the watershed. The major geologic characteristics of the watershed, including their composition and structure generate functions of water recharge and discharge. These functions determine the structure and characteristics of stream channels and valleys, which ultimately determine living conditions for fish species (Wright and Imhoff, 2001).

Coldwater and mixed water fish species rely on the discharge of groundwater to a stream in order to regulate the temperature of water throughout the year and provide a stable flow regime. Warm water fish species have a higher tolerance to increased water temperatures, and can therefore survive in areas of minimal or no groundwater discharge, and in streams of lower flow stability.

Within the Grand River watershed, coldwater and mixed water fish species are most often associated with the geologic middle portion, where outwash gravel and sand moraines provide adequate groundwater discharge to streams and rivers. Warm water species are most often associated with the upper and lower zones of the watershed, where clay and silt tills prevent or limit infiltration. In these areas, stream flow is mainly influenced by surface runoff, creating a less stable and flashy flow regime.

A major challenge in the watershed remains population growth and its impact on stream habitat quality. Land uses in both urban and rural areas also contribute to degradation of fish habitats in all areas of the watershed through runoff of contaminants, nutrients and soils, as well as discharges of wastewater effluents from municipal and other sources.

2.8.1.1 Fisheries Management Plan

Several issues have been identified in the Grand River watershed that impact the health of fish species, including the growth of the human population within the watershed, conflicting land uses, water quantity and use, and habitat degradation. These issues present serious implications for the health and diversity of the Grand River watershed fishery, and as such require comprehensive management strategies to mitigate their impacts and prevent further degradation.

In 1998, the Grand River Conservation Authority published *the Grand River Fisheries Management Plan* in cooperation with its partner organizations: the Ontario Ministry of Natural Resources, Fisheries and Oceans Canada, Six Nations, Trout Unlimited Canada, Izaak Walton Fly Fishing Club, and Dunnville District Hunters and Anglers.

Several principles have guided the development and implementation of the plan, many of which were adopted from the 2nd Strategic Plan for Ontario Fisheries (SPOF II, 1991). The principles include:

- Partners and the public play a key role in fisheries management and are important stakeholders in the development and implementation of the plan;
- The plan must start from scratch;
- The plan be based on the concept of the Ecosystem Approach (sustainable development);
- The recognition that there are limits to the resource
- Manage for naturally reproducing fish species and communities based on indigenous or naturalized populations of fish;
- The plan must use the best knowledge available; and
- The plan must ensure sound social and economic benefits.

The focus of the overall plan encompassed the entire watershed; however, detailed strategies were incorporated on a site specific scale including individual streams and features. At present, seven major sub-basins have fish management plans, and several important accomplishments have been made throughout the watershed, including:

- Improved access and signage;
- Regulation changes;
- The Exceptional Waters Program;
- The development of a promotion/marketing package to promote the Grand River fishery;
- Watershed-wide stewardship and rehabilitation projects;
- Completion of the Fish Species at Risk Recovery Strategy;
- Completion of a cross benefit analysis with the Rural Water Quality Program;
- Cooperative aquatic studies in the Southern Grand, including monitoring, habitat and water quality assessments, and coastal and riverine wetland studies; and
- The development of tailwater programs for brown trout on the Grand and Conestogo rivers.

2.8.2 Aquatic Macroinvertebrates

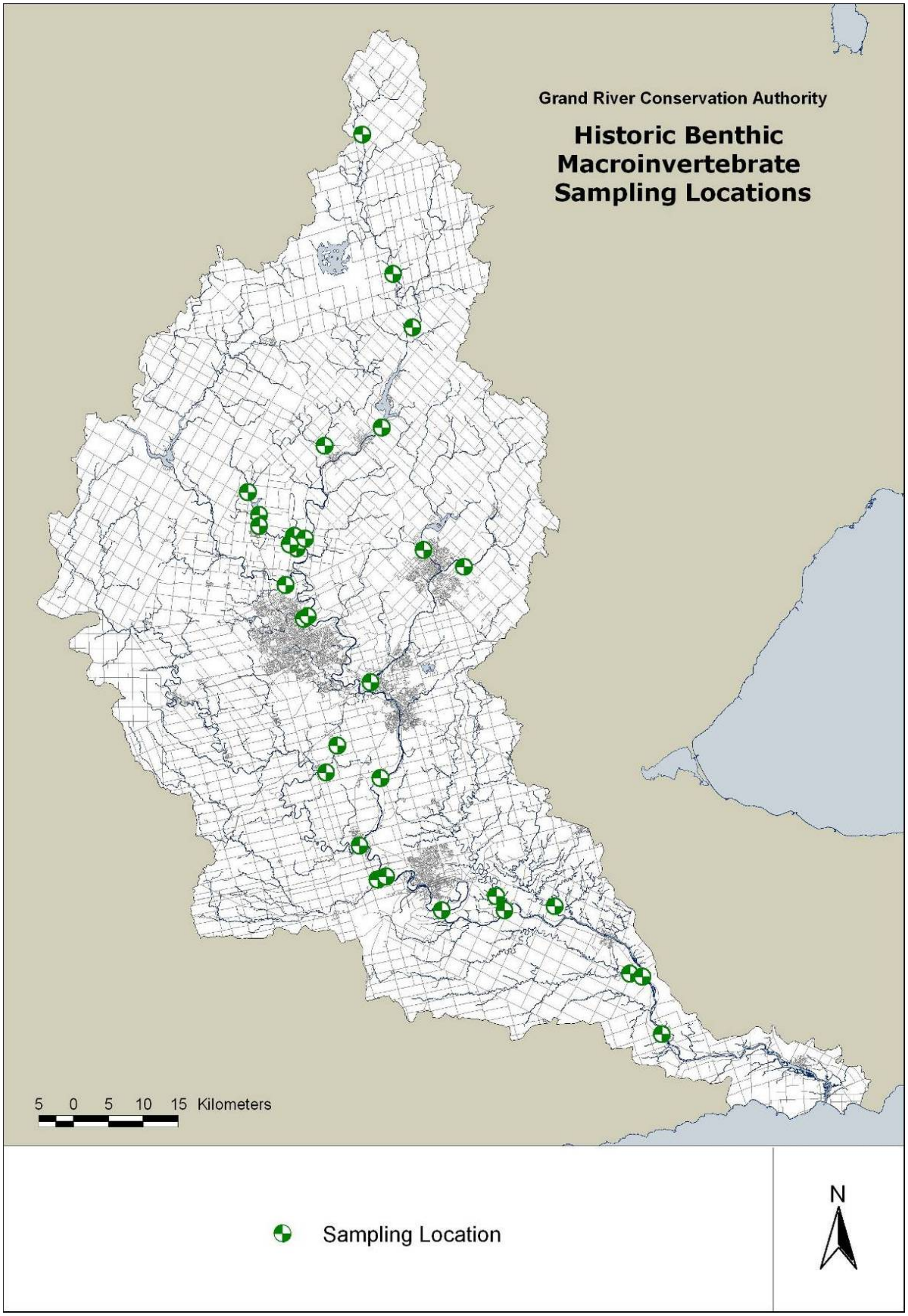
Benthic macroinvertebrates are excellent 'integrators' of the many different environmental stressors such as low dissolved oxygen, contaminant spills or chronic low pollutant levels that can impact or impair aquatic health. Due to their relatively low mobility they are good at reflecting local conditions and can potentially provide early warning of impending effects on fish communities.

The Grand River Conservation Authority (GRCA) does not currently have a routine benthic monitoring program in place. However, Wright (2002) outlined and described a set of objectives and requirements needed to set up a long-term benthic macroinvertebrate monitoring program at the GRCA. It was recommended that better integration of the water chemistry, flow and biological monitoring programs be coordinated (Wright, 2001).

Historically data has was collected during 1966, 1984 and from 1998 to 2000 at various sites throughout the Grand River Watershed. Benthic macroinvertebrates were monitored at a total of 35 sites during the 1998-2001 sampling periods; however, not all sites were sampled during each year (**Map 2.28**).

Generally, biotic indices are used as water quality assessment tools for a specific geographic location. A large population of many different kinds of benthic macroinvertebrates is a good indicator of a healthy stream and good water quality. The primary biotic index used by the GRCA during the 1998, 1999 and 2000 sampling years was the Hilsenhoff index. This index gives an indication as to the degree of organic pollution present. The data gathered as part of the benthic surveys from 1998-2000 was analysed by two external consultants, Ecoplans Ltd. and Jaques Whitford Environment Ltd (JWEL).

Map 2.28: Location of Historic Benthic Macroinvertebrate Monitoring Sites in the Grand River Watershed



A preliminary assessment of the benthic macroinvertebrate community monitoring from 1999 to 2001 indicates that most of the watershed experiences low to moderate organic enrichment (pollution). The sites where the invertebrate community indicates moderate pollution are consistent with the sites with poor water quality from very high nutrient concentrations. There were also areas surveyed (e.g. Laurel Creek, Nith River and the Grand River at York) which were devoid of both Mollusca and Crustacea communities, suggesting that historical impacts may have occurred (Jacques Whitford Environment Ltd., 2001 & 2002).

2.8.3 Species and Habitats at Risk

Several aquatic species at risk have been identified in the Grand River watershed, many of which are sensitive to increased pollution or changes to water temperature or flow. A list of species at risk is provided below, along with their distribution and the believed cause for their reduced numbers.

2.8.3.1 Kidneyshell (*Ptychobranchus fasciolaris*)

It is listed as Endangered by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) and is listed on Schedule 1 of the Species at Risk Act (SARA). The historical distribution of the Kidneyshell mussel in the Grand River watershed included the southern portion of the main stem of the Grand River. Populations in the Grand River watershed were likely extirpated due to the combined effects of sewage treatment plant effluent and agricultural impacts.

2.8.3.2 Wavy-rayed Lampmussel *(Lampsilis fasciola)*

This species is designated as Endangered by COSEWIC and is listed on Schedule 1 of SARA. This mussel is found in Southern sections of the Grand River, in the Branford area of the main stem of the Grand River, in the Township of Woolwich on the Main stem of the Grand River and in some areas of the main stem of the Nith River. The Wavy-rayed Lampmussel lives mainly in gravel or sand bottoms of riffle areas in clear, medium sized streams. The mussel inhabits clear rivers and streams of a variety of sizes, where the water flow is steady and the substrate is stable. This mussel species may be sensitive to siltation because it burrows into the river substrate and is not very mobile. Like all species of freshwater mussels, the Wavy-rayed Lampmussel uses bacteria and algae as its primary food source.

2.8.3.3 Round Pigtoe (*Pleurobema sintoxia*)

The Round Pigtoe is listed as Endangered by COSEWIC and is listed on Schedule 1 of SARA. This freshwater mussel is found in the main stem of the Southern Grand River. Human oriented stressors such as high loadings of sediment, nutrients and toxic compounds originating from urban and agricultural sources are potential threats to this species. Siltation resulting from intensive agriculture has fouled many of the sand and gravel riffles inhabited by this species. Tile drains, cattle access to streams, and the reduction or elimination of riparian buffer strips have all contributed to this problem. Nutrient loadings through the application of fertilizers and the discharge of municipal sewage can have detrimental effects on this species. Pesticides from farms and chlorides from winter road salting can also impact the Round Pigtoe.

2.8.3.4 Eastern Sand Darter (*Ammocrypta pellucida*)

This species has been identified as Threatened by COSEWIC and has been placed on Scheduled 1 of the Species at Risk Act. Schedule 1 is the official list of Extirpated, Endangered, Threatened, and special concern species in Canada. The Eastern Sand Darter is a minnow sized fish, but is a member of the perch family. The Eastern Sand Darter has declined throughout its range because of siltation, sand bar removals, water impoundments and water pollution. This fish species is found in the main stem of the Grand River from just upstream of the town of Dunnville upstream to the City of Brantford.

2.8.3.5 Black Redhorse Sucker (*Moxostoma duquesnei)*

The Black Redhorse Sucker has been designated as Threatened by COSEWIC and is listed on Schedule 2 of SARA. The Black Redhorse Sucker inhabits moderate to large rivers and hence is limited to the main stem of the Grand River and its larger tributaries such as the Nith River. Water quality at capture sites in Ontario can be characterized as well oxygenated and relatively fertile.

2.8.3.6 Redside Dace (*Clinostomus elongatus*)

The Redside Dace has been designated as a species of Special Concern and is listed on Schedule 3 of SARA. Redside Dace inhabit part of the Irvine Creek drainage basin in the upper middle Grand watershed. This is the only known population of Redside Dace on the north shore of Lake Erie. Sampling of Irvine Creek in recent years indicates the distribution of Redside Dace in this system is declining. The main factors which have adversely affected Redside Dace populations are destruction and degradation of habitat through siltation; removal of bank cover; and water quality deterioration. Widespread dispersal of this species is limited due to its preference for cool headwater streams.

2.8.3.7 Silver Shiner (*Entropies photogenes*)

The Silver Shiner has been designated as a species of special concern by COSEWIC and is currently listed on Schedule 3 of SARA. This species is distributed in various locations including the main Grand River, the Nith River, the Conestogo River, Whitemans Creek, Schneider Creek, Rogers Creek and McKenzie Creek. This fish species is abundant in moderate to large sized streams having relatively clear water throughout the year, moderate or high gradients and clean gravel and boulder strewn substrate. The Silver Shiner usually avoids heavily silted bottoms and rooted aquatic vegetation.

2.8.3.8 River Redhorse (*Moxostoma cranium*)

The River Redhorse is designated as Special Concern by COSEWIC and is listed on Schedule 3 of SARA. This fish species is found from the mouth of the Grand River at Lake Erie upstream to Caledonia. The distribution of the River Redhorse is restricted because of its requirements of moderate to large sized, fast flowing rivers, low silt substrates and clear water.

2.8.3.9 Bigmouth Buffalo (*Ictiobus cyprinellus)*

The Bigmouth Buffalo is designated as a species of Special Concern and is listed on Schedule 3 of SARA. Bigmouth Buffalo are found only downstream of Dunnville on the main stem of the Grand River to Lake Erie. They have been documented to inhabit areas where the current is slow. This species will tolerate high turbidity and they prefer waters that are warm and highly eutrophic. They are also found in areas where the bottom fauna and plankton are abundant.

2.8.4 Invasive Aquatic Species

No comprehensive studies have been completed to date regarding the extent of the spread of non-native aquatic invasive species in the Grand River watershed. However, research indicates that several species have been reported in Lake Erie.

Limited data on the Grand River watershed has shown that several non-native invasive aquatic species are present in the lower portions of the watershed. Species detected include the round goby, carp, goldfish and zebra mollusk. These species are limited to the lower Grand River below the Dunnville Dam; however, increased recreational access to the river and tributaries and the allowance of motor boats in Belwood and Conestogo Lakes (reservoirs) may facilitate the spread of non-native invasive species further up the Grand River watershed in the near future.

3.0 HUMAN CHARACTERISTICS OF THE GRAND RIVER WATERSHED

In order to understand the conditions and trends of the physical characteristics of the watershed that determine the availability of clean, potable water, a discussion is needed of the human characteristics and the human impact on the watershed. This section describes the history of human settlement in the Grand River watershed, the current land uses, patterns of human settlement, and provides future population growth projections.

3.1 Settlement History

The Grand River watershed has been inhabited by humans since the last ice age, over 10,000 years ago. Original settlers included the descendents of the Clovis Point People, who crossed the Bering Sea on a land bridge from Asia. By the time Europeans arrived in the 1600s, the original Eurasian settlers had been replaced by the Iroquoian-speaking tribes (State of the Watershed Report, 1997).

In the 1790's, an established means of colonizing the interior of Upper Canada was through the granting of large tracts of land. Land owners then sold lots or parcels to prospective settlers and developers. Large German, Mennonite and Scottish communities moved into the area, forming important demographic characteristics still evident throughout the watershed today (ibid).

The first settlers in the fertile lands in the south and middle of the watershed were farmers. They cleared the forest, and tilled the newly opened lands to grow wheat and other grains, and graze livestock (ibid). The cleared trees were used or sold as lumber, or burnt on the land to produce potash for export. The fast-flowing Grand River and its tributaries provided transportation routes and a reliable source of power for the grist and saw mills that sprang up in response to the needs of the early settlers. The Grand River also provided drinking water and a waste disposal system for the river communities. Mill ponds, created in some areas like Waterloo, provided a constant power source for local mills (ibid).

Patterns of settlement developed early. The well-drained fertile soils of the middle valley were prime agricultural lands, especially in the valleys of the Conestogo and Nith Rivers. In the lower basin, the sand and silt soils in the Brantford, Whiteman's Creek areas were used for crops, although irrigation of the land was needed for good productivity (ibid). The clay soils of the lower basin and the extensive marshes along the river banks were a poor agricultural prospect, and of less interest to most settlers. Few early settlers reached the swamps and high land of the upper reaches of the Grand River (ibid).

The middle basin became the focus for growth and development because of the advantages of water power from the fast flowing river, and the proximity of easily cultivated valley land. Communities such Guelph, Galt, Preston, Hespeler, Paris and Brantford grew around mills and the valley flats.

As the middle basin of the watershed became more populated, settlers moved north in search of agricultural land and arrived in the area of the headwaters of the Grand River around 1831 (ibid). However, poorly-drained clay soil of the Dundalk Till Plain in the north did not allow for extensive agriculture. The shorter growing season and difficult conditions led many farmers to turn to lumbering to provide a livelihood (ibid).

Massive timber cutting took place in Luther and Melancthon in the 1860's. Pine, cedar and tamarack logs were cut in the winter and floated downstream in the spring to Galt, to be shipped by train to Toronto. Thousands of logs were also taken from swamp lands near the Irvine and Conestogo Rivers (ibid). By 1894, the forests of Luther were almost completely cleared.

Deforestation changed the way the Grand River was able to deal with heavy spring rains and snowmelt. Surplus flows, previously restrained in woody swamps, now rushed downriver, flooding river side lands, destroying property and livestock, and sometimes claiming human lives (ibid). Drainage channels, built to create agricultural land, also provided avenues for the spring rains to flush from the high land into the already swollen rivers.

As Luther marsh and other swamps in the upper watershed were drained, summer flows in the river were no longer augmented by a steady seepage from these wetlands (ibid). Settlers downriver contended not only with heavy spring floods, but at other times had insufficient water to power their mills and remove their waste. Increased population meant increased sewage to be dealt with by a river that became sluggish and polluted. By the late 1800's there was growing public concern and recognition of serious community problems resulting from the environmental crisis occurring in the Grand River.

Throughout the recent history of settlement in the watershed, towns and cities developed on the banks and floodplains of the river and its tributaries. This development pattern has had significant impact on both the quality and quantity of surface water, and changed the natural cycles and hydrology of the river system. In addition, the watershed rests on large, good quality regional aquifers that have been the cornerstone for much of the population's domestic water use. Increasing population growth over the past several decades, along with changing land use patterns have undoubtedly degraded these groundwater resources.

3.2 Municipalities and Municipal Structure

The Grand River watershed contains, in whole or in part, 38 upper and lower tier municipalities including regional, county, township and city/town divisions, as shown on **Map 3.1**. Since the mid-1970s, the municipal structure in the watershed has changed dramatically through several amalgamations. As a result, responsibility for water, wastewater, stormwater and solid waste management has become more complex, often involving both upper and lower tier municipalities.

Table 3.1 provides a list of all upper and lower tier municipalities in the watershed, as well as the level of local government responsible for water supply and distribution, wastewater collection and treatment, stormwater and solid waste management.

Table 3.1: Municipalities in the Grand River Watershed

Municipality		Responsibilities					
Upper/Single Tier	**Lower Tier**	**Water Supply**	**Water Distribution**	**Wastewater Treatment**	**Wastewater Collection**	**Stormwater**	**Solid Waste**
Grey County							
	Southgate	√	√	√	√	√	√
Dufferin County							
	Melancthon						
	E Luther-Grand Valley	√	√	√	√	√	√
	Amaranth	√	√	√	√	√	√
	East Garafraxa						
Wellington County							√
	Wellington North	√	√	√	√	√	
	Mapleton	√	√	√	√	√	
	Centre Wellington	√	√	√	√	√	
	Erin	√	√	√	√	√	
	Guelph-Eramosa	√	√	√	√	√	
	Puslinch					√	
City of Guelph		√	√	√	√	√	√
RM Halton		√	√	√	√	√	√
	Halton Hills						
	Milton						
Perth County							
	North Perth	√	√	√	√	√	√
	Perth East	√	√	√	√	√	√
RM Waterloo		√		√			√
	Kitchener		√		√	√	
	Waterloo		√		√	√	
	Cambridge		√		√	√	
	Wellesley		√		√	√	
	Woolwich		√		√	√	
	Wilmot		√		√	√	
	North Dumfries		√		√	√	
Oxford County		√	√	√	√		√
	East Zorra-Tavistock					√	
	Blandford-Blenheim					√	
	Woodstock					√	
	Norwich					√	
Brant County		√	√	√	√	√	√
City of Brantford		√	√	√	√	√	√
City of Hamilton		√	√	√	√	√	√
Norfolk County		√	√	√	√	√	√
Haldimand County		√	√	√	√	√	√

3.3 Population Centres

Of the total population living with the Grand River watershed (approximately 821,000), 603,547 residents live in one of the five major urban centres of Kitchener, Cambridge, Waterloo, Guelph and Brantford (Regional Municipality of Waterloo, 2006, C. N. Watson, April 2003, and City of Brantford, 2006). This indicates that almost 74 percent of the population in the watershed lives on seven percent of the total land area. The average urban population density is estimated at 1,157 persons per square kilometre. **Map 3.2** indicates the distribution and density of population in the watershed, with the highest values corresponding to the five major urban centres listed above.

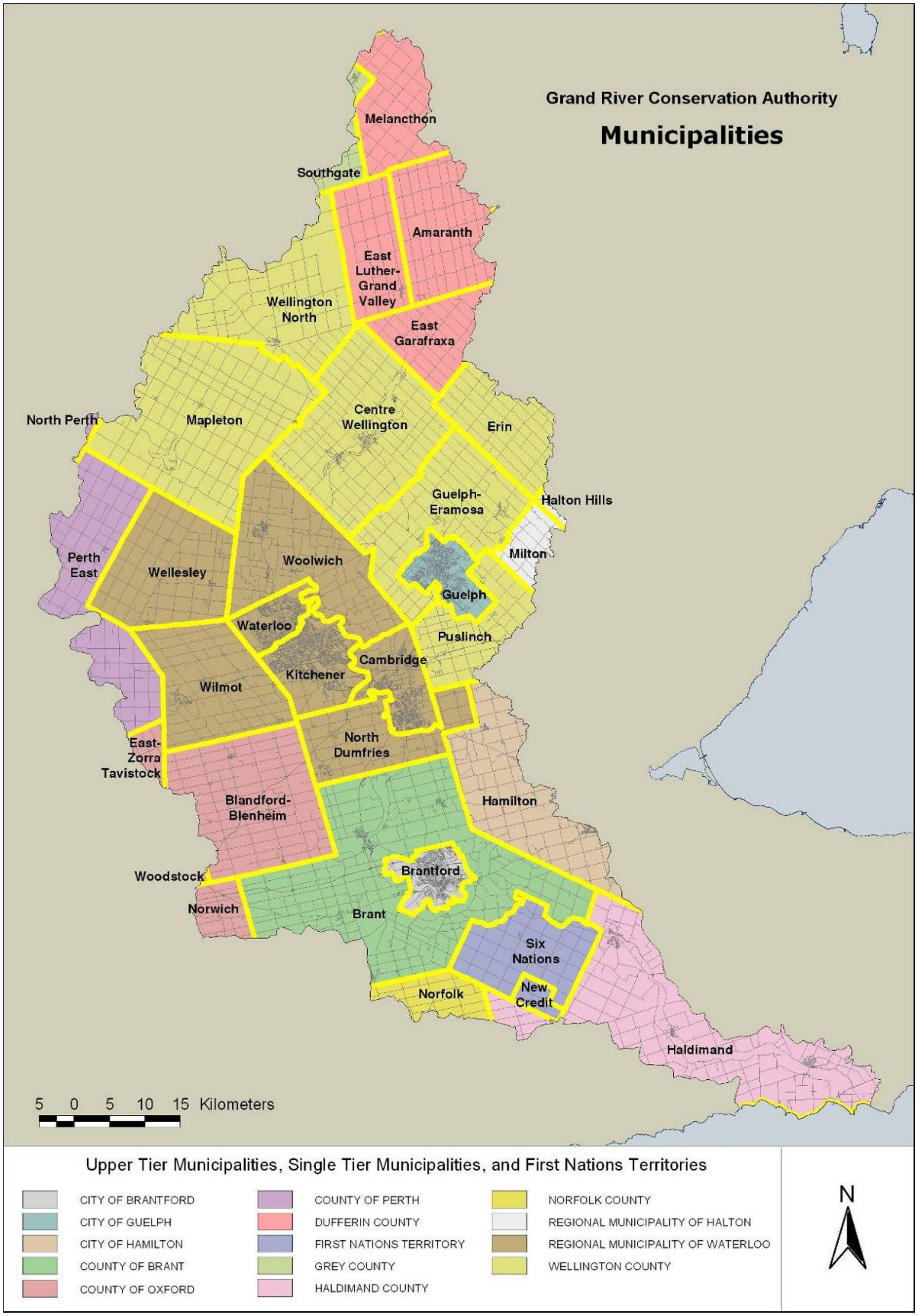
Recent population forecasts have estimated that growth over the next 25 years will be very high in these urban centres. Provincial initiatives such as the Greenbelt Act (2005) and the Places to Grow Act (Ontario Ministry of Infrastructure and Renewal, 2005) have identified where population growth will be located over the next several decades in Ontario. The cities of Waterloo, Kitchener, Cambridge, Guelph and Brantford have been designated as "urban growth centres", and according to the Places to Grow plan, these centres are expected to grow by 57 percent by the year 2031.

3.3.1 Cities of Kitchener, Waterloo and Cambridge

Approximately 390,000 people live in the cities of Kitchener (194,650), Cambridge (112,120) and Waterloo (100,910) (Regional Municipality of Waterloo, 2006), representing 89 percent of the population of the Region of Waterloo (456,000), the geographic centre of the Grand River watershed.

These three urban centres form the "Technological Triangle", one of Canada's leading growth areas. Factors accounting for the growth include the presence of three universities, proximity to major markets in Ontario and the United States, as well as a cost of living lower than that of the Greater Toronto Area. Highway 401 bisects the Region between the Cities of Kitchener and Cambridge and provides easy access for an increasing number of commuters.

Map 3.1: Municipalities in the Grand River Watershed



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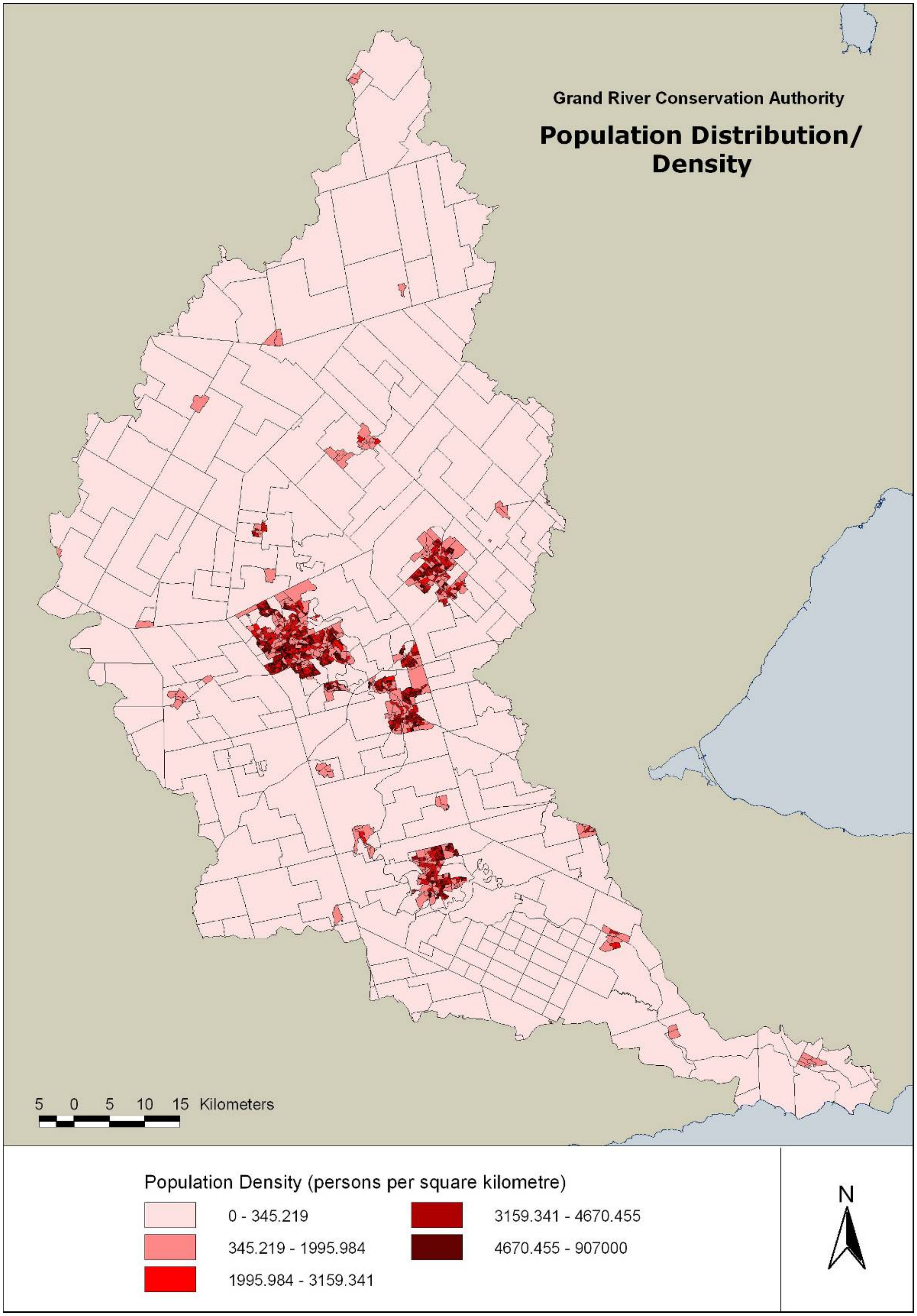
Map 3.2: Population Distribution and Density in the Grand River Watershed



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3.3.2 Guelph

Guelph is located at the confluence of the Speed and Eramosa Rivers in the southern part of Wellington County. In 2001, the population of Guelph was 109,450. Recent population forecasts for the provincial Places to Grow Act estimate that the population will increase to 175,000 by the year 2031 – an increase of over 50 percent over 30 years (based on City of Guelph Official Plan target of annual 1.5% growth rate per year). To accommodate future growth, Guelph has annexed lands to the south from the Township of Puslinch and lands to the north from the Township of Guelph. In addition, the city is initiating a growth management study in response to the provincial forecasts in order to adequately plan for and accommodate future growth.

Guelph has adopted extensive policies to protect the natural environment, including water quality and quantity. By prohibiting new development on private septic systems, these policies discourage urban sprawl, premature construction of infrastructure and servicing and negative environmental impacts. Development and redevelopment are directed to (in order of priority):

- Areas with existing municipal services;
- Areas designated as priority for municipal trunk services; and
- Unserviced areas where a secondary plan is adopted.

Extensive growth in the city is limited by the assimilative capacity of the Speed and Grand Rivers.

3.3.3 Brantford

The City of Brantford is located on the Lower Grand River, and has a population of over 86,417 people. As stated above, the city has been designated as an urban growth centre, and according to provincial forecasts, the population is expected to increase steadily over the next 25 years to approximately 132,018 by 2031 (City of Brantford, 2006).

Brantford is conveniently located on Highway 403, providing easy access to the Greater Toronto Area, as well as to other southern Ontario and US markets.

3.4 Population Projections

The Grand River watershed is located directly west of the Provincial Greenbelt, and much of the watershed falls within the Greater Golden Horseshoe, where significant population growth is estimated to occur over the next 25 years. As a result of provincially-imposed planning restrictions within the Greenbelt, growth is expected to “leapfrog” from the Greater Toronto Area (GTA) into the major urban centres surrounding the Greenbelt, including those identified in **Section 3.5** above, in the Grand River watershed.

In addition to the leapfrogging phenomenon created by the Greenbelt Act, population growth is expected to be higher in the Grand River watershed due to its position as a major economic driver in Ontario. Comparatively, the watershed contributes more to the national Gross Domestic Product than several other provinces, and is approximately equal to that of Nova Scotia (Grand River Conservation Authority, 1998).

3.4.1 General Population Trends and Projections

Most municipalities within the watershed have undertaken population forecast studies for municipal official plans (OPs). More recent forecast studies for many of the municipalities within the watershed were completed by Hemson Consulting Limited for the provincial government in 2005. In many cases, the Hemson forecasts identify higher growth rates than those incorporated into municipal official plans for major urban centres within the Greater Golden Horseshoe, including those within the Grand River watershed. The difference is reflective of the new growth constraints imposed by the Greenbelt Act and the Places to Grow Act.

Table 3.2 indicates population forecasts for all upper and single tier municipalities within the Grand River watershed, as well as the estimated average annual growth. The most recent population forecast studies adopted by municipal councils have been used, including, where applicable, *the Greater Golden Horseshoe Projections* by Hemson Consulting Limited (2005). Several municipalities in the watershed indicated that they were in the process of reviewing population growth forecasts, either for a review of the official plan or in response to the Places to Grow Act. The information presented here will be updated as new information becomes available.

Where municipalities have not yet developed population forecasts to 2031, this report includes figures taken from the *Grand River, Long Point Region, Catfish Creek and Kettle Creek Watershed Areas Population Forecasts Report* (GSP Group Inc., Oct. 2005). The GSP Group Report extrapolated existing Municipal forecasts to 2031 using the same trends assumed in the most recent municipal forecasts available. For details on the methods used to extrapolate existing municipal population forecasts to 2031, please consult the GSP Group report, available from the Grand River Conservation Authority on request.

As shown in **Table 3.2,** the municipalities designated as “urban growth centres” by the provincial government are also those projected to have the highest increases in population over the next 25 years: Waterloo Region; City of Guelph; and City of Brantford. Much of this growth will occur on the peripheries of the urban centres, where expansion of water and wastewater services will be required. Similarly, re-urbanization and intensified growth within the cities will heighten demand for water and require significant upgrades and expansion to existing wastewater infrastructure.

Table 3.2: Population Forecasts for Upper Tier Municipalities in the Grand River Watershed

Municipality	Population 2001	Population Forecast 2031	Average Annual Growth (people/year)	% Population in Grand River Watershed
Waterloo Region	456,000	729,000	9,100	100%
City of Guelph	109,450	175,000	2,185	100%
City of Brantford	86,417	132,018	1,520	100%
Brant County	30,994*	51,129*	671	97%
Grey County	2,202*	3,225*	34.1	2.5%
Dufferin County	8,962*	15,995*	234	17%
Norfolk County	1,639*	2,035*	13.2	5%
Hamilton	16,659*	16,915*	8.5	3%

Table 3.2: Population Forecasts for Upper Tier Municipalities in the Grand River Watershed

Municipality	Population 2001	Population Forecast 2031	Average Annual Growth (people/year)	% Population in Grand River Watershed
Haldimand County	25,114*	35,420*	343.5	55%
Halton Region	1,890*	1,890*	0	0.4%
Perth County	3,590*	4,583*	33.1	4.7%
Wellington County	59,442*	89,593*	1,005	70%
Oxford County	7,912*	9,361*	48.3	8%
First Nations	10,814	13,315	83.4	100%
Total	**821,085**	**1,279,479**	**15,281 ppl/yr**	

* Estimate of total population of area in the Grand River watershed.

In addition, the table shows significant growth will also occur in more rural areas of the watershed, such as Wellington, Brant, Haldimand and Dufferin Counties (Hemson Consulting Ltd, 2005, 2006). Population growth in rural areas of the watershed will spark demand for infrastructure expansion, including water, wastewater and roads where growth occurs outside serviced areas.

High population growth on the fringe and over the boundary of the Grand River watershed, such as in Halton Region, will require strong cooperation and coordinated planning between the two watersheds. The high rate of growth projected for Halton Region is expected to occur outside of the Grand River watershed in the towns of Halton Hills and Milton.

3.4.2 Serviced Population Trends and Projections

The Government of Ontario is directing that new growth should be placed on municipal services, thereby supporting additional intensification and diminishment of rural land development. This represents a shift from peripheral suburban development that has characterized growth in major centres in the watershed, such as Waterloo, Kitchener, Cambridge and Guelph. However, the government has indicated that the majority (60% of all new development) will occur in 'greenfield locations' on the edges of settlement areas.

Growth of rural non-serviced populations is expected to be limited, as a result of increased land use restrictions on non-farm residential uses in rural areas.

3.5 General Land Use

Land use planning plays a crucial role in management and protection of water. A strong understanding of the land use distribution across the watershed is required in order to understand where sources of existing and potential contamination can originate. An understanding of land use distribution will also allow appropriate planning to take place to protect existing and future drinking water sources.

Land uses in the Grand River watershed are characterized by several large urban commercial, industrial and residential centres, surrounded by less-populated rural land used for intensive agricultural production. **Map 3.3** shows the distribution of land cover across the watershed. The map illustrates the dominance of agricultural land uses in rural areas of the watershed.

According to the 2001 census, about 67 percent of the total land area of the watershed is actively farmed on about 6,400 farms. In some parts of the watershed, the proportion of farmland is even higher, especially in the western regions where soils are rich and the land is relatively flat. In the Conestogo River Basin in Wellington and Waterloo, 86 percent of the land is farmed. In the Nith River region (Wellington, Waterloo, Perth, Oxford and Brant) farms occupy 83 percent of the land.

As described in the Natural Features **Section 2.4**, only a small proportion of the watershed is covered in natural vegetation or wetland.

3.5.1 Designated Growth Areas

As discussed earlier in **Section 3.3** (Population Centres), the Province of Ontario has initiated an urban growth strategy for the Greater Golden Horseshoe, which includes much of the Grand River watershed. The *Places to Grow* initiative designates urban growth centres, where future growth should be concentrated to optimize services and reduce encroachment of urban areas on rural land uses.

Within the watershed, the larger urban centres of Guelph, Kitchener, Waterloo, Cambridge and Brantford will be the focus of the majority of future growth. This will require significant upgrades to existing services such as water and wastewater, ensuring that core areas can accommodate population intensification.

In addition, official plans for the identified growth areas will need to indicate where, and in what form, growth is to occur on the peripheries in order to minimize the loss of prime agricultural land, or natural heritage areas.

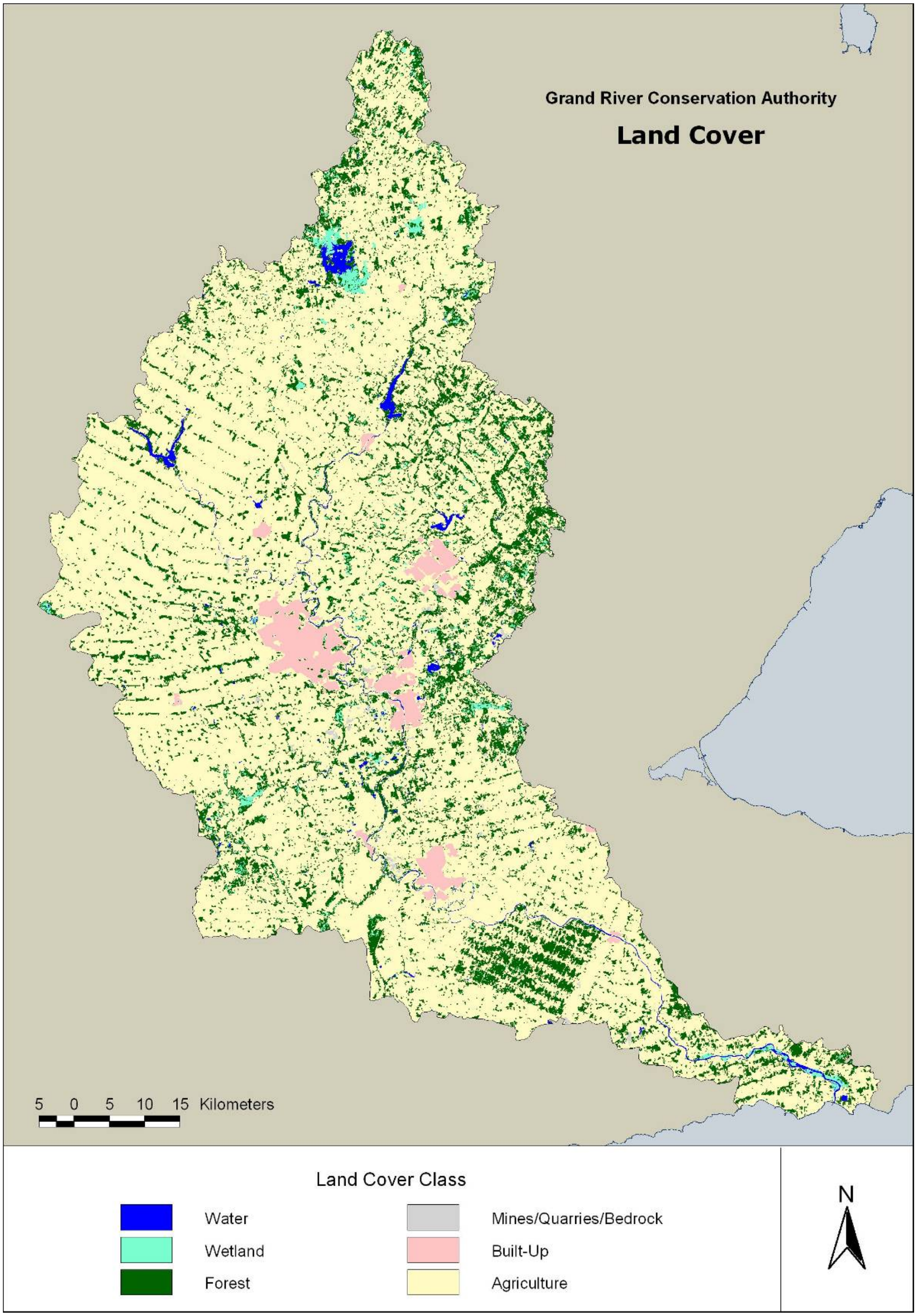
3.5.2 Industrial/Commercial Sector Distribution

Industrial and commercial sector operations are primarily located in urban, serviced areas within the watershed, as per municipal zoning by-laws.

Industrial sectors range from chemical manufacturing, automotive parts and assembly manufacturing, high-tech industry, textiles, and many other.

Historic industrial pollution is a chronic issue throughout the watershed, creating numerous brownfield sites in areas that housed industries during the nineteenth and twentieth centuries.

Map 3.3: Land Cover in the Grand River Watershed



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3.5.3 Brownfields

Old industrial areas or contaminated lands are often referred to as brownfield sites. Throughout the watershed, brownfields have the potential to contaminate both surface water and groundwater resources. However, identification of brownfields is often a difficult task, as contamination can remain undetected in soils and groundwater for many years.

Several brownfield remediation programs have been developed in municipalities throughout the watershed, including:

- City of Guelph Brownfields Strategy (2002);
- City of Brantford Brownfields Strategy (2002);
- Regional Municipality of Waterloo Brownfield Redevelopment Strategy (Regional Growth Management Strategy); and
- City of Hamilton Contaminated Sites Management Program and an Environmental Remediation and Site Enhancement (ERASE) program.

3.5.4 Mining and Aggregate Extraction

Mining is not an extensive industry in the Grand River watershed; however, aggregate extraction occurs in various locations. Many aggregate extraction activities occur throughout the watershed. These areas are rich in aggregates and provide high quality aggregate products for construction and building materials. Water issues related to aggregate extraction have not been studied extensively, but may impact the quality and quantity of groundwater when extraction occurs below the water table. In particular, more research is required to determine the cumulative environmental impacts of locating multiple licensed operations in proximity to each other.

3.5.5 Agricultural Resources

Although only 19 percent of the population of the Grand River watershed is rural, it controls over 75 percent of the land base. The majority of the land is used for agricultural production. The land use decisions made by rural residents and farmers have a significant impact on the water quality and landscape features of the Grand River watershed.

Rural land use is not expected to alter dramatically in the future. Since 1976, population in the rural areas has increased by approximately 23 percent. However, several general trends have been discerned which may change the impact of rural land use on the health of the ecosystem.

3.5.5.1 Agricultural Sector Distribution

Agricultural land use in the Grand River Basin is relatively high, with three quarters (75 percent) of the land area used for agricultural activities. Both livestock and agricultural crops are prominent practices, with 53 percent overall in cropped agricultural land. There are a total of 290,000 head of cattle, half a million heads of swine and almost 8.8 million heads of poultry across the watershed. The majority of the crops grown in the watershed by area are corn (29 percent), hay for fodder and forage (25 percent) and soybean (21 percent) (see **Figure 3.1**). The type of agricultural practice in a region depends on the climate, soils, water availability and many other factors, which creates clusters of certain practices.

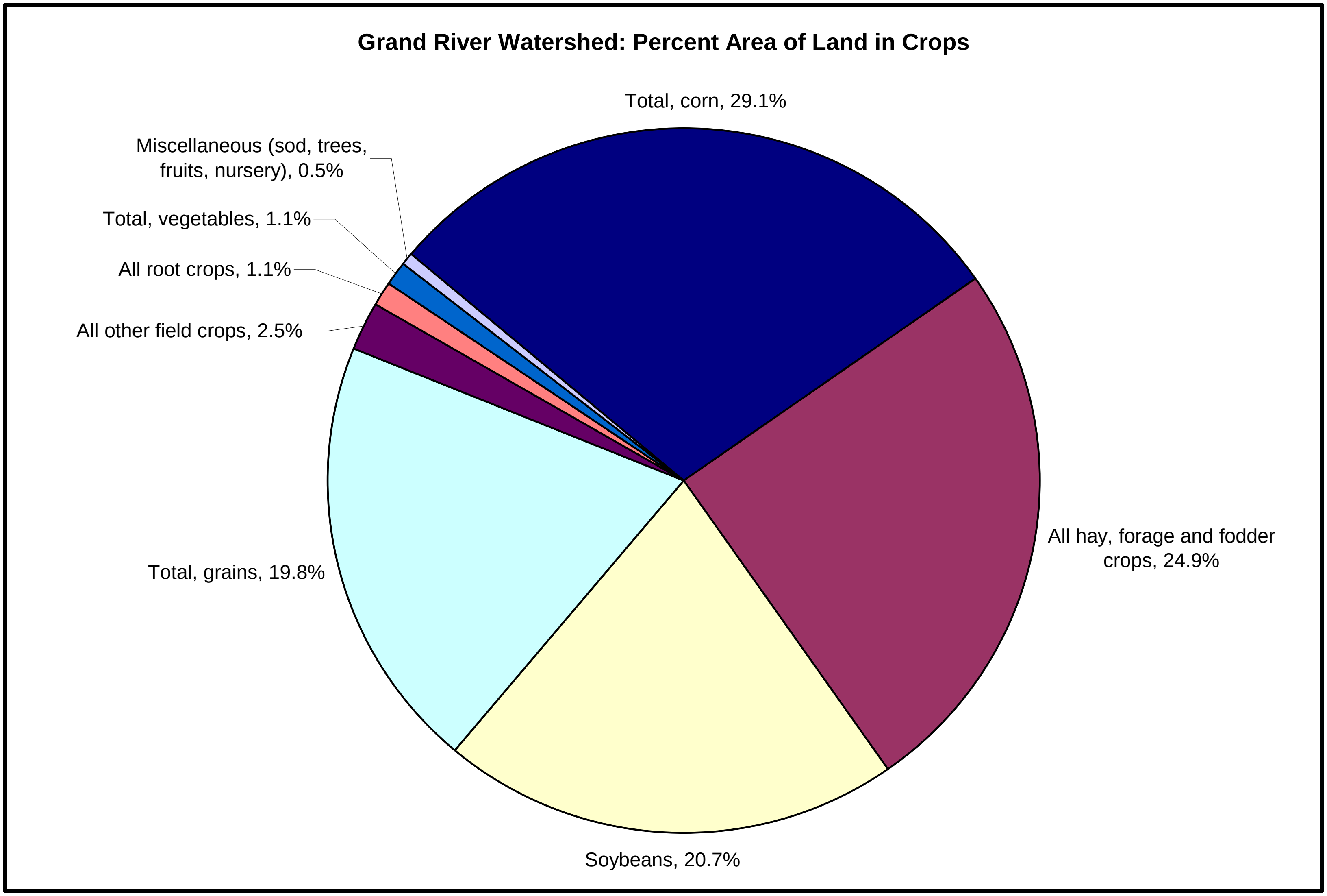
Subwatersheds with the highest percentage of land area in agriculture are located on the western central side of the Grand River watershed in Mapleton, Wellesley, Wilmot and Perth East Townships and have 90 percent or higher of the land area in agriculture. These include the Canagagigue Basin surrounding Elmira in Woolwich Township, the subwatershed below Conestogo Dam, between Glen Allan and St. Jacobs, and the Upper Nith River Basin above New Hamburg. These rural regions are located in the till plains with rich soils and hummocky topography. The crops grown here are predominantly corn, grains and hay, but very little of the specialty crops such as vegetables, fruits and root crops. The Horner Creek subwatershed between Hampstead and Princeton is just shy of 90 percent, but has more land area in specialty crops such as vegetables and field crops than the others, although corn still covers the greatest land area.

There are regional differences in the type of crops grown in the Grand River watershed, due in part to regional differences in climate and soils. For example, the southern Grand below Brantford has the highest percentage of soybeans in the watershed. Although some crops such as vegetables and root crops (tobacco, potatoes and sugar beets) make up a small portion of the watershed area (2.2 percent), they are concentrated mostly in Lower Whitemans Creek, and below Brantford. Sandy soils of the Norfolk Sand Plain dominate this region. This area has the greatest capability for agriculture, particularly for specialty crops. The concentration of vegetables and root crops in one region signify that a large quantity of irrigation water will be needed during the growing season to support these types of crops. The distribution, timing and quantity of water needed could impact the surface and groundwater supplies in the area.

Farming is less concentrated in the two watersheds that are located in Puslinch Township at 37 percent and the Region of Halton at 48 percent of the land area, which are the lowest with the exception of the watersheds with a major urban city. Forest cover in this region is relatively high for the Grand River watershed and the physiography of moist soil in low lying wetlands and swamps makes land less favorable for agriculture. The crops grown here are mainly all types of hay, with a higher percentage of land area (ten percent higher) than the watershed average, as well as corn and soybeans. There are some grains and vegetables, but no root crops in this region.

Livestock farming is more concentrated on the upper western portion of the watershed, and this is also the location of several of the highest proportion of grains, and a high portion of hay. Livestock farming is most prevalent in the northwestern subwatersheds of the Grand River watershed, with the upper Nith Basin having the greatest number of and types of livestock due to its large area. Based on heads of livestock per hectare of farmed land, the subwatersheds in Mapleton and Wellesley Townships in the Conestogo Basin surrounding the Conestogo Dam have the highest per hectare numbers of poultry, cattle and swine.

Figure 3.1: Percent Area of Land in Crops in the Grand River Watershed



Watersheds with a high proportion of livestock farming often have higher nutrient loads. Manure spreading could be a function of the impact of the livestock in this area. The highest nutrient loads correspond to the watersheds having the highest number of livestock per hectare. Runoff into the creeks and surface water system could be an issue in these watersheds.

3.5.5.2 Use of Irrigation

The use of irrigation in the Grand River watershed is not extensive, and is generally only used for specialty crops such as vegetables, sod, fruit and root crops such as tobacco, potatoes and ginseng. The use of irrigation is concentrated mostly in the Norfolk Sand Plain area in Brant Township and Norfolk County, where there is a higher percentage of specialty crops grown in well drained soils. Agricultural irrigation is concentrated in the months of July and August, with some exceptions earlier or later in the growing season. The concentration of these large water takings during warmer and often drier periods poses problems to water quantity in both groundwater and surface water sources.

3.5.5.3 Agricultural Management Practices

Management practices include such activities as conservation tillage and grassed waterways, and are preventative actions against erosion into the waterways or chemical runoff. Across the watershed, to reduce the amount of sediment loading in the waterways, 18 percent of farms reported using grassed waterways, six percent use contour cultivation and three percent use strip cropping, while 12 percent using winter cover crops and 13 percent using windbreaks or shelter belts help to prevent the removal of topsoil by wind. Crop rotation is the most widely used conservation practice at 70 percent of farms reporting, which increases the longevity, productivity and environmental quality of farmland by replacing nutrients into the soil.

The northern and eastern portions of the watershed generally use these management practices less than the overall watershed average, while the central western side of the watershed, including the more livestock intensive subwatersheds, reported more use of all of these conservation practices than the watershed average. The use of these conservation practices in this region and especially in the high livestock farming regions is a positive step for water quality improvement. The Lower Nith River Basin has the highest percentage of farms reporting use of grassed waterways (26 percent), which provides a buffer and filtering process for runoff before it reaches the stream.

Several programs have been developed to assist farmers and rural landowners in the watershed to implement best management practices. Existing programs include:

- The Rural Water Quality Program (RWQP), a voluntary initiative developed by the Grand River Conservation Authority, in conjunction with watershed municipalities, provincial and federal governments, the farming community and environmental associations to improve rural water quality through implementation of best management practices on farmland.
    - Through cost sharing formulas, farmers are able to access for financial assistance for eligible projects ranging from 50 percent to 100 percent coverage.

    - o Projects include construction of manure holding tanks, fencing along rivers and re-vegetation of river banks. To date over 1,000 projects have been completed throughout the watershed.

- The Environmental Farm Plan Program (EFP) sponsored by the Ontario Farm Environmental Coalition. Farmers completing a self-assessment workbook are eligible for up to $1,500 to help them make positive environmental changes on their land. The EFP program was started by farmers in 1993 through a coalition of farm associations with funding from the federal Green Plan. Funding was also recently received from CanAdapt to extend the program from 1997 to 2000 [UPDATE].

- The Wetland Habitat Fund provides advice and 50 percent of project costs to landowners to conserve their wetlands as wildlife habitat. The program is funded by Wildlife Habitat Canada and the Ontario Ministry of Natural Resources and delivered through the Easter Habitat Joint Venture.

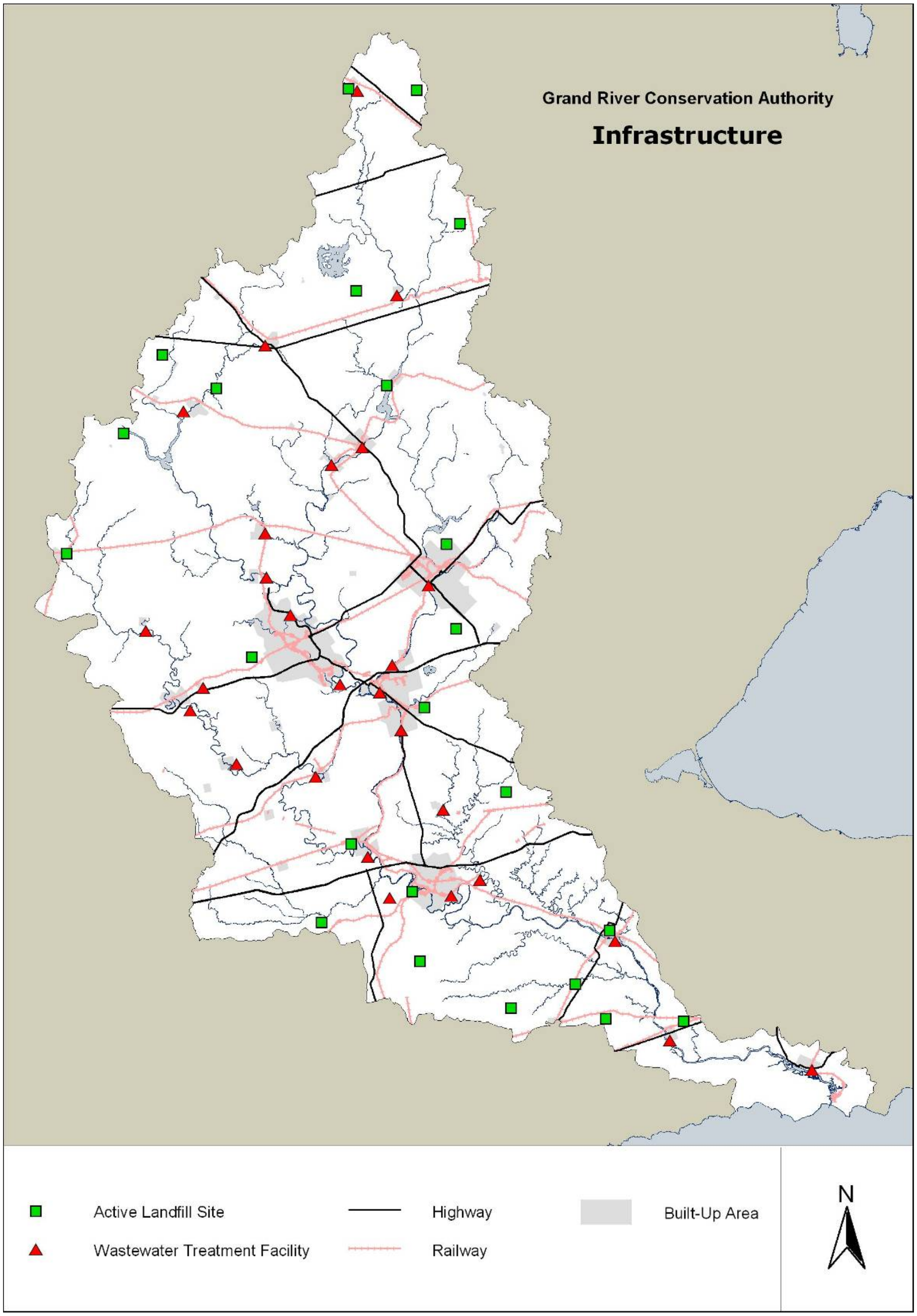
3.6 Infrastructure

A watershed's public infrastructure system represents a crucial link to population growth and ecological health. Efficient and well-planned transportation systems, including roads, railways, public transit and airports, are required to move people and goods throughout the watershed. In many cases, the accessibility and location of roads or public transit focuses population growth to an area, which in turn requires water, wastewater and stormwater management services.

The quality and adaptability of infrastructure systems ultimately determines long term sustainability of not only municipal drinking water services, but also drinking water sources.

The following sections briefly describe infrastructure systems currently in place in the Grand River watershed, including transportation, landfills, wastewater, and stormwater systems. Locations of selected infrastructure systems are shown on **Map 3.4**.

Map 3.4: Landfills and Wastewater Treatment Plants in the Grand River Watershed



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3.6.1 Transportation

Within the Grand River watershed, there are several major transportation corridors. Of greatest importance is the MacDonald – Cartier Provincial Highway (Highway 401). Highway 401 runs through the central portion of the watershed, entering south of Guelph, through Cambridge and Kitchener, and exiting in the southwest in Oxford County (near Woodstock). The 401 provides a vital link to the watershed, connecting it with neighbouring urban and industrial centres in the Greater Toronto Area and London.

Another inter-regional link is Highway 403 linking Brantford to the City of Hamilton and the Greater Toronto Area in the east and Woodstock and Highway 401 in the west.

Important regional roads linking urban centres as well as rural areas in the watershed include:

- Highway 7/8 between Kitchener and Cambridge;
- Highway 7/8 from Kitchener to Baden and Stratford;
- Highway 2 between Brantford and Paris;
- Highway 86 from Kitchener to Elmira;
- Highway 7 from Kitchener to Guelph;
- Highway 6 from Kenilworth in the north to Guelph and Highway 401 in the south;
- Highway 109 from Teviotdale in the northwest to Grand Valley and Orangeville in the northeast;
- County Road 124 from Guelph to Cambridge
- Highway 24 from Cambridge to Brantford; and
- Highway 3 land Highway 6 South in the southern portion of the watershed.

The Region of Waterloo International Airport is located east of the City of Kitchener, in the central portion of the watershed. Its proximity to all five major urban centres in the watershed made it the 12th busiest airport in Canada in 2000. The airport is considered a vital link in the technological and industrial economy of the watershed, with approximately 600 to 700 businesses making use of the facilities. In addition, the airport offers business and passenger charter services, recreational flying, and flight schools.

The Cities of Brantford and Guelph also have small regional airports servicing the immediate area. These provide services ranging from charter flights to recreational flying and flight training.

3.6.2 Wastewater Treatment

There are 29 municipal wastewater treatment plants discharging to the Grand River and its tributaries. The municipal wastewater treatment plants vary in size, as demonstrated by the rated capacity summarized in **Table 3.3**. Treatment level varies, and includes lagoon systems, as well as secondary and tertiary treatment systems. Secondary treatment refers to biological and chemical removal of organic matter from sewage. In tertiary wastewater treatment plants, advanced treatment processes are used to remove other constituents such as ammonia and phosphorus.

In most cases, the municipal wastewater treatment plants discharge continuously throughout the year, although there are four lagoon systems that are only permitted to discharge seasonally in spring and fall. There are no primary treatment systems or combined sewer overflows located in the Grand River watershed.

Approximately 85 percent of the total population of the watershed is serviced through municipal wastewater treatment plants. The remaining people have on-site septic or sewage systems. About two thirds of the serviced population is serviced by secondary treatment, while the remaining third have tertiary treatment, which includes advanced wastewater treatment such as the reduction of ammonia.

In addition to municipal wastewater treatment systems, there are several private or industrial wastewater treatment plants that discharge to the Grand River or its tributaries. **Table 3.4** provides a summary of privately-owned and operated wastewater treatment plants. Unlike municipal wastewater treatment plants, many of the operations listed in **Table 3.2** treat a diverse range of wastes related to industrial operations (e.g. food processing or metal finishing) or remediation of contamination (e.g. pump and treat systems to remove organic contaminants from groundwater in Elmira). For the most part, these private systems are small in comparison to municipal wastewater treatment plant discharges.

Table 3.3 Rated Capacity of Municipal Wastewater Treatment Plants in the Grand River Watershed

Wastewater Treatment Plant Name	Discharges to	Level of Treatment	Rated Capacity (million L/day)
Kitchener WWTP	Grand River	Secondary	122.742
Brantford WWTP	Grand River	Secondary	81.818
Waterloo WWTP	Grand River	Secondary	72.73
Guelph WWTP	Speed River	Tertiary	54.552
Galt WWTP	Grand River	Tertiary	38.641
Preston WWTP	Grand River	Tertiary	16.866
Hespeler WWTP	Speed River	Secondary	9.319
Dunnville WWTP	Grand River	Secondary	7.728
Paris WWTP	Grand River	Secondary	7.046
Fergus WWTP	Grand River	Tertiary	6.4
Caledonia WWTP	Grand River	Secondary	7.2
Elmira WWTP	Canagagigue Creek	Tertiary	4.546
Elora WWTP	Grand River	Secondary	3.064
Baden-New Hamburg WWTP	Nith River	Tertiary	2.728

Table 3.3 Rated Capacity of Municipal Wastewater Treatment Plants in the Grand River Watershed

Wastewater Treatment Plant Name	Discharges to	Level of Treatment	Rated Capacity (million L/day)
Arthur WWTP	Conestogo River	Tertiary	1.465
Ayr WWTP	Nith River	Tertiary	1.182
Dundalk Lagoon	Continuous discharge to Foley Drain	Lagoon	1.126
Wellesley WWTP	Nith River	Tertiary	1.1
St George WWTP	Fairchild Creek	Tertiary	1.064
St Jacobs WWTP	Conestogo River	Tertiary	0.955
Cayuga WWTP	Grand River	Secondary	0.873
Grand Valley WWTP	Grand River	Secondary	0.6
Plattsville Lagoon	Spring or fall discharge to Nith River	Lagoon	0.596
Drayton Lagoon	Spring or fall discharge to Conestogo River	Lagoon	0.559
Drumbo WWTP	Cowan Drain To Nith River	Tertiary	0.272
Cainsville Lagoon	Spring or fall discharge to Fairchild Creek	Lagoon	0.168
Conestoga Golf Course Subdivision	Grand River	Tertiary	0.148
Alt Heidelberg Estates Subdivision	Heidelberg Creek	Tertiary	0.13
Six Nations Oshweken Lagoon	Spring or fall discharge to McKenzie Creek	Lagoon	unknown

Table 3.4: Industrial/Private Wastewater Treatment Plants in the Grand River Watershed

Industrial Site	Wastewater type	Discharges to	Rated Capacity (million L/day)	Notes
All Treat Farms Limited, Arthur	Stormwater from composting facility	ATFL Drain to Conestogo River	0.14	Very limited discharge to surface water, most effluent is spray irrigated
Alma Research Station, Alma	Process wastewater from fish farm	Swan Creek	Not specified	
American Standard, Cambridge	Process wastewater containing metals	Speed River	0.212	
Byng Island Conservation Area, Dunnville	Wastewater from campground	Sulphur Creek	Varies with flow in Sulphur Creek	Seasonal discharge
Conestogo Meat Packers	Wastewater from hog processing operation	Randall Drain to Grand River	0.9	
Chemtura Canada Co., Elmira	Contaminated groundwater from On-Site Collection System	Canagagigue Creek	0.054	Continuous discharge
Chemtura Canada Co., Elmira	Contaminated groundwater from Off-Site Collection System	Canagagigue Creek	4.579	Continuous discharge
J.M. Schneider, Ayr	Wastewater from food processing	Nith River	Not specified	
Northstar Aerospace, Cambridge	Contaminated groundwater	Stormsewer to Grand River	0.16	
Rothsay, Moorefield	Wastewater from rendering process	Moorefield Creek	Varies with flow in Moorefield Creek to a maximum of 86.4	Seasonal discharge
Sulco Chemical, Elmira	Stormwater and boiler water blowdown	Canagagigue Creek	Not specified	

3.6.3 Stormwater Management

Few locations in the watershed are serviced by stormwater management systems, such as retention ponds, holding tanks or treatment systems. Approximately 80 percent of serviced areas in the watershed do not have stormwater management systems. Newer urban developments are required to have stormwater management systems; however, these areas account for only a small percentage of the urban landscape in the watershed.

The Ministry of the Environment (MOE) has prepared interim guidelines on storm water quality that are continually being upgraded and revised due to the expanding knowledge in this area of water management. Urban centres have storm sewers which collect runoff from precipitation events and discharge directly to surface water. Municipalities in the watershed are incorporating stormwater management planning; however, this remains a difficult task.

Without treatment or retention, stormwater entering rivers can carry high concentrations of pollutants and sediments, leading to contaminated source water for downstream users.

3.6.4 Landfills

There are currently 23 active municipal landfills located throughout the watershed.

Landfills pose potential threats to water sources if runoff and leachate are not managed accordingly. Runoff from active or closed sites may contain various contaminants that could enter surface water sources. In addition, landfill leachate infiltrating into the ground could end up in groundwater sources.

3.7 Implications of Geology and Land Use for Source Water Protection

Some land uses in the watershed can pose an increased threat to drinking water sources depending on the geology of the area. As discussed in **Section 2.0**, the geology of the Grand River watershed varies significantly. Deposits of clay and till found in the northern and southern portions of the watershed, form relatively impermeable barriers to the infiltration of water. As a result, runoff to nearby watercourses is increased. Glacial moraines and drumlins, located in the central portion of the watershed, can allow for higher levels of infiltration through permeable sand and gravel deposits.

The northern and southern portions of the watershed are predominantly rural, with agriculture as the main land use. Runoff of precipitation over the tight till and clay deposits can quickly move soils, nutrients (manure and fertilizer) and other contaminants into nearby watercourses. Tile drainage of farm fields and wetlands, and removal of riparian buffers, fence lines and forest cover to increase tillable acreage has increased runoff, and subsequently increased contamination of surface water over the decades. However, recent trends to adopt more environmentally friendly farming practices have increased riparian buffers and tree cover throughout the watershed.

The permeable sand and gravel deposits of the moraines and drumlins in the central portion of the watershed are overlain by both intense agriculture and densely populated urban areas. Much of the population in this area obtains their drinking water from the rich groundwater sources, characteristic of the middle watershed. In permeable areas, where aquifers don't have additional shallow or deep aquitards, there is an increased potential for spills and runoff from both urban and rural areas to infiltrate into the ground and contaminate groundwater resources.

4.0 WATERSHED MANAGEMENT

4.1 A Managed River System

The Grand River is a managed river system where reservoir operations, water supply, and wastewater management were designed as an integrated system on a watershed basis.

The Grand River watershed has a long history of using a watershed approach for water management and resolving water related issues. Following the devastating flood in 1929, the Grand River Valley Boards of Trade, an amalgamation of local Boards, petitioned the provincial government for a solution to the problems of flooding and water quality. The first basin plan for managing the system, called the ‘Findlayson Report’, was completed in 1932. The Grand River Conservation Commission was formed in 1938 to implement the recommendations of the report, with Brantford, Elora, Fergus, Galt, Kitchener, Paris, Preston, and Waterloo as charter members. The construction of Shand Dam was completed in 1942.

The plan was renewed with the Grand River Hydraulics Report, completed in 1956 and updated in 1962. The construction of Conestogo Dam was completed in 1957 and the Guelph Dam was completed in 1976. The Grand River Conservation Commission and the Grand Valley Conservation Authority were amalgamated in 1966 to form the Grand River Conservation Authority.

The most recent water management plan, called the Grand River Basin Water Management Plan, was completed in 1982 with a 50 year planning horizon to 2031. It established objectives and targets for reducing flood damage, providing water supply, and improving water quality, and recommended actions for achieving these objectives. Its recommendations included modifications to the operating procedures for Shand, Conestogo, and Guelph Dams, to address water supply and water quality issues; construction of dykes at the major damage centres to address flooding concerns; wastewater treatment plant upgrades to address the cumulative impacts of wastewater treatment plants in the watershed; and sources of municipal water supply for each serviced community.

4.2 Multi-purpose Reservoirs

The reservoir system in the Grand River Watershed is operated to reduce flooding and to add water to the river during low flow periods to provide municipal water supply and improve wastewater assimilation and river water quality. **Table 4.1** lists the seven multi-purpose reservoirs in the Grand River watershed and the primary functions for which they were designed.

The major dams, Shand, Luther, Conestogo, and Guelph Dams, provide flow augmentation and flood control for the main Grand River. The others influence the local tributary on which they are situated. The location of these reservoirs is illustrated by **Map 4.1**.

Map 4.1: Dams and Reservoirs in the Grand River Watershed

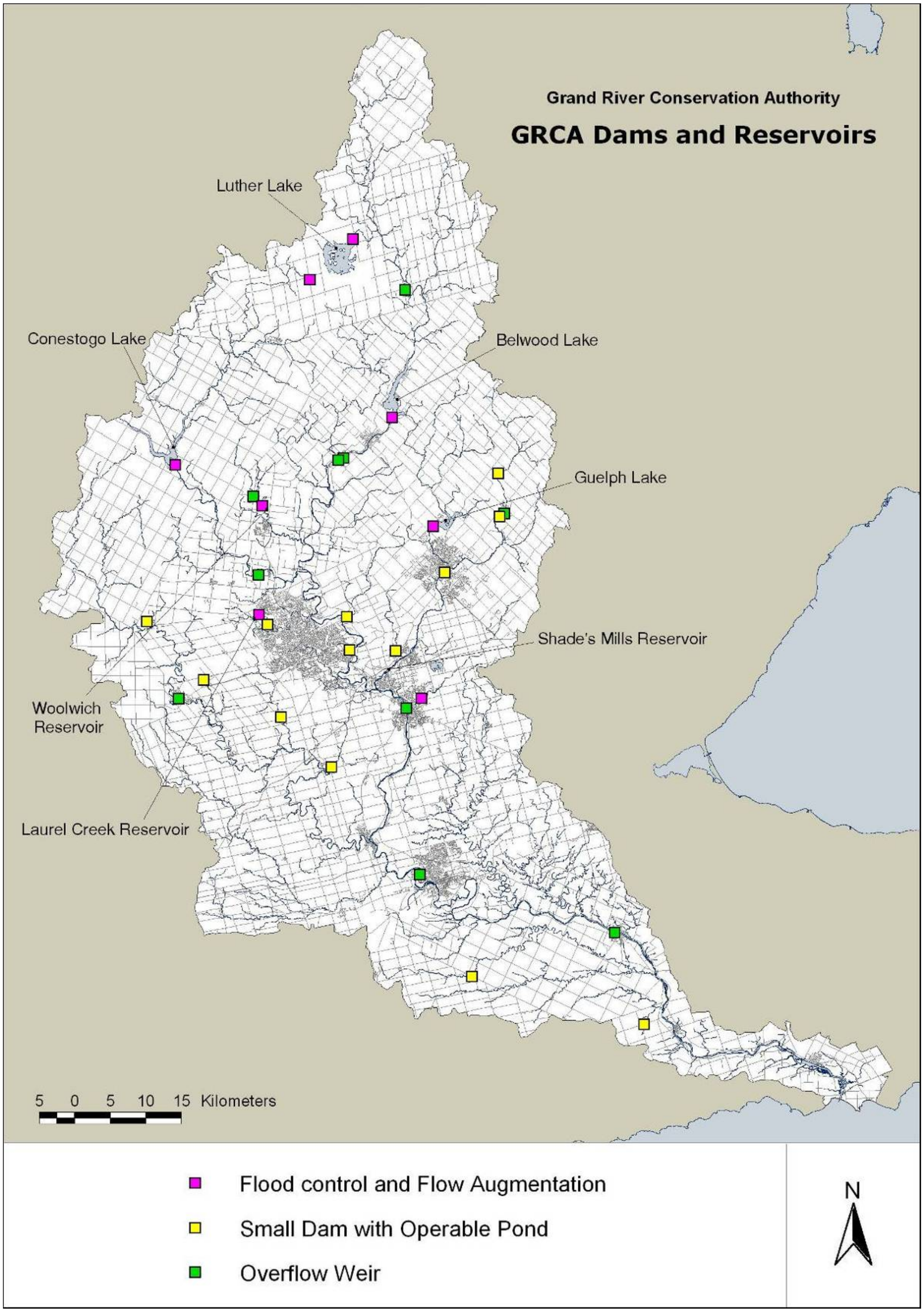

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Table 4.1: Multi-purpose Dams and Reservoirs

Reservoir Name	Primary Reservoir Function	Year Built	Dam Height (metres)	Storage Capacity (cubic metres)
Shand Dam	Flood Control, Flow Augmentation	1942	22.5	63,874,000
Conestogo Dam	Flood Control, Flow Augmentation	1958	23.1	59,457,000
Luther Dam	Flood Control, Flow Augmentation, Wildlife Management	1952	5.0	28,075,000
Guelph Dam	Flood Control, Flow Augmentation, Recreation	1976	14.3	22,387,000
Woolwich Dam	Flood Control, Flow Augmentation	1974	11.7	5,491,000
Shade's Mill	Flood Control, Induced Infiltration, Recreation	1973	9.8	3,240,000
Laurel Creek	Flood Control, Recreation	1968	5.6	2,450,000

4.2.1 Operating Procedures for Multi-purpose Reservoirs

The operation of multipurpose reservoirs follows a yearly filling and drawdown cycle. This cycle is guided by a "rule curve". A rule curve is an operating procedure developed for each dam to deal with competing needs for downstream flood control and low flow augmentation. This curve reflects physical operating constraints related to the dam structure, location and seasonal weather factors.

Figure 4.1 illustrates how the operating range of the three largest dams varies throughout the year. Normally, reservoirs levels are drawn down or held constant throughout the January and early February. During late February to early June, reservoirs are filled to their summer operating level. Between June and December, water is released slowly to provide flow augmentation.

The target reservoirs levels for April 1st, May 1st, June 1st, and October 15th were established for the major reservoirs in response to the recommendations of the Royal Inquiry into the May 1974 Flood. These levels are intended to balance the risks associated with the conflicting objectives for flood control and low flow augmentation.

The current low flow targets, shown in **Figure 4.2**, were established as part of the Grand River Basin Water Management Study, 1982. These targets were established based on what could be reliability supplied by the reservoirs (and not, as one might assume, the flow that is needed in the river for water quality purposes).

Figure 4.1: Operating Rule Curves

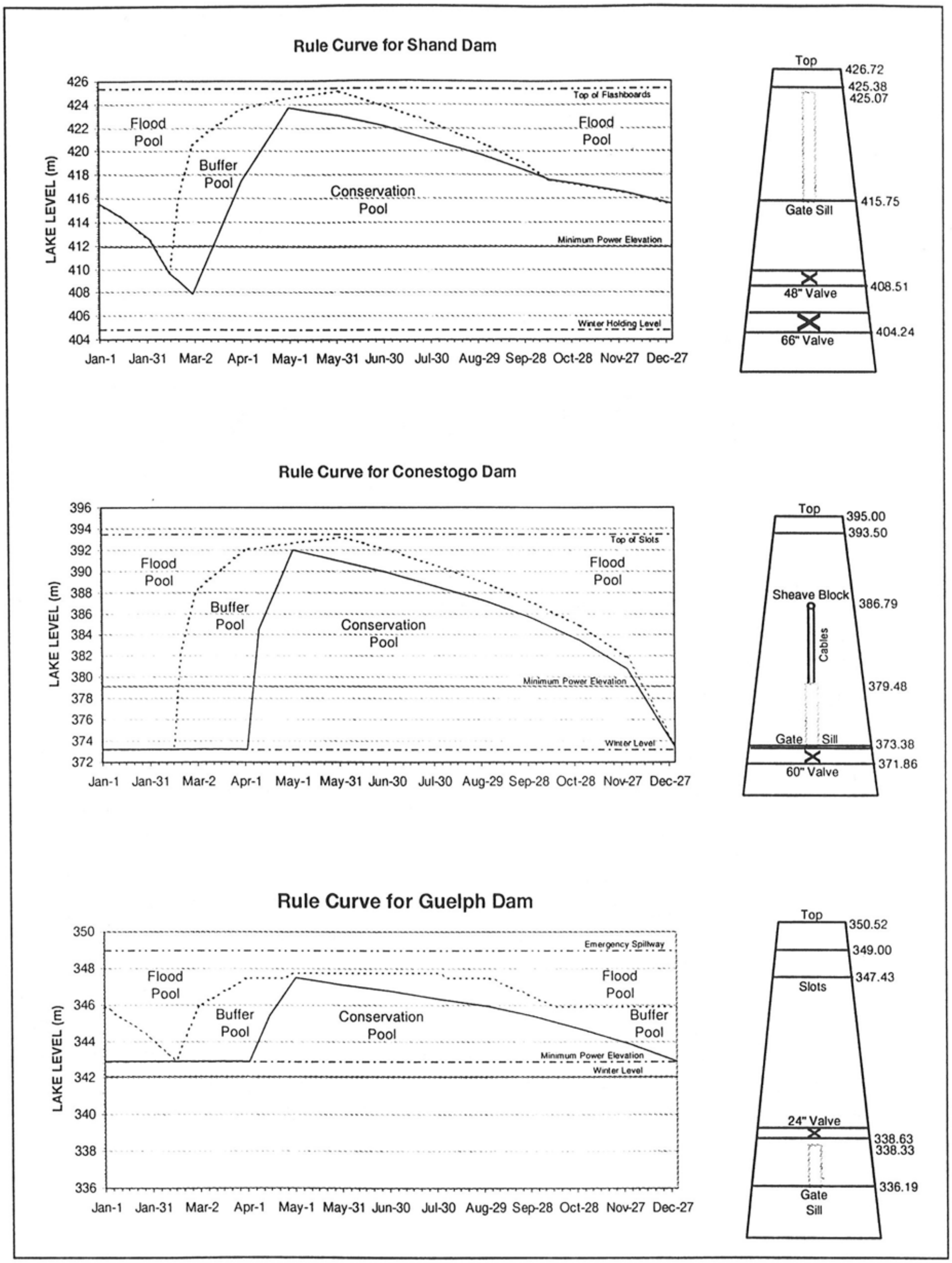


Table 4.2: Reliability of Meeting Minimum Flow Targets at Kitchener and Brantford

	Grand River Minimum Summer (May 1 to Oct 31) Targets at:		Grand River Minimum Fall (Nov 1 to Dec 31) Targets at:		Grand River Minimum Winter (Jan 1 to Apr 30) Targets at:	
	Doon (m^3/s)	Brantford (m^3/s)	Doon (m^3/s)	Brantford (m^3/s)	Doon[4] (m^3/s)	Brantford (m^3/s)
Minimum Flow Target[1]	9.9	17.0	7.1		2.8	
Reliability (occurrence)[2]	82.4%	88.2%	88.2%		100%	
Reliability (time)[3]	98.9%	99.6%	94.5%		100%	
Actual Minimum Weekly Flow	8.5	144.8	5.5	10.1	3.9	7.2
Actual Minimum Daily Flow	8.3 (Oct)	14.4(Oct)	5.1	9.5	3.8	6.6

[1]Because of the 30 hour travel time from the reservoirs to Doon, the daily flows can vary approximately +/- 0.9 m^3/s from the target/ The travel time from the reservoirs to Brantford is 48 hours. The daily flows can vary +/- 1.4 m^3/s from the target.

[2]Reliability (occurrence) refers to the percentage of days target was met in 17 years of flow records.

[3]Reliability (time) refers to the percentage of days target was met within operating period for 17 years of flow records.

[4]During November to December, flows can be measured at Doon and Brantford, but, due to ice conditions during January to April, flows can not be accurately measured at these stations. Therefore, from January to April, equivalent target flows are set at Shand Dam where winter flows can be estimated.

4.2.2 Shand and Conestogo Dams

Shand Dam and Conestogo Dam are operated as a system and provide flood control and flow augmentation for communities downstream of the confluence of the Grand and Conestogo Rivers. Major flood damage centres downstream of this confluence include Kitchener (Bridgeport), Cambridge (Galt), Paris, Brantford, Caledonia, Cayuga, and Dunnville.

Shand and Conestogo Dams are also operated to maintain minimum summer flows at Kitchener (Doon) of 9.9 m^3/s, and Brantford of 17 m^3/s. These minimum flows are critical to ensure adequate water supply and dilution of wastewater effluent along the main Grand River.

Shand Dam is located upstream of Fergus. It has a May 1st target storage of 57.8 million cubic metres (m^3). The minimum required discharge from Shand Dam is 2.5 cubic metres per second (m^3/s) but summer discharges range from 3 to 5 m^3/s during low flow periods. A significant tail-water brown trout fishery exists downstream of Shand Dam that is dependent on discharge from the Shand Dam.

Conestogo Dam is located downstream of Drayton on the Conestogo River. It has a May 1st target storage of 53 million m^3. The minimum required discharge from Conestogo Dam is 2 m^3/s and discharges from Conestogo Dam range from 2.5 to 4 m^3/s during low flow periods. During low flow periods, there is virtually no inflow to Conestogo Reservoir; therefore discharges from this reservoir come directly from water in storage. In addition to its system function, the Conestogo Dam provides flow augmentation to St. Jacobs located on the lower Conestogo River.

All of the water stored at Shand and Conestogo Dams is in heavy demand to meet water supply and water quality needs downstream. Only during unusually wet periods is there excess storage. In most years, the lakes are drawn down steadily to meet downstream flow augmentation requirements. In addition, Shand and Conestogo Dams were not designed with designated flood storage separate from conservation storage, as was the case for the more modern dams such as Guelph Dam. The same space that is reserved for flood control in the spring and fall is used to store water in the late spring and early summer for flow augmentation. As a result, the lakes at Shand and Conestogo Dam are drawn down throughout the summer to create flood control space for the fall tropical storm season, whether the storage is needed to augment flows or not.

Belwood Lake (i.e. the Shand Dam reservoir) and Conestogo Lake are used extensively for recreation. Cottages lots have leased around these lakes since their construction decades ago. The reservoirs are used for motor boating, skiing, swimming and fishing. Although it would be beneficial to hold the lake levels steady for these recreational activities, the dams are not designed to accommodate steady recreational lake levels, as described above. Periodically, lake levels are lowered below acceptable levels for recreation to ensure that downstream water quality, water supply, and flood control needs are met.

4.2.3 Luther Dam

Luther Marsh is operated in tandem with Shand Dam, typically providing an additional 10 million cubic metres (m3) of storage for flow augmentation. Luther is operated to maintain an unofficial target of 0.42 m^3/s in the river through the Village of Grand Valley and adds water to Shand Dam later in the season. The operating procedure for Luther Dam was recently reviewed and modified as past of the Luther Marsh Management Plan to accommodate habitat considerations in recognition of the importance of the area for wildlife.

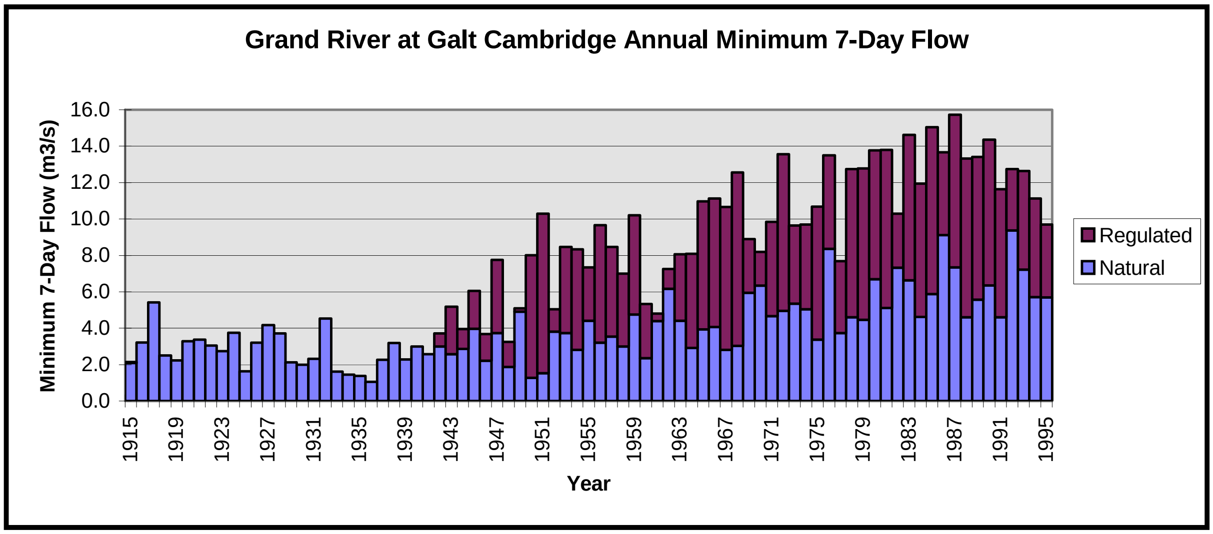
4.2.4 Guelph Dam

Guelph Dam is located upstream of the City of Guelph on the Speed River and provides flood control and flow augmentation to Guelph and Cambridge (Hespeler and Preston) on the Speed River. It has a May 1st target storage of 15.5 million m^3. The minimum required summer discharge from Guelph Dam is 0.7 m^3/s and discharge from Guelph Dam varies from 0.8 to 1.1 m^3/s during low flow periods. This dam is operated to maintain a minimum summer low flow of 1.7 m^3/s in Guelph, thereby increasing the capacity of the Speed River to receive Guelph's wastewater effluent, and enhancing water quality in the Speed River.

4.2.5 Low Flow Augmentation

The effectiveness of the reservoirs to augment river flows can be seen in **Figure 4.2** which illustrates the difference in summer flows under existing reservoir operations and under natural conditions at Cambridge (Galt). **Figure 4.2** illustrates the strong influence of the reservoirs on summer low flows over the period 1915 to 1995 as reservoirs were added to the system: Shand Dam in 1942, Luther Dam in 1953, Conestogo Dam in 1958, and Guelph Dam in 1976.

Figure 4.2: Minimum 7 Day Flow of the Grand River at Cambridge

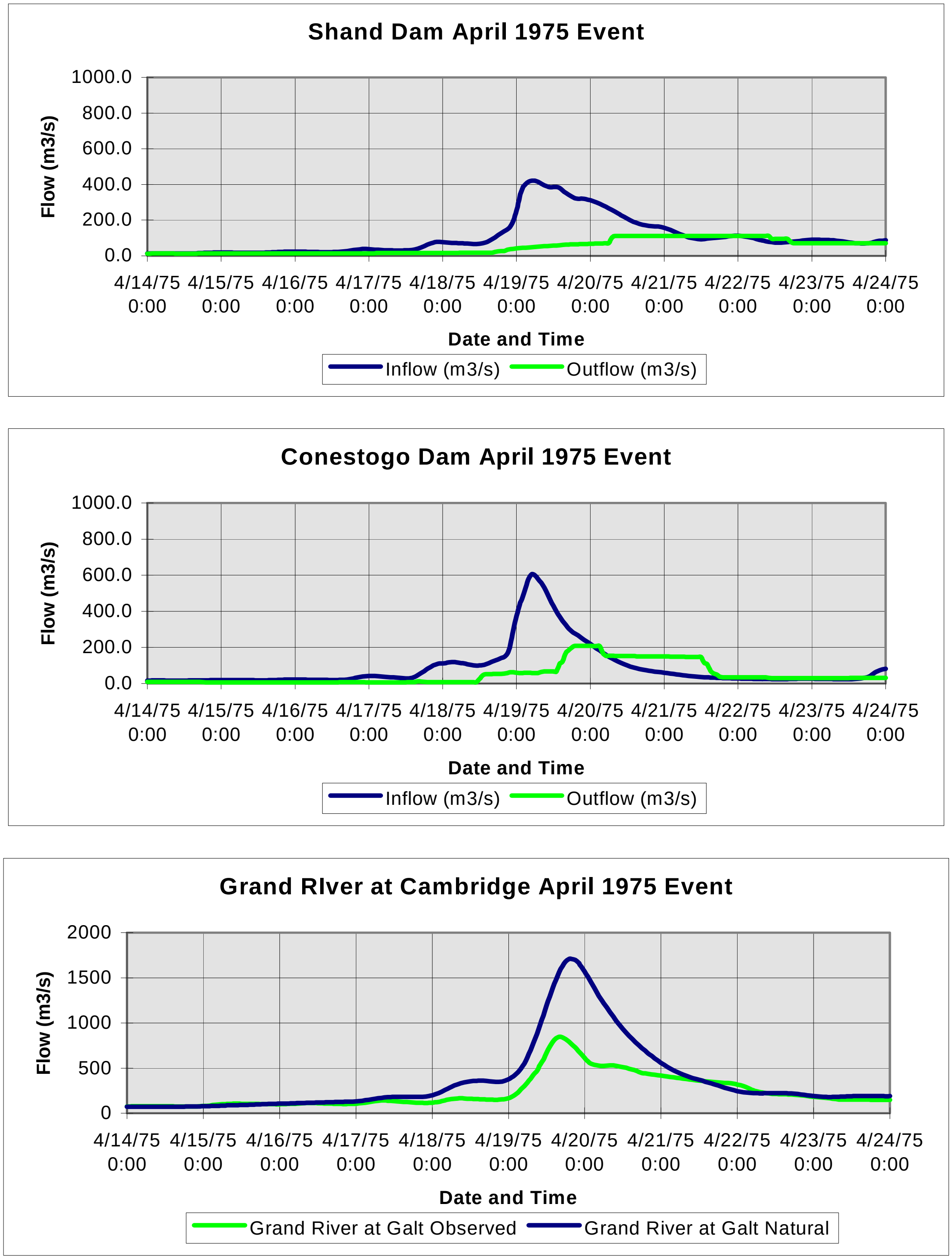


4.2.6 Flood Control

Flood flows on the main Grand River are influenced primarily by Shand and Conestogo dams and to a lesser extent by Guelph Dam. The other reservoirs provide flood control primarily to the local tributary on which they are situated. The competing needs for flood control and low flow augmentation reduce the amount of storage available for flood control during certain months of the year.

The effectiveness of the reservoirs to reduce flood damages can be seen in **Figure 4.3** which illustrates the April 1975 snowmelt/rainfall event. In Cambridge (Galt) the flood peak was reduced by 50% and major flooding was avoided. Without regulation provided by upstream reservoirs, the peak flow from 1975 event would have exceeded the 1974 peak flow and widespread flooding would have occurred.

Figure 4.3: Effect of Dams on April 1975 Flood Event



4.3 The 1982 Grand River Basin Plan and Status of Implementation

The most recent basin plan, the Grand River Basin Water Management Plan, was commenced in 1977 and completed in 1982 at a cost of $1.6 million. It was prompted by the recommendations of two provincial reports, "Review of Planning for the Grand River Watershed", 1971 and "Royal Commission Inquiry into the Grand River Flood", 1974.

The plan was developed to meet water management objectives over a planning horizon of 50 years, to 2031, for reducing flood damages, providing adequate water supplies, and maintaining adequate water quality.

The study was directed by the Grand River Implementation Committee (GRIC), led by the Ministry of the Environment, with members representing the 5 Provincial Ministries (Agriculture and Food, Environment, Municipal Affairs and Housing, Natural Resources, Treasury and Economics) and the Grand River Conservation Authority. Five sub-committees with membership from the agencies and local municipalities carried out the technical work of the basin study. Twenty-nine technical reports containing much of the study's data and technical analyses were published.

The basin study examined twenty-six different water management plans and assessed their relative economic, social and environmental costs and benefits associated with meeting the water management objectives. The screening process narrowed the alternatives down to four plans and their options. After a detailed review of the various inputs, the Grand River Implementation Committee, the Basin Study's coordinating committee, identified Plan A4 as the preferred plan to meet the water management needs of the basin.

The four alternative plans and the recommended plan are detailed in the 1982 Summary Report - Grand River Basin Water Management Study.

The 1982 Recommended Plan included:

- Channelization and dyke construction at major damage centres;
- Continuation of flood plain regulations and development restrictions, and incorporation of these policies into municipal plans and bylaws; registered fill lines along river valleys;
- Protection of the Eramosa valley wetland areas by planning controls and acquisition;
- Development of new groundwater sources for Cambridge, Guelph, and Fergus-Elora;
- Supplementation of Kitchener-Waterloo water supplies by withdrawal from the Grand River;
- Installation of improved sewage treatment facilities in Kitchener, Waterloo, and Guelph, and maintenance of water quality monitoring stations;
- Adoption of urban storm water management practices;
- Modified operating procedures for Shand, Conestogo, and Guelph Dams;

- Identification of rural non point sources of water pollution, and evaluation of the effectiveness of improved management practices;

- Protection of the West Montrose site for future water management purposes by acquiring the land as it became available and by planning controls.

- A coordinating committee to carry out a periodic re-evaluation of the plan, coordinate activities and investigations, and recommend new or modified alternatives to achieve the water management objectives of the Grand River Basin.

In 2002, it was estimated that 84 percent of the recommendations had been implemented. The recommendations were largely implemented by existing government agencies. Recommendations for establishing a coordinating committee supported by a small technical staff were never officially implemented. However, the GRCA gradually assumed this role with support from the various government agencies.

The targets for flood control, and water supply have generally been met.

While water quality has improved since the mid 1970's, there are frequent violations of a dissolved oxygen 4 mg/L criterion in the central Grand and lower Speed Rivers. Routine monitoring indicates that total phosphorus levels in the upper basin are usually in compliance with the PWQO of 0.03 mg/L, but downstream total phosphorus levels usually exceed the PWQO.

As a result of the improvements in river water quality from sewage treatment upgrades and the installation of urban and rural non-point source controls, there was a noticeable increase in fishery health.

The study recommended that the selected plan should be reviewed on an ongoing basis and re-evaluated every five years. This would ensure that the plan would be kept abreast of the latest developments in water resources management and that the assumptions made in deriving the original plan were still valid. This was not done. Very little reporting on implementation progress was done.

Since 1982, the major components of the plan had largely been completed by the existing government agencies. Many of the original implementers had retired, been transferred or promoted and a new set of implementers was badly needed. In addition, many of the day-to-day resource management functions were being delegated to municipalities and conservation authorities and any new watershed initiatives would have to be led by the local agencies (municipalities and the conservation authorities) rather than the province. Adding impetus to this need for a renewed watershed plan was the designation in 1994 of the Grand River as a Canadian Heritage River. During this process, a management plan for heritage and recreational resources was developed. Most of the participants, local government and the public, stressed that other pressing resource issues (not just heritage) should be addressed collectively on a watershed basis. Recognizing this, the GRCA in 1994 formed a Grand Strategy Coordinating Committee made up of municipalities and government agencies to review and revitalize the watershed plan.

In 1996, the GRCA produced for the committee a review entitled "State of the Grand River Watershed, Focus on Watershed Issues 1996-1997". The report outlined the current state of the watershed with respect to population growth, business development, water supply, flooding, water quality, fisheries, natural areas and biodiversity, outdoor recreation and human heritage. For each of these topics, the report summarized the visions, goals and management principles set out by the participants, as well as the major sources and management issues and what needed to be done to deal with them. A companion document to the above report was also produced entitled “State of the Watershed Report Background Report on the Health Of the Grand River Watershed”.

Components of an updated watershed plan have been completed:

1. The Fisheries Management Plan for the entire Grand River Basin;

2. The Forest Management Plan;

3. A basin water budget model to aid in water supply planning;

4. Updating/reapplying the 1982 Grand River Water Quality Simulation Model. This model plays an important part in determining the degree of treatment that is required for each treatment plant that discharges into the Grand River.

5. Initiation of the Rural Water Quality Program for over eighty percent of the watershed.

However, despite the progress made in the development of the models and data needed to answer questions related to the water management, the Water Management plan has not been updated. Meanwhile, growth in the Grand River watershed continues to put pressure on water resources. The Places to Grow legislation has established new population targets and municipalities are updating growth strategies, water supply strategies, and wastewater master plans without the benefit of a watershed context or collective decision-making that is provided by an up-to-date watershed plan.

5.0 WATER USES AND VALUES

The Grand River and its tributaries provide multiple functions for the communities in the watershed. Recreational, commercial/industrial and aesthetic uses of the river system draw both watershed residents and visitors to the area.

5.1 Water Uses

As the Grand River watershed continues to experience both economic and population growth, there will be increased demands on the basin's water resources to supply sufficient water to residential, commercial and industrial consumers. A report entitled *Water Use in the Grand River Watershed* (Bellamy and Boyd, 2005) was prepared as an initial summary of present-day water use within the Grand River Basin. Water use was broken into four subgroups: Municipal Water Supply Systems, Agricultural Water Use, Rural Domestic, and Operations on Private Supply (greater than 50,000 litres per day).

Water use estimates were determined using the best available data. Municipalities were contacted directly to establish municipal water use. Census of Population and Census of Agriculture were utilized to determine rural domestic as well as agricultural water use. Lastly, the Permit to Take Water (PTTW) database was used to quantify any water uses that were not municipal, rural domestic or agricultural. This analysis has identified the following top 15 water uses within the Grand River watershed.

1. Municipal Water Supply
2. Dewatering
3. Aggregate Washing
4. Aquaculture
5. Remediation
6. Golf Courses
7. Agriculture
8. Agricultural Irrigation
9. Other – Industrial
10. Miscellaneous
11. Manufacturing
12. Food Processing
13. Rural Domestic
14. Cooling Water
15. Recreational

The uses listed above are based on annual allowable takings. However, seasonal and temporal changes in water uses must be considered to give a more accurate representation of water takings. While agricultural irrigation is the eighth largest water user on an annual basis, this use is actually concentrated into only a few months of the year. During the month of July, water use for irrigation rises substantially and becomes the second highest water use. During an extremely dry year, this effect is much more pronounced.

Many of the top 15 water use categories were derived from the PTTW database, which is a collection of permits approved by the Ontario Ministry of the Environment (MOE) for water takings greater than 50,000 litres per day (animal watering, domestic usage and firefighting is excluded). Users apply for a permit and declare the maximum volume of water they may require to take on any given day of the year. Reporting of the maximum permitted rate, but not the actual water use, in the database limits its usability in determining the volume of water extracted from groundwater and surface water sources, as the quantity may be far more than the users would actually take on an average day. However, in absence of accurate data, the PTTW database gives a crude estimate of the types of water uses and distribution of water takings throughout the watershed. The MOE has begun to require certain permit holder categories to submit annual reports on their actual water takings in an attempt to address this shortcoming. In lieu of this information, the PTTW database information was queried to determine the maximum amount of water required for each category and some of these uses are described in the following sections.

Some additional water uses are also described that are of importance to the Grand River watershed, including in-stream and recreational uses, but do not require a permit to take water from the MOE.

Map 5.1 indicates the amount of water use as well as the main uses by subwatershed.

5.1.1 Industrial Water Uses

There are many industries in the five urban regions of the watershed as well as the rural/settlement areas that have applied for Permits to Take Water for their operations. Industrial uses make up approximately 13.5 percent of the total volume of water uses in the watershed, with the major industries being the aggregate industry (7.7 percent) and manufacturing (2.6 percent). Other industrial water requirements are often incorporated in the municipal supply if they are connected to the system, and these uses are not accounted for in this estimate.

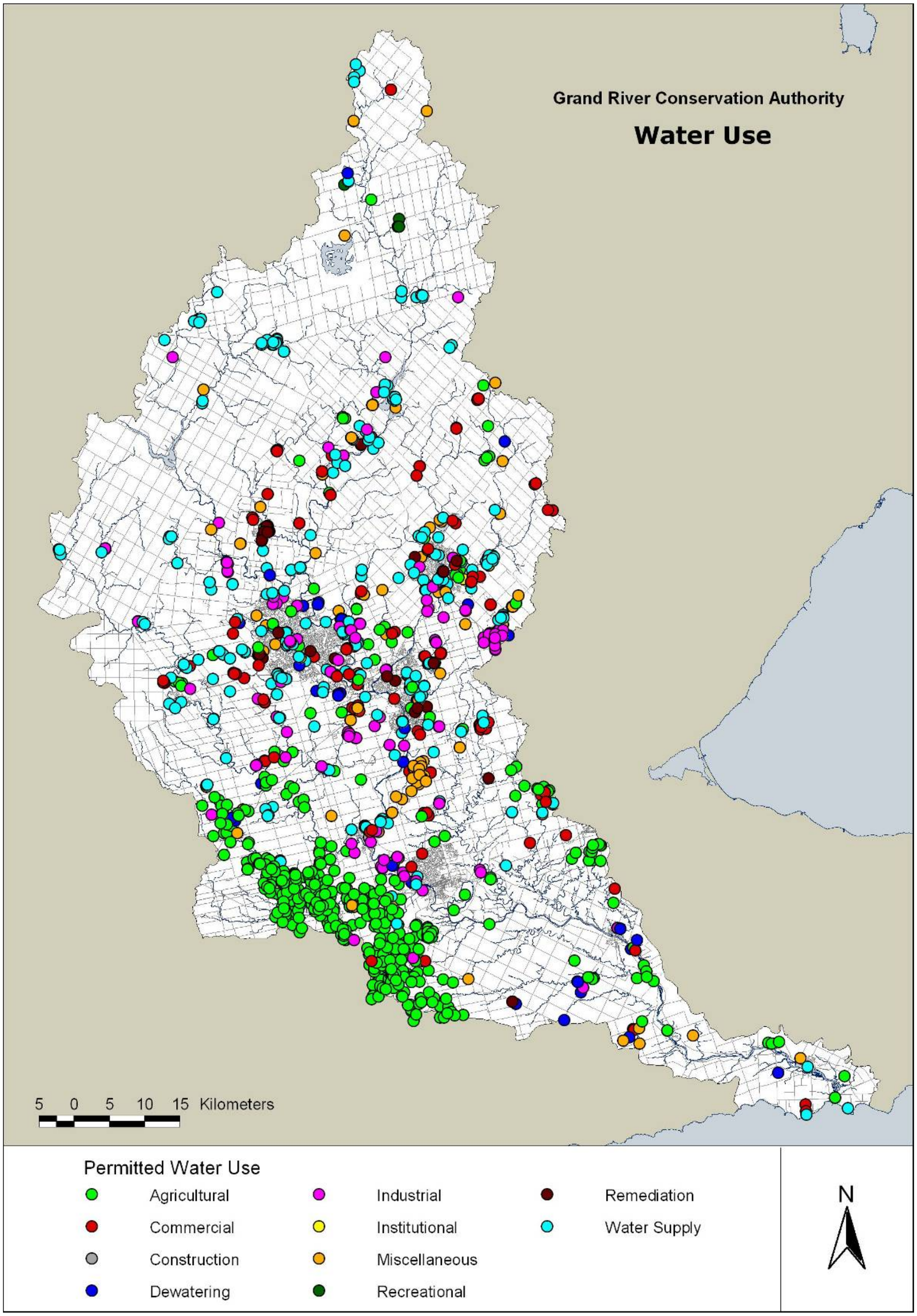
Aggregate producers require water on a daily and seasonal basis for washing, and often re-circulate the water through a series of settling ponds. When aggregate producers are extracting below the water table, there will be a need to dewater the quarry before excavation can occur. Dewatering also requires a Permit to Take Water as the water is removed from the source (groundwater). In many cases, water recovered from dewatering is used in the aggregate washing process before being returned to the environment. Dewatering accounts for 16 percent of the water use volume in the Grand River watershed, including dewatering of pits, quarries, mines, construction and dewatering of newly excavated landfill sites.

Other industrial uses include food processing (two and a half percent), pipeline testing, cooling water and other non-specified industrial uses which comprise 3.1 percent of total water use volumes in the Grand River watershed. Food processing operations with water use permits in the Grand River watershed include such industries as meat packing and production of dairy foods.

5.1.2 Agricultural Water Uses

Livestock farms require water year round to provide drinking and washing water for the animals, while crop irrigation is only required during the summer months of the growing season. Livestock farms are concentrated in the western portion of the watershed in Mapleton, Wellesley and Woolwich townships as well as in the edge of the City of Hamilton, in the southern portion of the watershed. Although not requiring a permit to take water, livestock watering accounts for about 3.2 percent of the water volume used in the watershed, as estimated using coefficients of water use for agricultural operations.

Map 5.1: Water Use in the Grand River Watershed



Agricultural irrigation occurs in specific regions of the watershed. Only certain crops require irrigation and these are generally specialty crops such as tobacco, root and vegetable crops, which are predominantly grown in the southern half of the watershed. The highest water uses for crop irrigation occur in Brant and Oxford Townships in the subwatersheds of Whitemans Creek, the Lower Nith River and McKenzie Creek. Crop irrigation comprises 3.3 percent of the total volume of water on an annual basis, but due to the temporal nature of crop irrigation being concentrated in only two months, the impact of this water use is much more substantial. While most water uses stay relatively constant throughout the year, in the month of July, for example, agricultural water takings for crop irrigation jump to the second highest water use in the watershed, after municipal uses.

5.1.3 Commercial Water Uses

The majority of the commercial water taking permits are for golf course irrigation, aquaculture and water bottling. Permits have also been issued for commercial businesses such as malls, as well as ski hills (for snowmaking). Golf courses, similar to agricultural irrigation, require the bulk of their permitted taking during the summer months when the courses are in operation. Some permits include year round sanitary uses; however, the majority of their water use is in the summer for irrigation. Golf courses make up 3.6 percent of water use volumes in the Grand River watershed.

Aquaculture or fish farms generally use permits to divert water from the source to fish tanks or ponds. In many cases, aquaculture operations return most of the water back into the environment. Larger aquaculture operations may treat the water leaving their farm as it is discharged back to a surface water body to remove excess nutrients.

Water bottling is a completely consumptive water use as it removes water from the environment and bottles it for commercial sale. Water bottling accounts for only a small portion of the water uses in the Grand River watershed, at 0.6 percent, but could represent a complete removal of the water taken from the watershed. The small proportion of water removed from bottling is not of immediate concern, but could become one if water bottling operations expand in the watershed.

5.1.4 Ecological Water Uses

Ecological water uses are important for the maintenance of environmental quality in a watershed and cannot be overlooked. Different aquatic organisms, including fish and invertebrates, have varying requirements for water levels in rivers during the year. Sufficient flows need to be maintained to ensure the quality of the environment such as stream structure or geomorphology, to function properly to support the organisms.

The concept of instream flow needs is still fairly new, and much research is needed to grasp the complex relationships that aquatic organisms have to their physical, chemical and biological environments. It is known that ecological flow requirements differ from site to site, from reach to reach along the entire length of the any river and its tributaries. A pilot project by the GRCA was completed in 2005 on the evaluation of instream flow assessment techniques, which provides a good basis for the understanding of instream flows in the Grand River watershed (Bellamy and Boyd, 2005). Eight reaches were studied to gain an understanding of how a variety of techniques would rate on very different watercourses with differing demands by both humans and the environment. This project found that not only are minimum flows required to maintain healthy aquatic organism communities, but high flows and a variety of other requirements such as water temperature and groundwater contributions can also be a part of ecological flow requirements.

Many physical factors such as stream bank stability and vegetation can play a major role in the maintenance of ecological flow requirements. For example, in the Mill Creek study, it was found that stream bank vegetation was crucial to maintain suitable water temperatures and bank stability for habitats. Thus the flows in the creek need to be within reach of the roots of the bank vegetation to prevent detrimental loss of ecological integrity of that system.

High flows, as mentioned, are also important for the proper function of a river system, as high flows can flush out sediments that may otherwise settle and clog riverbeds with fine sediments, reducing the invertebrate habitats and possibly covering eggs laid by fish in their spawning grounds. High flows over the banks also reintroduce floodplain nutrients back into the stream, benefiting the aquatic organisms along that reach.

Ecological flow requirements should be considered within the framework of the Permit-to-Take-Water program in order to reduce the impacts on aquatic habitat from reduced flow.

5.1.5 Recreational Water Uses

Recreational water activities are quite popular throughout the Grand River watershed. Fishing, swimming and boating are some of the most popular recreational activities related to water in this watershed. Many of the GRCA conservation areas support these activities and provide access to the river and other water bodies (reservoirs, ponds and quarries) year round. In 2005, over 1.1 million visitors to GRCA parks enjoyed many water activities including swimming, tubing down the Elora Gorge, canoeing, kayaking, motor boating, sailing and wind surfing in the summer, as well as ice fishing in the winter. The watershed has many multi-purpose dams that create large reservoirs, which provide the residents and visitors with many recreational water activities. Conservation areas are often adjacent to, or incorporate, the reservoir area. Cottages on the banks provide seasonal and year round access for more long term residency.

Fishing is enjoyed across the watershed, and is popular for many species of trout, bass and many other game fish. Coldwater fisheries are both stocked and natural to create additional fishing venues or to enhance the fishing in some areas of the watershed. Coldwater fisheries require specific flows and water temperatures. Fishing is a year-round activity, as several reservoirs provide ice fishing in the winter. The reservoirs also create coldwater fishing sites in the summer months due to the cooler water being released below the dam. The Shand Dam and Dunnville Dam both provide good fishing sites at their outlets to the Grand River for trout and other coldwater fish.

Other recreational activities include bird watching, duck hunting, biking and cross country skiing. The aesthetic appeal of water bodies on the landscape also serve as points of interest for sight seeing and photography. The watershed boasts a higher concentration of pedestrian and biking trails than the Ontario average. Rivers with heritage bridges such as the West Montrose covered bridge are also of importance as they provide aesthetic appeal.

Many parks, gardens, multi-purpose sports fields and other heritage locations, that have both aesthetic and recreational appeal, have requirements for water. Irrigation of fields and gardens, water parks and decorative fountains are some of the additional uses for water that create additional benefits for residents and visitors. Heritage locations offer non-monetary benefits by providing places for leisure, sports, games, festivals and family time that are known to increase the wellbeing of the people who enjoy these activities. Water requirements for aesthetic and recreational uses may be minimal in comparison to other more distinguishable water uses, yet they are very important to consider for the interests of the public and their involvements in protecting these resources.

5.2 Water Use Inventory

This section is a summary of the water uses within the Grand River watershed as described in a report entitled “Water Use in the Grand River Watershed” (Bellamy and Boyd, 2005). Water use estimates are broken down into four subgroups: Municipal Supply, Agricultural, Unserviced Population and Other Permitted Takings (larger than 50,000 Litres per day). The water use estimates were determined using the best available data, including Census of Population, Census of Agriculture, municipalities, and the Permit to Take Water (PTTW) database, as well as expert opinion of water managers. The analysis of all water use data identified the water uses and percentages within the basin, as seen in **Figure 5.1** and in **Table 5.1** with the volumes per month.

Figure 5.1: Major Water Uses on an Annual Basis in the Grand River Watershed

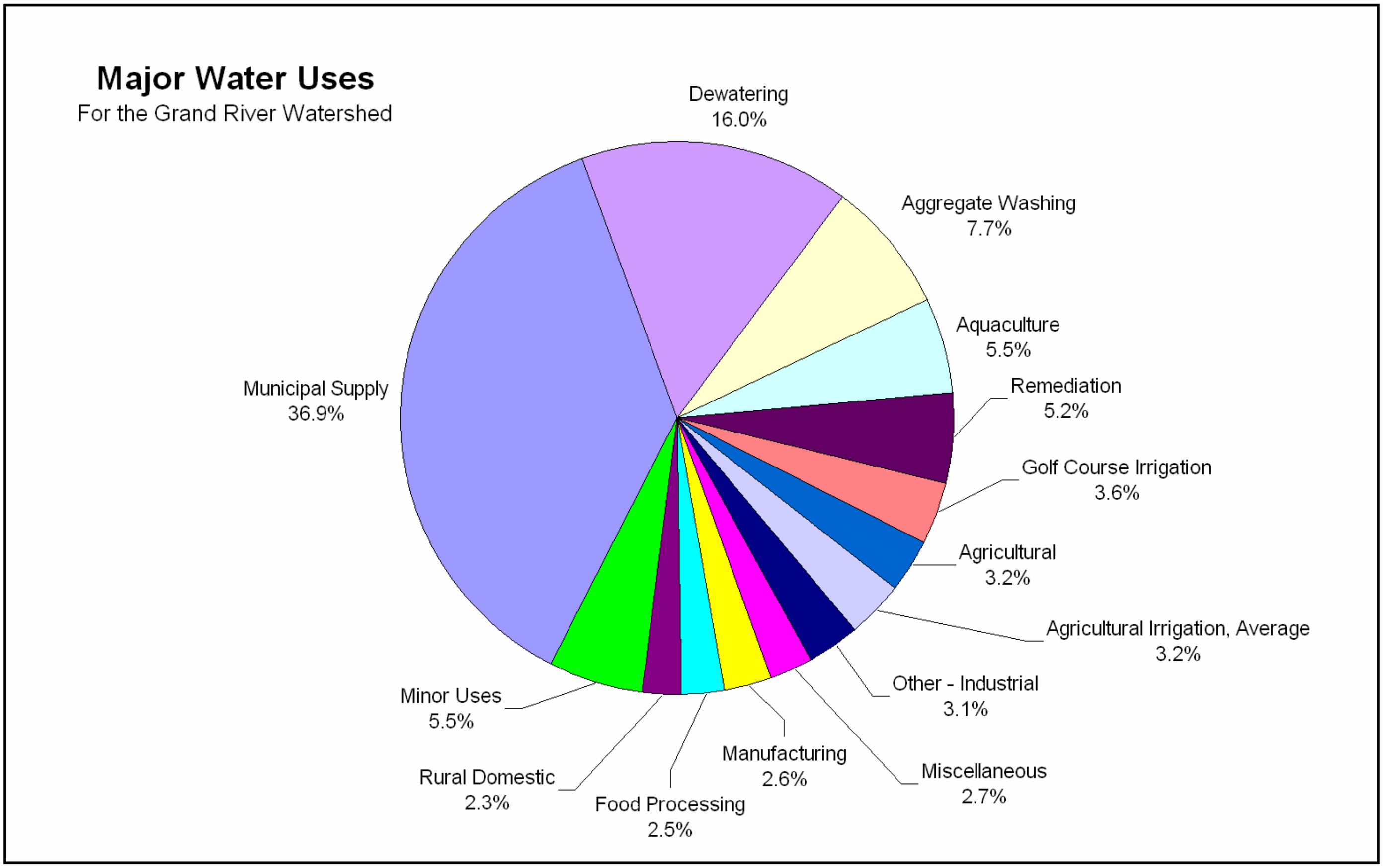


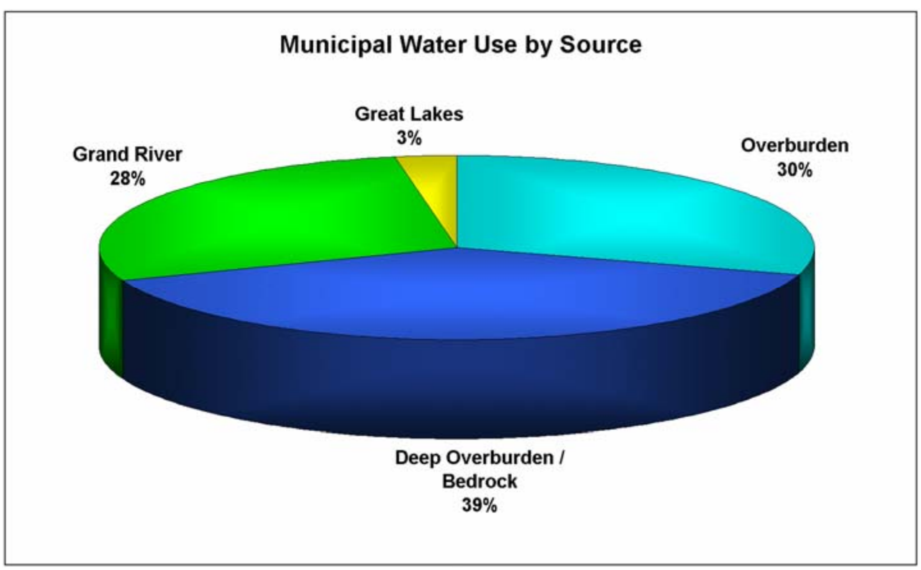
Table 5.1: Total Water Use Comparison (in cubic metres)

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
		(,000's of cubic metres)												
1	Municipal Supply	8,780	7,340	8,920	8,550	9,520	9,440	11,220	10,630	9,290	9,210	8,390	8,560	**109,840**
2	Dewatering	4,030	3,640	4,030	3,910	4,030	3,910	4,030	4,030	3,910	4,030	3,910	4,030	**47,490**
3	Aggregate Washing	-	-	-	-	3,330	3,220	3,330	3,330	3,220	3,330	3,220	-	**22,980**
4	Aquaculture	1,380	1,250	1,380	1,340	1,380	1,340	1,380	1,380	1,340	1,380	1,340	1,380	**16,270**
5	Remediation	1,320	1,200	1,320	1,280	1,320	1,280	1,320	1,320	1,280	1,320	1,280	1,320	**15,560**
6	Golf Course Irrigation	-	-	-	-	1,800	1,740	1,800	1,800	1,740	1,800	-	-	**10,680**
7	Agricultural	760	760	760	760	760	760	940	940	940	760	760	760	**9,640**
8	Agricultural Irrigation, Average	-	-	-	-	-	2,360	4,730	2,360	-	-	-	-	**9,460**
9	Other - Industrial	780	700	780	750	780	750	780	780	750	780	750	780	**9,160**
10	Miscellaneous	680	610	680	660	680	660	680	680	660	680	660	680	**8,010**
11	Manufacturing	660	600	660	640	660	640	660	660	640	660	640	660	**7,780**
12	Food Processing	640	580	640	620	640	620	640	640	620	640	620	640	**7,540**
13	Rural Domestic	560	560	560	560	560	560	560	560	560	560	560	560	**6,700**
14	Cooling Water	280	250	280	270	280	270	280	280	270	280	270	280	**3,290**
15	Recreational	-	-	-	-	-	670	690	690	670	-	-	-	**2,720**
16	Water Supply, Other - Water Supply	210	170	210	200	230	210	250	260	240	240	220	220	**2,660**
17	Other - Commercial	180	160	180	180	180	180	180	180	180	180	180	180	**2,140**
18	Water Supply, Communal	160	140	170	160	180	170	200	210	190	200	170	170	**2,120**
19	Bottled Water	140	130	140	140	140	140	140	140	140	140	140	140	**1,670**
20	Water Supply, Campgrounds	-	-	-	-	140	130	140	140	130	140	130	-	**950**
21	Mall / Business	40	40	40	40	40	40	40	40	40	40	40	40	**480**
22	Snowmaking	90	80	-	-	-	-	-	-	-	-	-	90	**260**
23	Heat Pumps	10	10	10	10	10	10	10	10	10	10	10	10	**120**
24	Other - Institutional	5	5	5	5	5	5	5	5	5	5	5	5	**60**
	Total	20,705	18,225	20,765	20,075	26,665	29,105	34,005	31,065	26,825	26,385	23,295	20,505	**297,580**

5.2.1 Municipal Water Supply

Municipal water use is the supply of water provided through a central distribution system operated by a municipality. Municipal water use includes urban domestic use, whether indoor or outdoor, and also includes uses for industrial, commercial, institutional or other uses that rely on municipalities for their water supply.

Figure 5.2: Municipal Water Use by Source



There were 41 separate municipal systems in 11 municipalities across the watershed, as detailed in the 2005 report. The sources of water include deep bedrock groundwater wells, shallower overburden groundwater wells, the Grand River itself and the Great Lakes. The breakdown of sources is seen in **Figure 5.2** and volumes in **Table 5.2.** The total amount of municipal water use as stated in the report was 110 million cubic metres per year.

Table 5.2: Volume of Municipal Water Use by Source

Source		Volume of Use
Groundwater	Overburden	32,604,000 m^3
	Deep Overburden/ Bedrock	43,281,000 m^3
	Total Groundwater	75,885,000 m^3
Surface Water	Grand River	30,594,000 m^3
	Great Lakes	3,040,000 m^3
	Total Surface Water	33,634,000 m^3
Total Municipal Water Use		109,519,000 m^3

5.2.2 Agricultural Water Use

Agricultural water use was divided into two categories; livestock/farming operation water use and crop irrigation water use. This division was based on the information available for the two categories, as well as the differing water requirements for each use throughout the year. Water use for livestock and other farming operations are generally year-round takings, as opposed to crop irrigation, which only occurs during the summer growing season. Other farming operations considered in this water use category include greenhouse operations.

Livestock water demands were estimated using a water use coefficient for daily water requirements and the number of livestock in the watershed. The volume of livestock and other year-round agricultural water requirements, excluding irrigation water, accounts for 9.6 million cubic metres per year.

Crop irrigation is the application of supplemental water onto cropped fields when natural precipitation is insufficient. The estimation of irrigation water requirements was completed using the irrigated area estimation from Census of Agriculture information and a demand model, estimating an average number of irrigation events likely to occur in the watershed per growing season. This demand model (GAWSER - Guelph All Weather Sequential Event Runoff), bases the irrigation water requirements on soil moisture content, and averaged four irrigation events per year, for the GRCA watershed. The irrigation demand model only considers irrigation events meant for maintaining soil moisture at adequate levels for plant growth. Irrigating for climate control, such as spring irrigation to protect against frost, was not considered in this exercise. To determine a possible breakdown of the source of irrigation water, the Permit to Take Water database was consulted. It was determined that from the 509 agricultural irrigation sources, 313 were supplied by groundwater and 196 were supplied from surfacewater, producing a 61 percent, 39 percent split, respectively. Irrigated crops in this watershed may include tobacco, ginseng, potatoes and vegetables, and the water requirements for all irrigation activity accounts for seven million cubic metres per year.

5.2.3 Un-serviced Domestic Water Use

Un-serviced domestic water use is all water uses for domestic (indoor and outdoor residential water use) use that are not on a municipal distribution system. Generally, these are rural communities and water could be taken from private wells. The estimation of un-serviced domestic water use was based on population estimates and per capita water use rates for rural residents.

Rural domestic per capita water use has traditionally been much lower than urban domestic use. While the actual rate varies depending on a large number of factors, 160 litres per day was assumed to be the rural domestic per capita water use rate (Vandierendonck and Mitchell, 1997). It should be noted that a large percentage of this water is likely returned to the shallow groundwater system via septic systems. This water use is assumed to be relatively constant throughout the year. The rural population in the Grand River watershed is estimated to be 115,000 and draw 6.7 million cubic metres of water per year.

In addition to groundwater supplies, a significant proportion of rural properties in Haldimand County use cisterns as sources of water.

5.2.4 Other Permitted Water Takings

For water uses in the watershed that did not fall into the three previously mentioned categories (municipal, agricultural and rural unserviced), the Ministry of the Environment Permit to Take Water database was used. The MOE requires any person taking greater than 50,000 litres of water on any day of the year (animal watering, domestic usage and firefighting excluded) to apply for a PTTW. This generally includes many industrial and larger commercial operations, as well as many agricultural water requirements, such as irrigation.

Excluding the permits that have been expired for over ten years, cancelled, temporary, agricultural or municipal water supply permits, 313 Permits to Take Water remain in the Grand River watershed. These 313 permits have a total of 462 sources associated with them. Of the 462 sources, 343 rely on groundwater, and 119 draw from surfacewater bodies, relating to 74 percent and 26 percent, respectively. The top five water takings were listed as uses for dewatering operations, aggregate washing, aquaculture, remediation activities, and golf course irrigation.

The PTTW database supplies only a permitted maximum volume that the permit holder is allowed to take on a daily basis. However, in many cases the permit holder has a certain period of time when most water takings occur, based on the seasonality of the water demand. Monthly adjustment factors were applied to determine which months water takings would occur, and when they would not, and these were applied based on expert opinion for each category of water use. For instance, irrigation for golf course would only occur in the months of May to October, whereas snowmaking for ski hills would only occur in the months of December to February. The monthly adjustment factors allowed for a more accurate assessment of water demands throughout the year. The table of adjustment factors can be seen in Bellamy and Boyd (2005).

The total volume of water takings for the permits in the Grand River Watershed, as stated in the report is 162 million cubic metres.

5.2.5 Summary and Data Gaps

Municipal water use is the largest user in the Grand River watershed. The data is provided by the municipalities and is the only sector that consistently has reports on actual water takings. The only gap in municipal water taking values is the data is reported in an aggregated format for all water uses in the municipality. Information gathered from the municipal sector would be more beneficial if it could be separated into industrial, commercial, institutional (ICI) and residential components of water use, however most municipalities lack the capacity to separate these uses.

Agriculture is a water use sector, with water needs during both the summer growing season and throughout the year for livestock. Continued work into actual water uses is needed to further refine the estimates of water use in agriculture and for permitted takers. The new required reporting structure of the MOE PTTW program could provide beneficial information to water managers for water budgets and water use calculations.

There are many other permitted water uses in the watershed, and each sector has different timing and volume requirements and to fully understand their individual needs. Updates to the water takings using actual water use information will be beneficial to refine the water demands across the watershed. It is suggested that the development of a central database of water use in the watershed continues. This database would house recent information on actual water needs information gathered from permitted water users. Finally, a gap in the data is the lack of consumptive ratios of all major water sectors, as well as the occurrence of water diversions.

5.3 Heritage River Designation

In 1987, the Grand River Conservation Authority began a participatory process to have the Grand River and its major tributaries declared a Canadian Heritage River. The status was achieved in 1994, based on outstanding river-related human heritage and recreational values of national significance.

The designation of the Grand River as a Canadian Heritage River marked the beginning of a second generation of Canadian Heritage Rivers. Prior to 1990, almost all nominated rivers were either within protected areas or were short sections of larger rivers. The Grand's designation includes the entire river, as well as its four major tributaries: the Nith, Conestogo, Speed and Eramosa Rivers.

As a requirement of the designation, a management plan had to be developed and tabled with the Canadian Heritage Rivers Board. The plan is called the Grand Strategy, and provides "a collaborative framework for managing important values and for actions that strengthen the knowledge, stewardship and enjoyment of the heritage and recreational resources of the Grand River Watershed" (Veale, 2004). The values are discussed in more detail below.

5.3.1 Human Heritage Values

Human heritage values in the Grand River watershed encompass the rich history of Aboriginal and European settlement in the area. Many of the river valley's features and landscapes reflect the attitudes, values and effects of a wide variety of people. These values were captured in the Grand Strategy under the following five themes:

- The watershed's cultural mosaic since the mid-nineteenth century.

- The strong association of Native Peoples with the watershed for thousands of years.

- The Grand River's industrial heritage.

- Human adaptation to fluctuating river flows.

- The many famous persons associated with the Grand River watershed.

Additional human heritage values were added in 2000 after the Canadian Heritage Rivers Board adopted new thematic frameworks. These additions include the areas of bridges, mills and cemeteries, as well as early river uses such as river harvesting, river transport and riparian or river valley settlement.

5.3.2 Recreational Values

Recreational water values in the Grand River watershed describe the many opportunities for outdoor recreation that have arisen as the health of the river and its tributaries has improved. In 1994, as part of the designation as a Canadian Heritage River, recreational values were categorized into five themes:

- Water sports: canoeing, kayaking, sailing, power boating, water skiing and swimming.

- Nature/Science appreciation: picnicking, camping, and naturalist activities such as bird watching and photography.

- Fishing and hunting.

- Trails and Corridors: pedestrian and /or equestrian trails, scenic drives and or cycling routes, and cross country skiing or snowmobiling trails.

- Human heritage appreciation: historic walking tours, historic buildings, and events and festivals.

6.0 DRINKING WATER SOURCES

6.1 Summary of Municipal Drinking Water Systems

There are 47 municipal groundwater supply systems within the Grand River watershed that rely on groundwater as a drinking water source in the County of Grey (1), County of Dufferin (3), County of Wellington (7), County of Perth (1), City of Guelph (1), Regional Municipality of Waterloo (24), County of Oxford (4), Brant County (6) and City of Hamilton (1).

Within the GRCA, a number of MOE municipal groundwater studies have been completed, including; the Grey-Bruce Groundwater Study (Waterloo Hydrogeologic, 2003), the Town of Orangeville; Groundwater Resources and Contamination Assessment / Prevention Study (Burnside, 2001), the Guelph–Puslinch Groundwater Protection Study (Golder Associates Ltd., 2006), the County of Wellington Groundwater Protection Study (Golder Associates Ltd., 2006), the Perth County Groundwater Study (Waterloo Hydrogeologic, 2003) the County of Oxford Phase II Groundwater Protection Study (Golder Associates, 2001), the County of Brant Municipal Groundwater Study (Lotowater Geoscience Consultants Ltd., 2004), and the City of Hamilton Groundwater Resources Characterization and Wellhead Protection Partnership Study (Charlesworth and Associates, and SNC-Lavalin, 2004). **Map 6.1** shows the distribution of both municipal and domestic wells in the watershed.

Within the Grand River watershed there are 4 surface water intakes related to drinking water that take directly from the river system (Regional Municipality of Waterloo, City of Guelph, City of Brantford and Six Nations) which drains a predominantly agricultural watershed that empties into Lake Erie. The remaining 2 surface water intakes that supply drinking water to portions of Haldimand County within the Grand River watershed are sourced from Lake Erie (for the community of Dunnville) and Lake Ontario (for the communities of Caledonia, York and Cayuga). **Map 6.2** shows the location of municipal surface water intakes in the watershed.

6.2 Summary of Private Drinking Water Supplies

A variety of private drinking water systems exist throughout the Grand River watershed that service small residential developments, schools and private institutions. The systems reported below are primarily groundwater fed. There exists little information about private water systems from surface water sources.

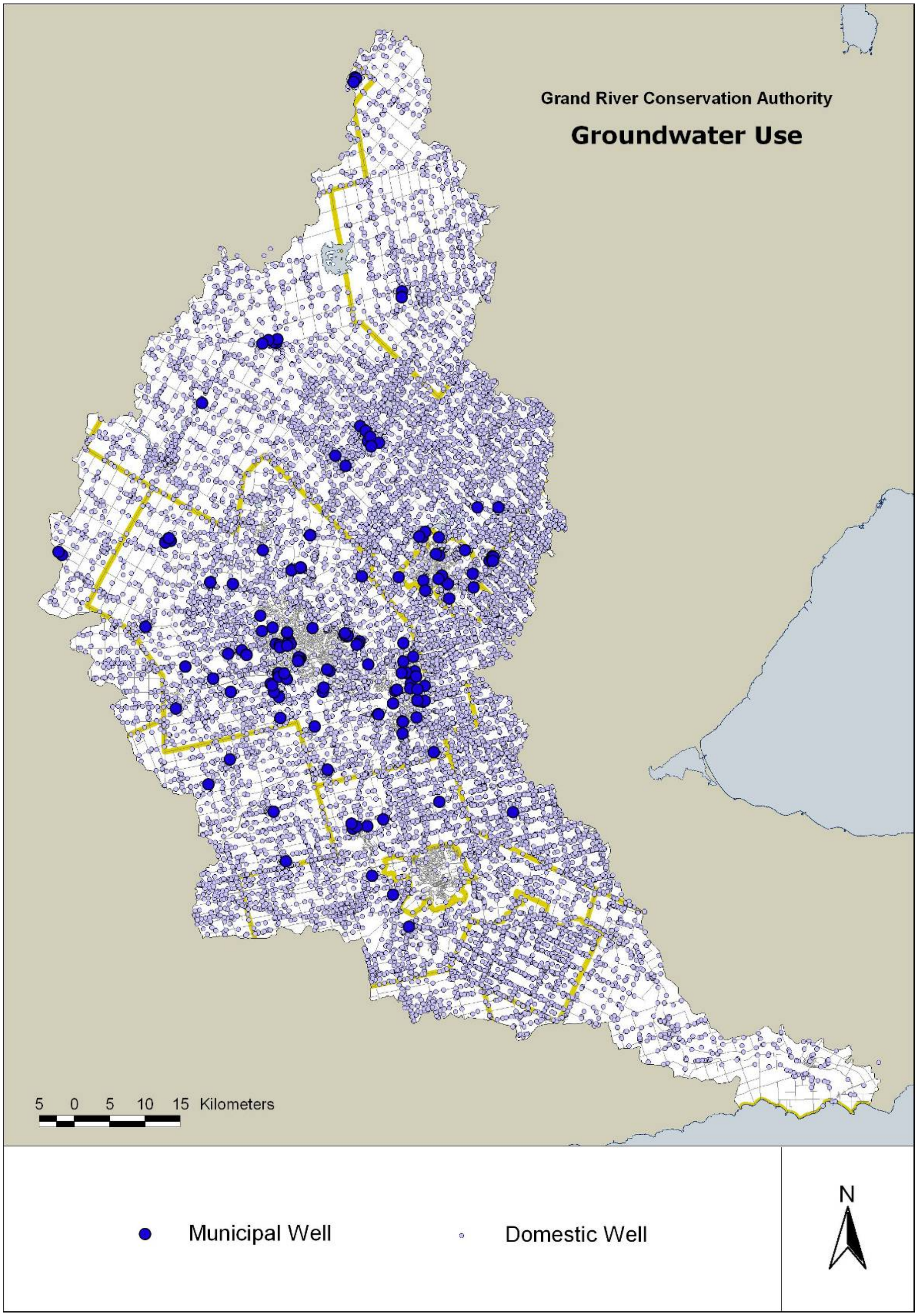
6.2.1 Wellington County Private Drinking Water Systems

6.2.1.1 Township of Puslinch

Description of Capture Zones

The capture zones for the Mini-Lakes and Mill Creek wells and the Irish Creek Estates well are shown on **Map 6.4** and **Map 6.5** respectively. The capture zones for the Mini-Lakes and Mill Creek wells extend towards the northeast, in the upgradient direction of the regional groundwater flow in the bedrock. The capture zones for the Mini-Lakes wells are considerably larger than those for the Mill Creek well as the forecasted rates are about four times larger and 2 of the Mini-Lakes wells obtain a portion of their supply from beneath the Eramosa Member, which behaves as an aquitard.

Map 6.1: Groundwater Use for Drinking Water in the Grand River Watershed



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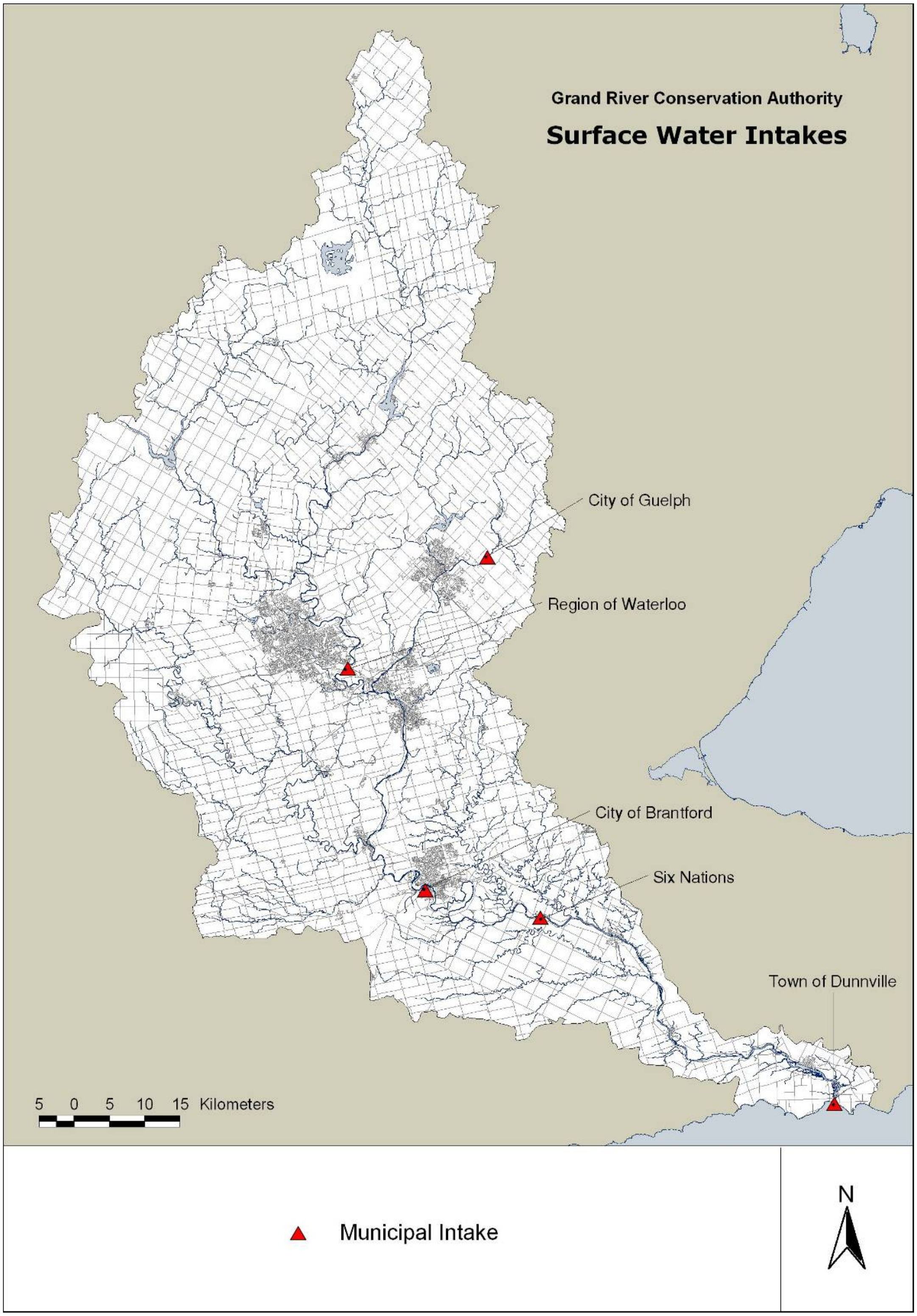
Map 6.2: Municipal Surface Water Intakes in the Grand River Watershed



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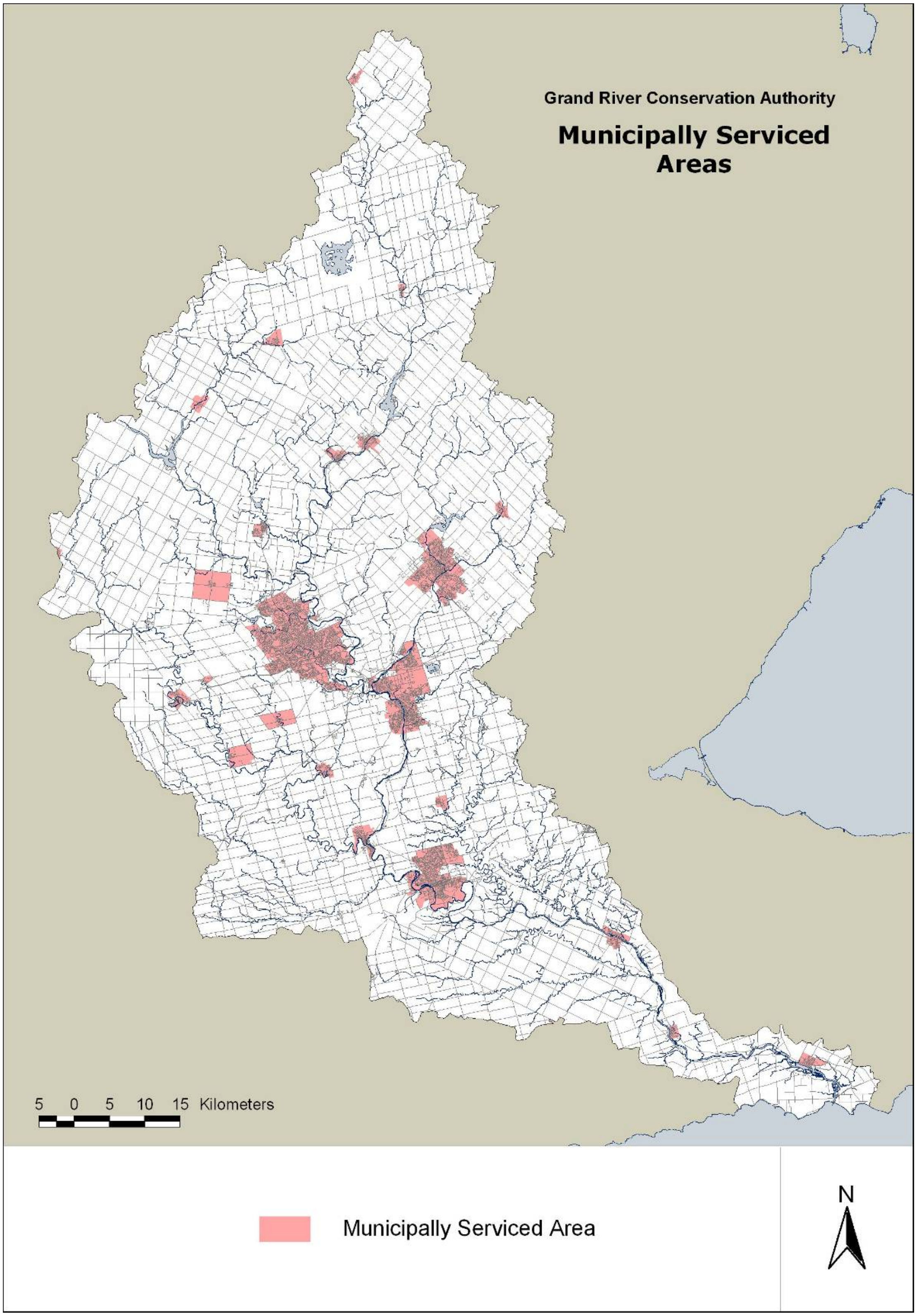
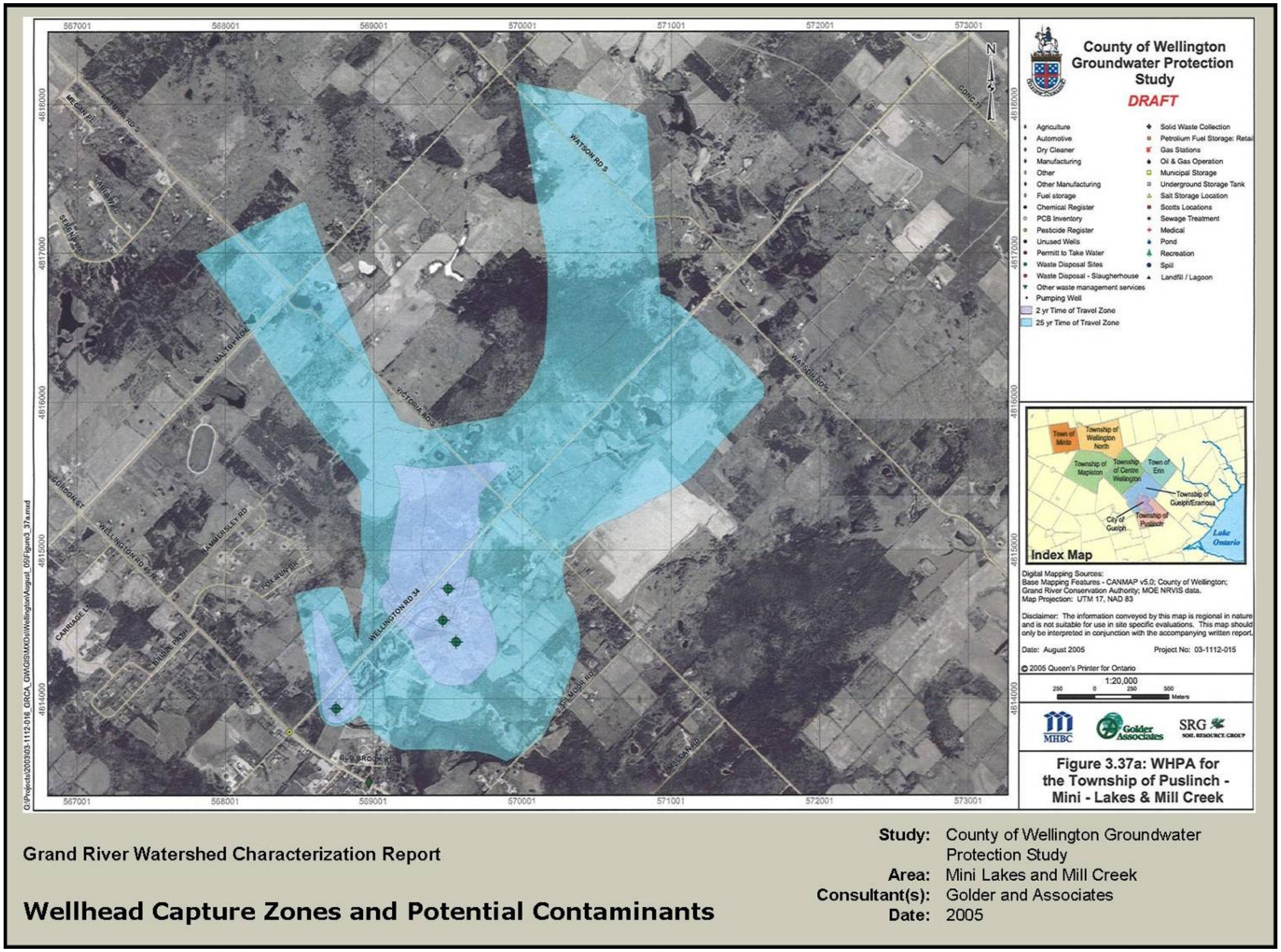
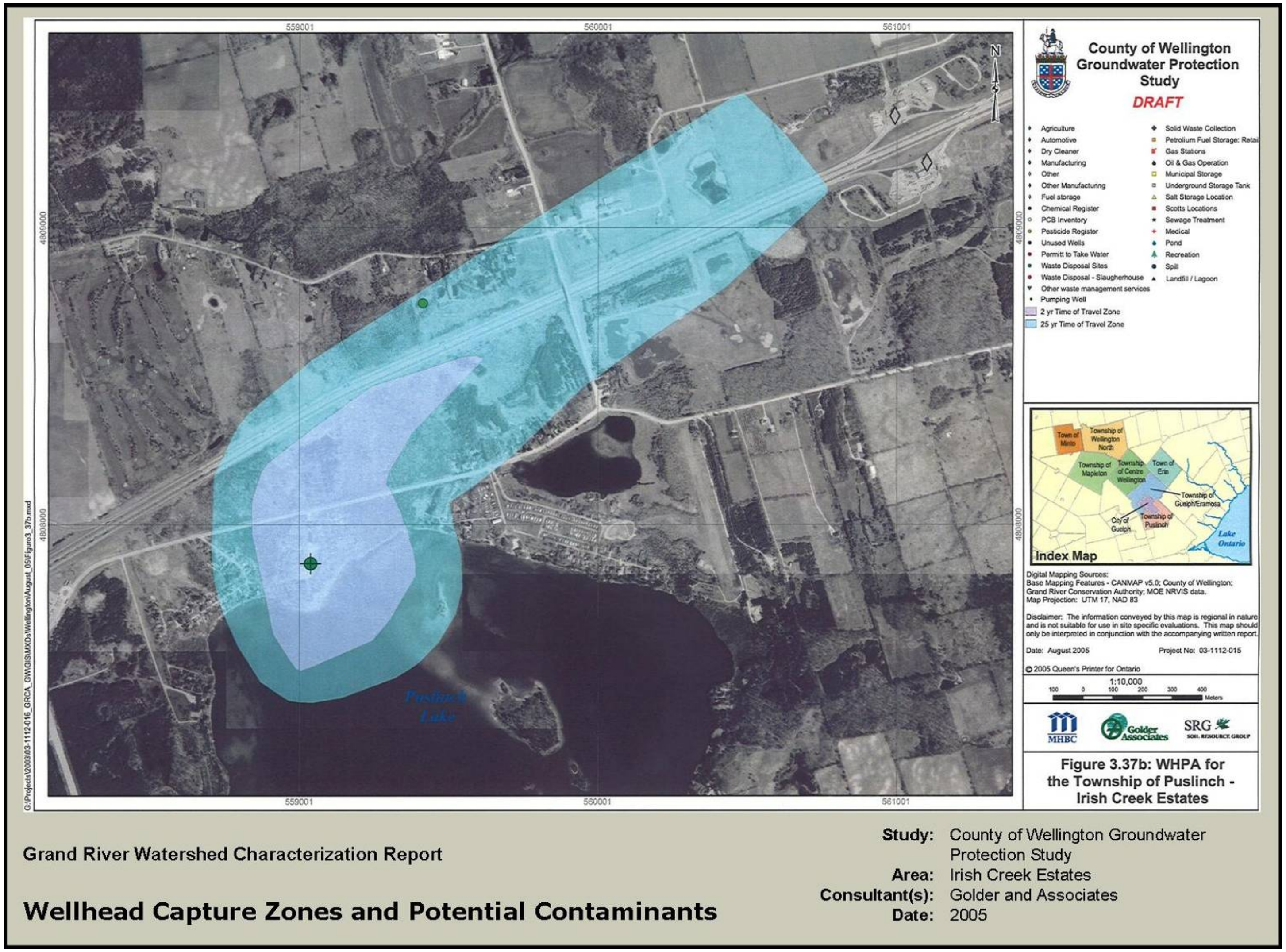
Map 6.3: Municipally Serviced Areas in the Grand River Watershed



Map 6.4: Mini Lakes and Mill Creek Wellhead Capture Zones and Potential Contaminants



Map 6.5: Irish Creek Estates Wellhead Capture Zones and Potential Contaminants



The Irish Creek Estates well's capture zone also extends to the northeast, in the upgradient direction of the regional groundwater flow in the bedrock.

Water Quality

Water quality within the Township of Puslinch is based on data collected from a field sampling program (Golder, 2006) and a compilation of data from previous Township monitoring. In 2004, a sampling program was carried out by Golder Associates where samples were collected from 10 domestic wells in Aberfoyle and 52 domestic wells throughout Puslinch Township. Samples were analyzed for general chemistry, metals, and microbiological parameters. Additionally, water quality data from 32 wells, many in the Mill Creek area, was compiled from the Puslinch Groundwater Monitoring Program (Harden Environmental Ltd., 2001).

The Golder (2006) study identified the wells in the Township as either overburden or bedrock wells. The bedrock wells did not distinguish between the Guelph and/or Amabel aquifers. The bedrock aquifer displayed a calcium-magnesium-bicarbonate type of water common to dolostone aquifers. The overburden aquifer displayed a similar calcium-magnesium-bicarbonate type of water which is expected since the overburden materials were derived from erosion of the dolostone bedrock of the region.

Hardness exceeded the ODWS esthetic guideline (200 mg L-1) in all overburden and bedrock wells. Total dissolved solids (TDS) were expected to be elevated due to the calcium-magnesium-bicarbonate type of water and in 18 bedrock wells and 4 overburden wells throughout the study area concentrations exceeded the ODWS esthetic guideline (500 mg L-1).

Nitrate concentrations exceeded the ODWS maximum acceptable concentration (10 mg L-1) in 6 bedrock wells, suggesting impacts due to domestic wastewater or agricultural activities. Four of the bedrock wells were clustered just west of Arkell (MW1-Calvary, Arkell-34, Arkell-44, Arkell-46) and nitrate concentrations ranged between 19.6 and 35.7 mg L-1. The nitrate impacts were attributed to agricultural activities in the area. The remaining two private domestic bedrock wells were located west of the City of Guelph (well #13 and well #42) and nitrate concentrations ranged between 12.8 and 15.9 mg L-1. Site specific investigations are needed to establish whether impacts are associated with nearby septic systems or agricultural activities, but one well (well #13) was situated in a highly vulnerable area of the Guelph aquifer.

Nineteen bedrock and overburden wells tested in the field monitoring program or compiled from the Puslinch Groundwater Monitoring Program exceeded at least one of the ODWS limits for bacteria in groundwater. There was no pattern to the distribution of these wells and the water quality results likely represent impacts due to poor well construction and/or improper land use in the vicinity of the well.

All concentrations of fluoride, aluminum, and metals were below ODWS. Concentrations of iron exceeded ODWS esthetic guideline (0.3 mg L-1) in many wells, but unusually high concentrations were measured in private bedrock well #9 near Aberfoyle (6.23 mg L-1) and in Badenoch Community Centre bedrock well #113 (7.26 mg L-1).

Vulnerable Areas Within the 25-year Capture Zone

The majority of the capture zones for the communal wells located in the Township of Puslinch have been mapped as a WHPA 2 with localized areas assigned a WHPA 1 rating. The WHPAs are shown on **Map 6.6.** Areas surrounding the City of Guelph have also been assigned WHPA ratings. These areas correspond to the City's capture zones that have extended into the Township.

Threats Within the 25-year Capture Zone

Mapped threats within the vicinity of the Township of Puslinch's capture zones are shown on **Map 6.4** and **Map 6.5**. Land use within the Mini-Lakes and Mill Creek capture zones has been identified as primarily greenlands with some secondary agricultural land.

The Irish Creek Estates well's 2- and 25-year capture zones cross Highway 401, which could result in impacts from road salt application and/or potential spills. Additionally, the 25-year capture zone extends towards the Petro-Canada service stations on each side of Highway 401.

Summary

The Township of Puslinch is groundwater dependent. As of 2001, the total population of the Township was approximately 5,885 people. There are no public water supply systems within the Township and 100% of the Township population uses a private supply of drinking water. Since no municipal systems are present within the Township of Puslinch, capture zones and subsequent WHPAs were developed for the Mini-Lakes, Mill Creek and Irish Creek Estates communal systems.

6.2.1.2 Township of Erin

Brisbane Public School (Brisbane)

System Description

The Brisbane Public School system is privately owned and operated by the Upper Grand District School Board. This facility is located within the village of Brisbane, has a capacity of 45 l/minute and supplies treated drinking water to staff and students of the school. The well has a diameter of 127mm and is terminated in the overburden at a depth of approximately 42.7m. Water treatment is achieved by water softening, cartridge filtration and ultraviolet disinfection.

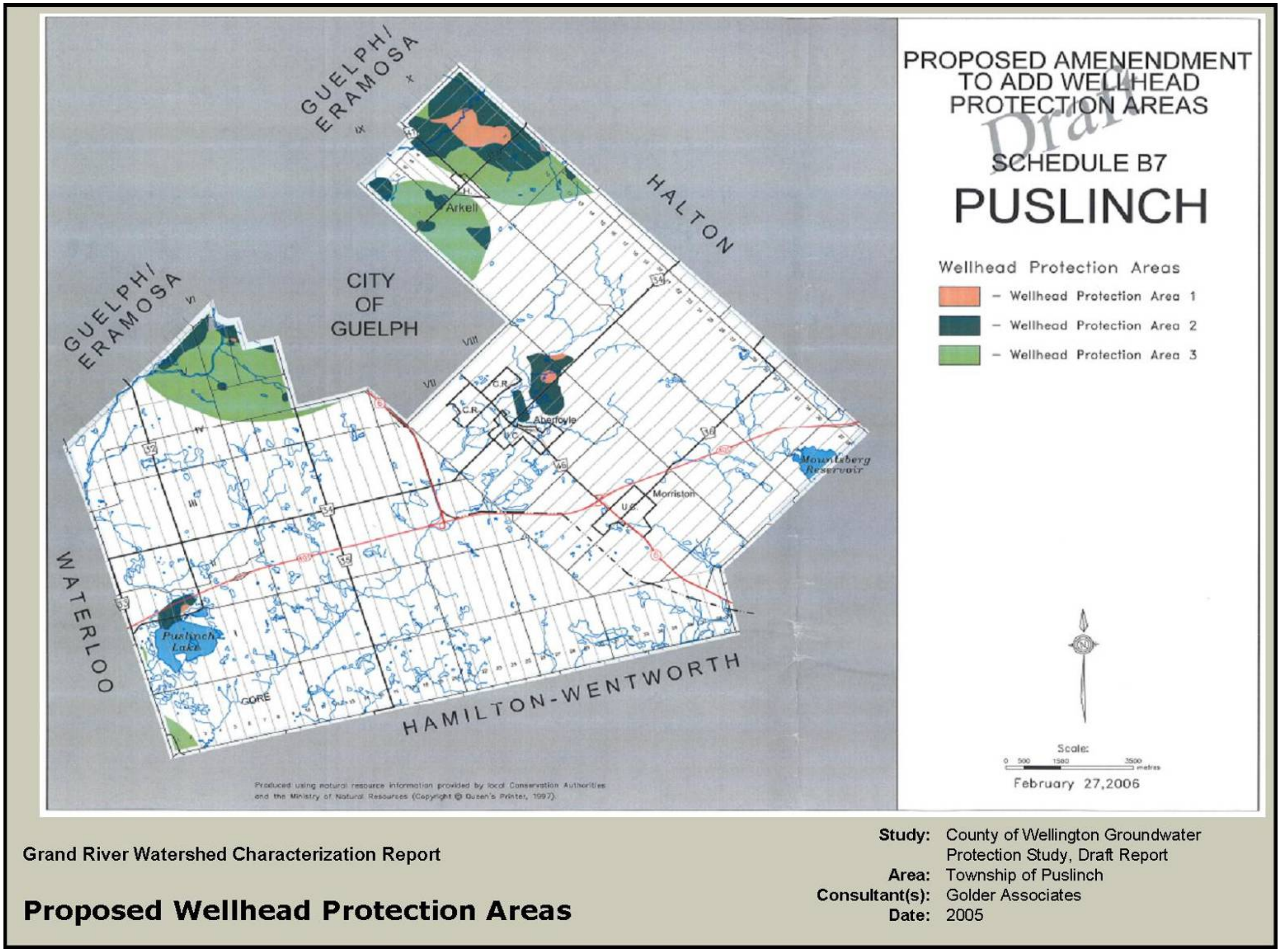
Distribution System

Treatment facilities are located in the school's boiler room. Water is pumped from the well by a submersible pump and stored in two 321 litre pressure tanks.

Treated Water Quality

The 2005 AWQI Report stated there was one adverse water quality incident on June 14, 2005 when a sample was found to have an E.Coli count of 1cfu/100 mL. Appropriate corrective actions were taken immediately and all resamples were reported to be non-adverse for all microbiological parameters.

Map 6.6: Proposed Wellhead Protection Areas in the Township of Puslinch



Annual Reports describing the treatment plant's operations and water quality monitoring results can be obtained by contacting Tara Doherty at the Upper Grand District School Board.

Issues & Concerns

Inspection of the facility has confirmed that there is adequate separation distance from pollution sources. The septic system is located approximately 29m from the well.

6.2.2 Regional Municipality of Waterloo Private Drinking Water Systems

6.2.2.1 Township of Woolwich

Floradale Public School (Floradale)

System Description

The Floradale Public School system is privately owned and operated by the Waterloo Region District School Board. This facility is located within the village of Floradale, has a capacity of 75.7 l/minute and supplies treated drinking water to staff and students of the school. The well has an inside diameter of 130mm and is terminated in the overburden at a depth of approximately 30m.

Disinfection is achieved by sodium hypochlorite injection with contact time being achieved by 5.6m of 600mm diameter piping complete with baffles. Iron and manganese removal is achieved with two sand filters.

Distribution System

Treatment facilities are located in the school's boiler room with the exception of the underground chlorine contact piping. Water is pumped from the well by a submersible pump and two pressure tanks.

Treated Water Quality

The 2005 AWQI Report stated there were no AWQIs during the reporting period. However, AWQI 51982 was reported on January 19, 2005 for a sodium exceedance.

Annual Reports describing the treatment plant's operations and water quality monitoring results can be obtained by contacting Craig Hynd at the Waterloo Region District School Board.

Issues & Concerns

Inspection of the facility has confirmed that there is adequate separation distance from pollution sources. The septic system is located approximately 56m southwest of the well. The school is surrounded by agricultural lands and a retirement facility across the road. Several high potential threats have been identified in the Village of Floradale.

Koinonia Christian Academy (Bloomingdale)

System Description

The Koinonia Christian Academy well supply system is privately owned and operated by the Koinonia Christian Academy. This facility is located within the village of Bloomingdale, has a capacity of 90.0 l/minute and supplies treated drinking water to staff and students of the school. The well has a casing diameter of 150mm and is terminated in the overburden at a depth of approximately 37m.

The treatment system consists of ion exchange softening followed by ultraviolet irradiation prior to distribution to the schools plumbing system.

Distribution System

The drinking water system has several point of use device installed throughout the plumbing system including carbon filtration in the drinking fountain, reverse osmosis purification in the kitchen and several UV disinfection systems.

Treated Water Quality

During the 2004/05 inspection period there were 9 AWQIs that involved exceedances for bacteriological parameters (ie. Heterotrophic Plate Count, Total coliform background and total coliform). It appears that in all cases the AWQIs were reported and corrective action taken per the requirements of the regulation.

Annual Reports describing the treatment plant's operations and water quality monitoring results can be obtained by contacting Steve Martin at the Koinonia Christian Academy.

Issues & Concerns

Inspection of the facility has confirmed that there is adequate separation distance from pollution sources. The septic system is located away from the well. The school is surrounded by agricultural lands and one high potential threat has been identified in the Village of Bloomingdale.

6.2.3 County of Oxford Private Drinking Water Systems

6.2.3.1 Township of Blandford-Blenheim

Brethren of Early Christianity School/Daycare (Bright)

System Description

The Brethren of Early Christianity School/Daycare Well Supply system is privately owned and operated by the Brethren of Early Christianity. This facility, located about 5km east of the Village of Bright, has a permitted water taking of 1164 m3/day. The system supplies treated drinking water to staff and students of the school and daycare and untreated water to adjacent commercial/industrial complexes, a livestock and poultry barn, a duplex apartment and a mobile home. The system has four sand point wells approximately 4m deep with 50mm casings. Water treatment is achieved by micro-filtration and ultraviolet disinfection. A small amount of sodium hypochlorite is pumped into the system every 2-4 weeks to disinfect the system before water enters the UV chambers

Distribution System

Raw water from the four wells is collected in a 12,000 gallon primary reservoir for bulk water use and subsequent pumping to an 8,000 gallon secondary reservoir which services the school/daycare facility. Individual treatment facilities are located in the school and daycare.

Treated Water Quality

The 2005 AWQI Report stated there was one AWQI during the reporting period. AWQI 52680 was reported on February 17, 2005. Corrective actions were taken to address exceedances, including any other steps as directed by the Medical Officer of Health.

Annual Reports describing the treatment plant's operations and water quality monitoring results can be obtained by contacting Arnold Entz at the Brethren of Early Christianity.

Issues & Concerns

Inspection of the facility has identified that there is a large fuel tank adjacent to the waterworks building that houses the primary reservoir that stores and distributes water to the school and daycare. The fuel storage tank possesses no secondary containment.

6.2.4 County of Brant Private Drinking Water Systems

6.2.4.1 Crestwood Lake Trailer Park (Burford)

System Description

The Crestwood Lake Trailer Park system is privately owned and operated by Crestwood Lake Limited. This facility, located approximately 10km west of the Village of Burford, supplies treated drinking water to approximately 300 trailer lots. The details of the well are not available. Disinfection is achieved by sodium hypochlorite injection.

Distribution System

Raw water from the wells is chlorinated and pumped to two 2,000 gallon storage tanks and distributed via 20mm black plastic services to the trailer lots. The service lines are not looped.

Treated Water Quality

A Boil water Advisory was issued by the Brant County Health Unit on June 10, 2005 due to the presence of E.Coli and total coliforms.

Issues & Concerns

The owner has several wells on the property that are not in compliance with Ontario Regulation 903. The wells are not in use and not properly maintained. These wells should be immediately abandoned in such a manner to prevent surface water contamination from entering the aquifer. The owner does not have proper spill containment for diesel storage on site.

6.2.4.2 Onondaga Farms Kids Camp (St. George)

System Description

The Onondaga Farms Kid's Camp Well Supply system is privately owned and operated by the Tim Horton Children's Foundation Inc. This facility, located about 5km southwest of the Village of St. George, has a permitted water taking of 55.3 m3/day. The system supplies treated drinking water to staff and guests of the camp by way of two raw groundwater wells. Water treatment is achieved primarily by ultraviolet disinfection with sodium hypochlorite injection for secondary disinfection.

Distribution System

Raw water for the two wells is collected in the water treatment facility pressure tanks, treated and distributed to the various buildings on site.

Treated Water Quality

The 2005 AWQI Report stated there were no AWQIs during the reporting period. Copies of the annual report are available at the camp office.

Issues & Concerns

Inspection of the facility did not identify any recommendations regarding source water protection.

6.2.4.3 St. Anthony Daniel Elementary School (Scotland)

System Description

The St. Anthony Daniel Elementary School system is privately owned and operated by the Brant Haldimand-Norfolk District School Board. This facility, located within the village of Scotland, supplies treated drinking water to staff and students of the school. Disinfection is achieved by sodium hypochlorite injection.

Distribution System

Treatment facilities are located outside the school's boiler room. Water is pumped from the well by a submersible pump, chlorinated and held in a 1400 l pressure tank prior to distribution within the school.

Treated Water Quality

The 2005 AWQI Report stated there were no AWQIs during the reporting period. Annual Reports describing the treatment plant's operations and water quality monitoring results can be obtained by contacting Don Zalem at the Brant Haldimand-Norfolk District School Board.

Issues & Concerns

Inspection of the facility did not identify any recommendations regarding source water protection.

6.2.5 Private Surface Drinking Water Intakes

6.2.5.1 Haldimand County

Currently anecdotal information indicates that there are some private surface drinking water supplies within Haldimand County. However there is no reporting mechanism in place so quantitative information is not easily obtained. Further information from the County or the local health units may be able to provide more detailed information on the number of private surface water supplies within the region.

6.3 Municipal Drinking Water Systems Descriptions

6.3.1 Municipal Groundwater Systems Descriptions

6.3.1.1 County of Grey

Within the County of Grey, the only Grand River Conservation Authority community with a groundwater-based municipal supply system is the Village of Dundalk in the Township of Southgate. The remainder of the County of Grey is part of the Saugeen Valley C.A. draining to Lake Huron.

A groundwater model (using MODFLOW and MODPATH) developed for the Dundalk well field was used to generate 50-day, 2-, 10-, 25-year, and steady state time of travel capture zones for the Dundalk municipal wells (Waterloo Hydrogeologic, 2003). Average pumping rates were used to calibrate the model and projected flow rates for the year 2021 were used to model the capture zones. Uncertainty in the modeled capture zones was evaluated by varying the hydraulic conductivity, recharge and porosity values through 2 uncertainty simulations. The WHPAs defined for each of these simulations were digitally overlain to derive envelopes defining the best estimate WHPA.

The Grey and Bruce Counties Groundwater Study approached the groundwater vulnerability assessment using the GwISI approach outlined in the MOE Technical Terms of Reference (Land Use Policy Branch, 2001). Using this approach, the geology of each well and the water table surface were used to determine the 'first significant aquifer'. The ISI value was calculated at each well by summing the multiplication of the thickness of each unit by the K-factor that represents its geology over this depth. Values were then classified according to high (<30), medium (30-80) and low (>80) vulnerability and interpolated to create the map.

Polygons representing the identified karst areas within the study area and polygons representing overburden thickness of less than 6.0 m were overlain on the initial ISI map assigned an ISI value of 20 (high vulnerability). The original ISI map was then re-interpolated across the study area to provide a final ISI map.

Additionally, within the Grey-Bruce groundwater study (Waterloo Hydrogeologic, 2003), a regional potential contaminant sources inventory was completed along with a detailed, field-verified inventory within municipal well capture zones. Field-truthed potential contaminant sources were classified within municipal well capture zones into Industrial/Manufacturing, Automotive, Fuel Storage, Agricultural/Livestock, Landfill, Hospitals and Other (dry cleaners, beauty salons, photo finishing, construction yards, medical/veterinary offices, cemeteries, golf courses, schools, clubs, funeral homes, well houses, offices, aggregate pits). Waterloo Hydrogeologic (2003) stated that the quality of the data for the potential contaminant sources inventory was poor and that many threats had unreliable locations and many were not mapped.

Township of Southgate (Village of Dundalk)

System Description and Hydrogeologic Setting

The community of Dundalk has an estimated serviced population of 1,500 people. The Dundalk water supply system consists of 2 groundwater wells (Wells D3 and D4) located within the Town of Dundalk. Each well is equipped with disinfection facilities. There is one above-grade reservoir located at Well D3. The well locations feed into a common distribution system.

Well D3 is housed in a concrete pumping house. The well is 86.9 m deep with a steel well casing terminating in bedrock at a depth of 28.0 m. Well D4 is approximately 100.6 m deep with a 250 mm diameter casing that terminates in bedrock at a depth of 32 m

Sodium hypochlorite solution is used at the well sites to disinfect raw water. All microbiological and physical/chemical water quality monitoring is conducted as required by provincial legislation.

The surficial Quaternary geology of the Dundalk area is mapped primarily as Catfish Creek Till, a poorly drained, drumlinized sandy silty till in the Dundalk vicinity. Surficial Quaternary geology mapping also shows the presence of sand and gravel proglacial outwash units. Bedrock in the area consists of, from youngest to oldest, the Guelph Formation, the Amabel Formation and the Fossil Hill Formation, all of which are local aquifers for the area.

Municipal Groundwater Quality

As a component of the Grey and Bruce Counties Groundwater Study, (Waterloo Hydrogeologic, 2003) water quality information was summarized from Engineers Reports for the municipal water wells throughout the study area however no information on hardness, iron, chloride, nitrate, fluoride or turbidity was presented for the three bedrock wells at Dundalk.

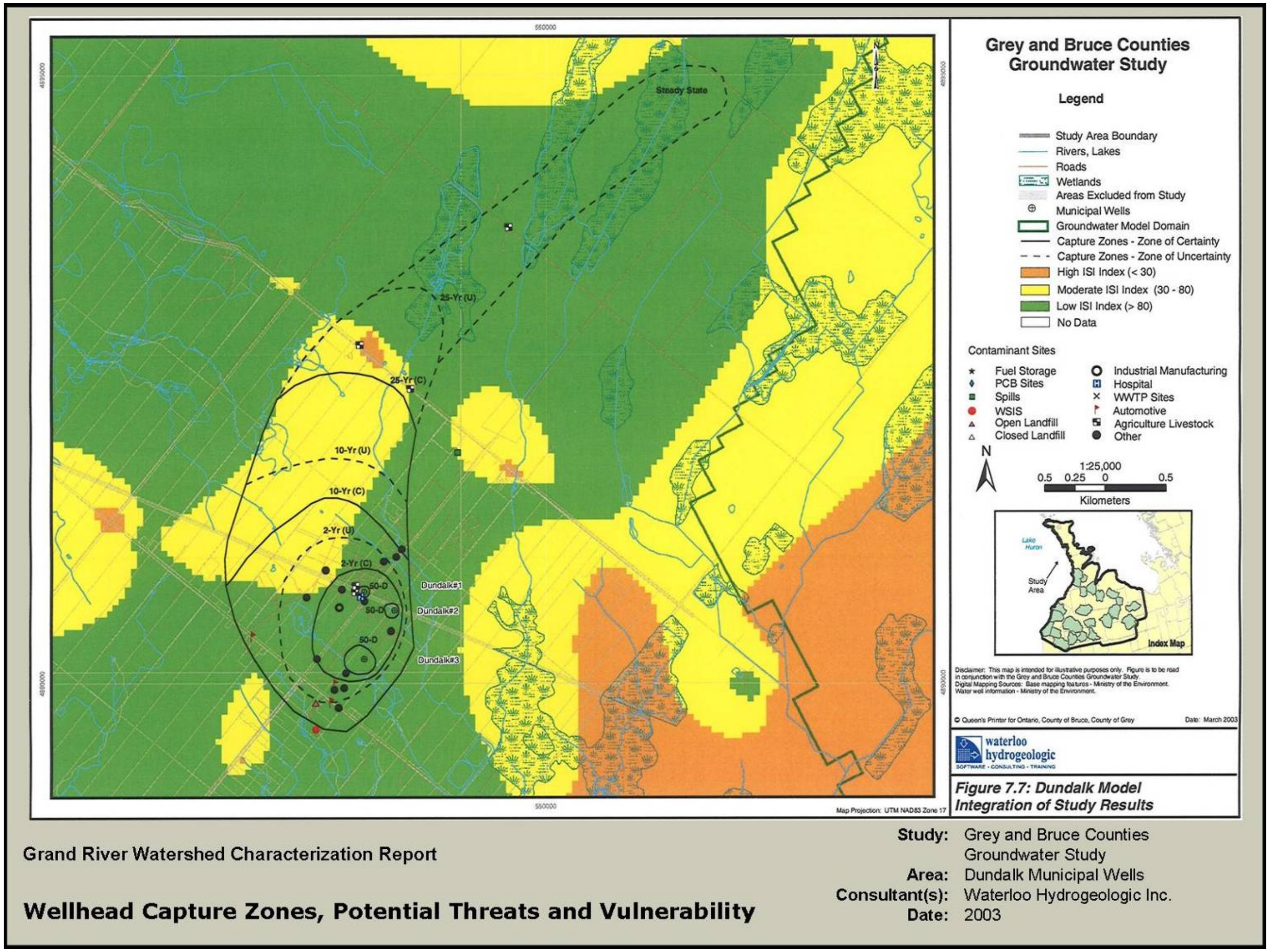
Impacts from surface contamination are not expected in the Dundalk municipal wells since the wellhead protection areas are protected by the till overburden and the first significant aquifer was assigned a low susceptibility to contamination in the combined 2-year capture zone.

Description of Capture Zones

Capture zones were developed for the Dundalk municipal supply wells D1, D2, and D3 (see **Map 6.7**) as a component of the Grey and Bruce Counties Groundwater Study (Waterloo Hydrogeologic, 2003c). Since completion of the capture zone mapping, Wells D1 and D2 have been abandoned, and Well D4 has been added.

The resulting WHPAs for the Dundalk municipal supply wells are large and incorporate much of the community. Generally, the WHPAs are oriented northeast towards the recharge area of the Niagara Escarpment.

Map 6.7: Dundalk Wellhead Capture Zones and Potential Contaminants



A study is currently in progress to update the groundwater model and capture zones for Dundalk's municipal wells. This study will also include 5-year capture zones for the municipal wells.

Vulnerable Areas within the 25-year Capture Zone

Vulnerability mapping completed by Waterloo Hydrogeologic (2003) shows the 2-year and 10-year capture zones as having low vulnerability according to the MOE intrinsic susceptiblity index. As shown on **Map 6.7**, portions of the 2-, 10-, and 25-year capture zones, located upgradient from the wells are mapped as moderately vulnerable.

This mapping is in the progress of being updated along with the new capture zones to reflect more accurate conditions in the area surrounding the wellheads.

Threats within the 25-year Capture Zone

For the Dundalk capture zones, the majority of the potential contaminant sites have been classified as 'other' and are located within the 2-year capture zone. In addition, livestock and industrial operations and a senior's home are located within the 2-year capture zones. The Grey and Bruce Counties Groundwater Study included an inventory threats that is shown on **Map 6.7** (Waterloo Hydrogeologic Inc., 2003c).

Table 6.1 outlines a summary of high level threats identified in an interview with Southgate's consultants. The interview identified that most high risk activities are not a threat to Dundalk's well head protection area and that further work should assess the risk of agricultural activities around the village. There is currently a study in progress to update the threats assessment once capture zones have been re-modeled.

Summary

The groundwater source for the Village of Dundalk has a low susceptibility to contamination since the wellhead protection areas are protected by the till overburden and the first significant aquifer was assigned a low susceptibility to contamination in the combined 2-year capture zone. Projected water use calculations have identified that sufficient water supply exists in Dundalk for up to 25 years. The County of Grey has completed groundwater studies to quantify existing supplies and potential threats to wellhead protection areas and is currently updating capture zone mapping and the threats database.

Table 6.1: High Level Threats for Dundalk

	Groundwater
Direct Introduction	
Water treatment plant wastewater discharge	none
Sewage treatment plant effluent	Aerated lagoons with an effluent filter
Sewage treatment plant by-passes	Lagoons discharge to upper reaches of the Grand R.
Industrial effluents	One small automotive industry in the town
Landscape Activities	
Road salt application	none
De-icing activities	none
Snow storage	none
Cemeteries	none
Stormwater management systems	none
Landfills	Landfill 500m SW of Well #3

Table 6.1: High Level Threats for Dundalk

	Groundwater
Organic soil-conditioning	none
Septage application	none
Hazardous waste disposal	none
Liquid industrial waste	none
Mine tailings	none
Biosolids application	none
Manure application	Rural agricultural uses surround the village
Fertilizer application	
Pesticide / herbicide application	Pesticides detected in Well #2 in 2000
Historical activities – contaminated lands	none
Storage of Potential Contaminants	
Fuels / hydrocarbons	none
DNAPL's (dense non-aqueous phase liquids)	none
Organic solvents	One small automotive industry in the town
Pesticides (of concern to drinking water)	none
Fertilizers	none
Manure	none

6.3.1.2 County of Dufferin

The Townships of Amaranth, East Garafraxa, East Luther – Grand Valley, and Melancthon are all located within the County of Dufferin. Portions of the Townships of Amaranth, East Garafraxa and Melancthon and all of East Luther – Grand Valley are located within the Grand River watershed. Municipal groundwater studies (refer to Burnside, 2001a; 2001b; 2001c; Burnside and Waterloo Hydrogeologic, 2001) have been completed for all of these Townships with the exception of Melancthon since no groundwater-based municipal water supplies are found within this Township.

As a component of the Town of Orangeville; Groundwater Resources and Contamination Assessment / Prevention Study, the Orangeville Groundwater Model was developed by Burnside and Waterloo Hydrogeologic (2001). This is a regional MODFLOW model which encompasses the Townships of East Luther - Grand Valley, East Garafraxa and Amaranth. This model was used to develop time of travel capture zones for the municipal wells within the communities of Grand Valley, Marsville and Waldemar (among other) using average pumping rates. Capture zones were modelled for 2-, 5-, 10-year and steady state saturated travel times.

Vulnerability mapping for the Townships of Amaranth, East Luther - Grand Valley, and East Garafraxa was completed as a part of their Groundwater Management Studies (Burnside, 2001a; 2001b; 2001c). The method used to delineate vulnerable areas was based on the depth to the first aquifer and the type of overlying material. Using this method, sensitivity values were calculated by adding the values (thickness of each unit multiplied by an exponent of the vertical hydraulic conductivity) calculated for each unit overlying the aquifer. Areas with a value < 24 were considered highly sensitivity, 24 – 80 were of moderate sensitivity and >80 were of low sensitivity.

A potential threats inventory was also completed for the Townships of Amaranth, East Luther – Grand Valley, and East Garafraxa as a component of their respective Groundwater Management Studies (Burnside, 2001a; 2001b; 2001c). These inventories were completed at a Township (regional) scale and detailed inventories were not completed within municipal well capture zones. Potential contaminant sources that were that were identified by street addresses in the database were field-located to obtain UTM coordinates. Not all points were mapped because of poor location information.

Through recent MOE-funding, Townships within the County of Dufferin are currently updating their Groundwater Management Studies. The Townships of Amaranth, East Garafraxa, and East Luther – Grand Valley are updating their vulnerability mapping across the township to develop a set of maps for the ‘first significant aquifer’ and also for the deeper municipal supply aquifers. A detailed threats inventory is in the process of being completed within the 25-year capture zones for each of the municipal wells. This inventory will include a review/compilation of existing data and a field investigation on a parcel-by-parcel basis. Additionally, groundwater issues for each municipal well and ‘preferential pathways’ will be compiled and evaluated.

Vulnerability maps for each identified ‘significant’ aquifer’ are in the process of being prepared for the Township of Melancthon. Mapping for this project will seamlessly match mapping for the Townships of Amaranth and East Luther – Grand Valley.

Township of Amaranth (Waldemar)

System Description and Hydrogeologic Setting

Two wells (Well 1 and Well 2) supply groundwater to the Waldemar Heights water supply system. Both wells are completed in bedrock and draw water from the locally confined Guelph – Amabel aquifer (Burnside and Waterloo Hydrogeologic, 2001). In addition to these two wells, the Waldemar water supply system consists of a pumphouse, distribution monitoring station, watermains, plus one additional well that is not in use. According to the Waldemar Heights Drinking Water Systems 2004 Annual Report, the municipal system supplied water to 72 homes in the Waldemar Heights subdivision and 23 homes in the Accione subdivision.

Well 1, which was constructed in 1975, has a 150 mm diameter steel casing and is 107 m deep, terminating in bedrock. The well is equipped with a submersible pump and a 75 mm diameter supply line. Well 2, constructed in 1989, has a 150 mm diameter steel casing and is 117 m deep, terminating in bedrock. This well is also equipped with a submersible pump and a 75 mm diameter supply line. Both wells are located outside the pumphouse.

Raw water is treated with a 12% sodium hypochlorite solution for disinfection. Water is tested for microbiological contaminants within the overall system, including the raw water at the well source, after treatment and within the distribution system of watermains.

Groundwater Quality

The two municipal supply wells were reported to contain naturally-occurring fluoride concentrations that slightly exceeded the Ontario Drinking Water Standard (ODWS) of 1.5 mg/L (Waldemar Heights MOE Drinking Water Regulation O. Reg. 170/03, Annual Report, 2005).

Groundwater quality data from municipal wells in Waldemar and the Acchione subdivision was also summarized as a component of the Township of Amaranth Groundwater Management Study (Burnside, 2001a). Raw water and/or treated water samples (this was not always clear) collected during the year 2000 were analyzed for hardness, nitrate, metals, benzene and xylene. Hardness exceeded non-health related ODWS (200 mg L-1) in all municipal wells. The concentrations of metals, benzene and xylene were low or below laboratory detection limits.

Description of Capture Zones

Capture zones for Waldemar's municipal supply wells were modelled as a part of the regional Orangeville groundwater MODFLOW model (Waterloo Hydrogeologic Inc., 2001). This model was used to develop time 2-, 5-, 10-year and steady state time of travel capture zones for the municipal wells in Waldemar using average pumping rates. The resulting capture zones, as shown on **Map 6.8**, for the Waldemar supply wells are oriented in an eastward direction, away from the Grand River and follow the surface topography receiving recharge water from tributaries to Waldemar Creek.

Vulnerable Areas within the 25-year Capture Zone

The first significant aquifer in the vicinity of the Waldemar municipal supply wells has been mapped as 'medium' vulnerability using the MOE's intrinsic susceptibility index, as shown on **Map 6.9** (Burnside, 2001a).

The deeper municipal production aquifer however, is completed in bedrock. While drilling Well 1, 15 m of overburden was encountered, of which 7 m was primarily clay. Overburden encountered during the drilling of Well 2 was approximately 24 m thick and primarily composed of clay (Burnside, 2001a). The clay overburden encountered during drilling was assumed to be Tavistock Till, a clayey silt to silt diamicton. This clay-rich overburden provides the underlying bedrock aquifer some degree of protection from surficial activities.

A study is currently underway to assess the vulnerability of the bedrock municipal supply aquifer.

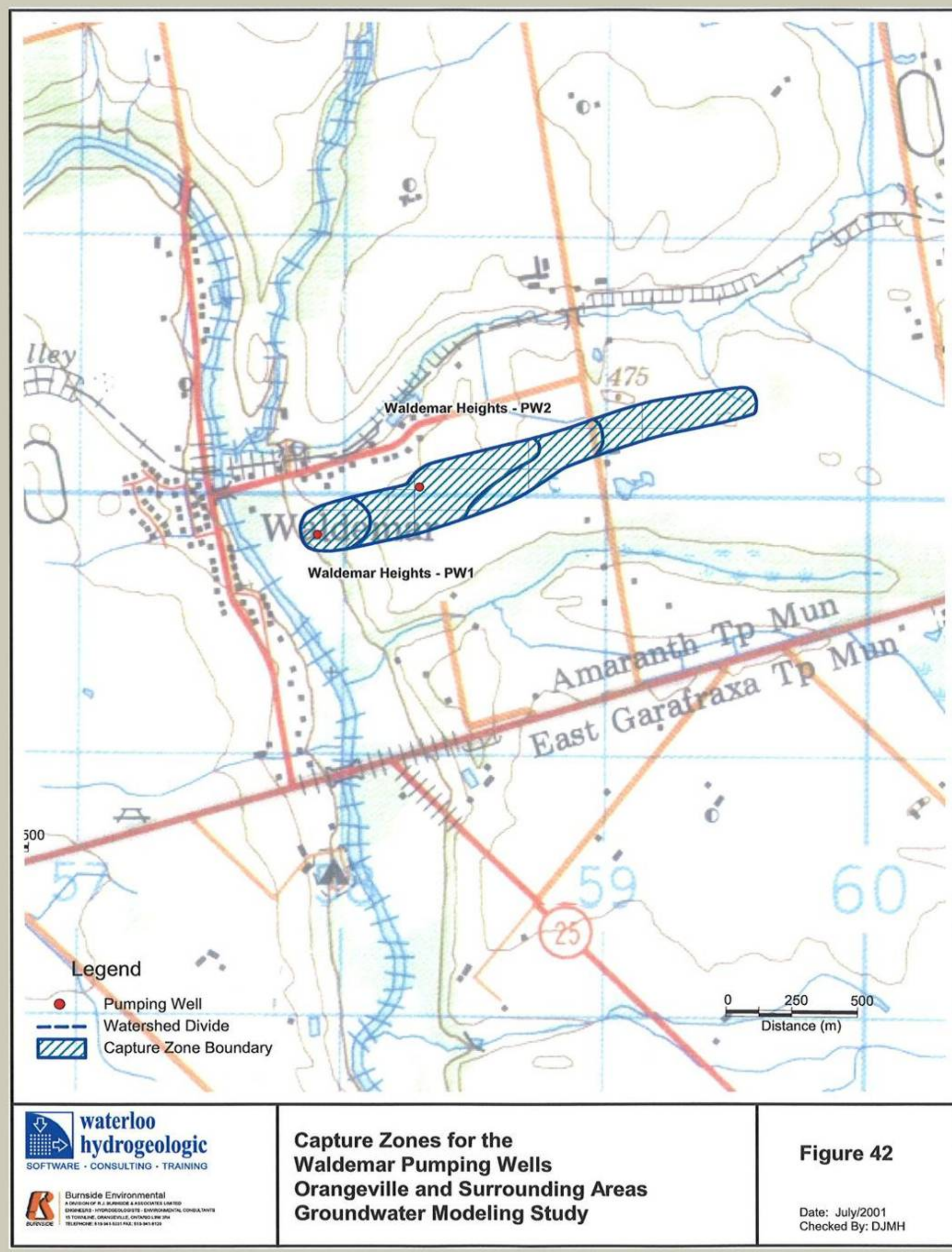
Threats within the 25-year Capture Zone

A study to inventory potential threats within the 25-year capture zone is currently underway. In August of 2006 staff from the GRCA met with Township staff to discuss high level threats to the municipal groundwater supply as summarized in **Table 6.2**.

Summary

Within the portion of the Township of Amaranth situated within the boundary of the Grand River watershed, only one community, Waldemar, is serviced by a municipal well system. The Village of Waldemar is groundwater dependant, with a source from an aquifer mapped as 'medium' vulnerability. The primary threats are related to the use of private septic systems to service the village and agricultural activities in the surrounding rural land uses. The village has sufficient long term water supplies to address growth projections and potential reduction of existing supplies due to climate change impacts. The Township has completed a groundwater study to identify aquifer susceptibility and areas for wellhead protection and is currently assessing threats and the vulnerability of the bedrock municipal supply aquifer.

Map 6.8: Wellhead Capture Zones for Waldemar

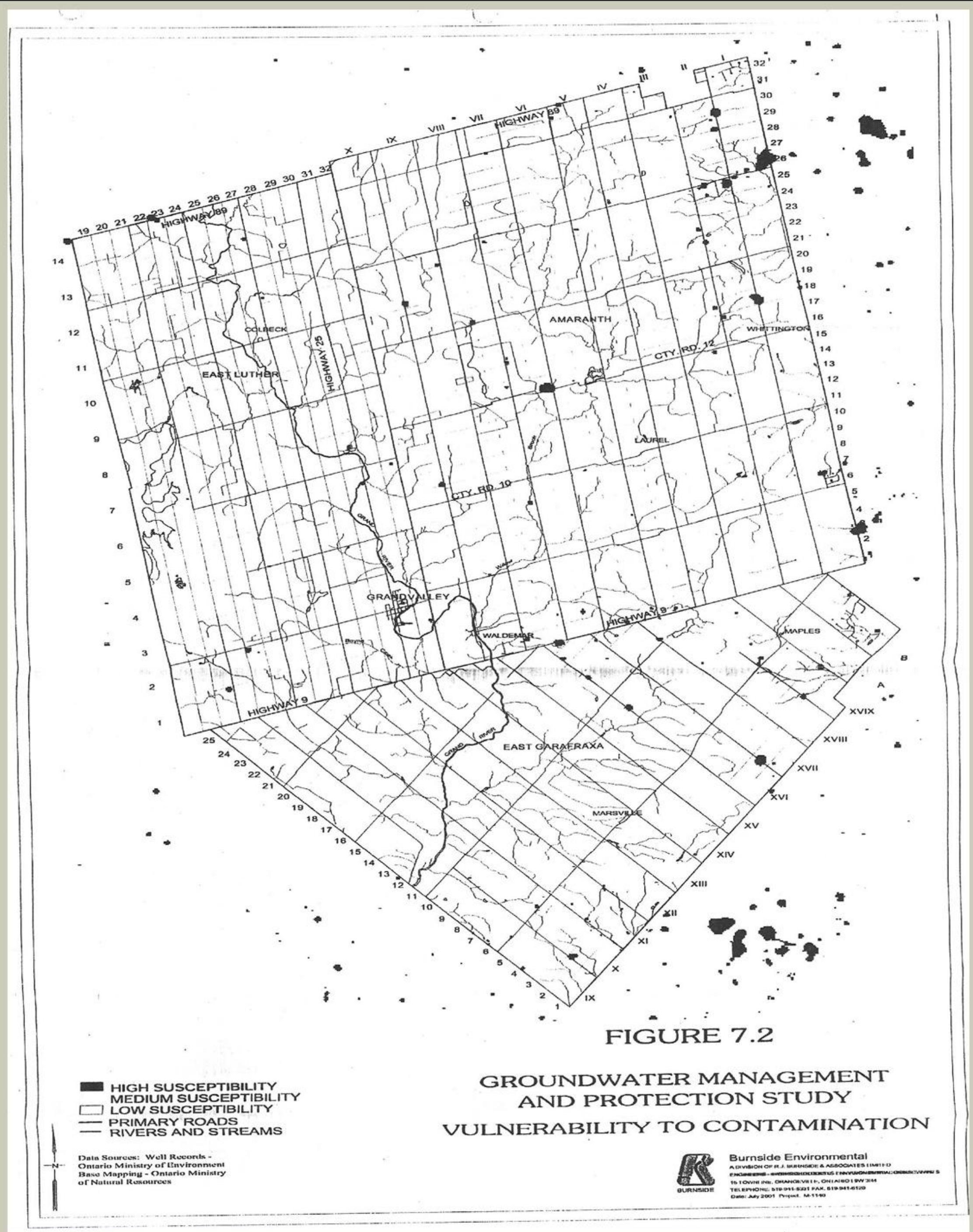


Grand River Watershed Characterization Report

Wellhead Capture Zones

Study: Orangeville and Surrounding Areas Groundwater Modelling Study
Area: Waldemar Pumping Wells
Consultant(s): WHI / Burnside Environmental
Date: 2001

Map 6.9: Vulnerability of First Significant Aquifer in Grand Valley



Grand River Watershed Characterization Report

Vulnerability of First Significant Aquifer

Study: Orangeville and Surrounding Areas Groundwater Modelling Study
Area: Grand Valley Area
Consultant(s): WHI / Burnside Environmental
Date: 2001

Table 6.2: High Level Threats in the Village of Waldemar

	Groundwater
Direct Introduction	
Water treatment plant wastewater discharge	none
Sewage treatment plant effluent	Private residential septic systems
Sewage treatment plant by-passes	none
Industrial effluents	none
Landscape Activities	
Road salt application	Pickled sand for winter operations and CaCl for dust suppression
De-icing activities	none
Snow storage	none
Cemeteries	One cemetery in village
Stormwater management systems	none
Landfills	On 4th Line outside WHPA
Organic soil-conditioning	none
Septage application	Some active permits (application being phased out)
Hazardous waste disposal	none
Liquid industrial waste	none
Mine tailings	Aggregate pit near village has closed
Biosolids application	Township has licensed sites for biosolids application
Manure application	Village is surrounded with agricultural land uses (cash crops and livestock) that require application of nutrients and pesticides
Fertilizer application	
Pesticide / herbicide application	
Historical activities – contaminated lands	none
Storage of Potential Contaminants	
Fuels / hydrocarbons	No gas stations in village
DNAPL's (dense non-aqueous phase liquids)	none
Organic solvents	none
Pesticides (of concern to drinking water)	none
Fertilizers	
Manure	Farm specific storage (check individual nutrient management plans)

Township of East Garafraxa (Marsville)

System Description and Hydrogeologic Setting

The Marsville water supply system consists of one well, one pumping station and a distribution system of watermains. Water is distributed to 33 homes which services approximately 130 people (Marsville Drinking Water Systems 2004 Annual Report). The well, which taps the locally confined Guelph – Amabel aquifer, draws water from the upper weathered and competent middle portion of the bedrock aquifer. Overburden in the vicinity of the Marsville well is approximately 62 m in thickness.

The Marsville supply well is 150 mm in diameter, 91 m deep, and is completed within the top 32 m of the Guelph – Amabel Formation. The well is equipped with a submersible pump, a sanitary well seal, a cast aluminum cap, and a 100 m diameter raw water discharge line to the pumphouse. The pumphouse contains disinfection equipment (a sodium hypochlorite solution storage tank, chemical metering pumps, residual analyzer and alarm), and pressure tanks.

Raw water for the Marsville water supply system is treated with a 12% sodium hypochlorite solution for disinfection. Water within the overall system is regularly tested; this includes raw water at the wells source, after treatment and within the distribution system (Marsville Drinking Water Systems 2004 Annual Report).

Groundwater Quality

As a component of the East Garafraxa Groundwater Management Study, Burnside installed nested monitoring wells at four sites. Two sites were situated in the Orangeville Moraine near the eastern boundary of the study area, but only the site near Hwy 109 (East Garafraxa MW-1) was within the boundary of the Grand River watershed (the East Garafraxa MW-3 monitoring wells were outside the boundary). Drilling logs for MW-1 show a shallow overburden sand aquifer below a sandy clay cap and a gravel till layer, and a deeper overburden sand aquifer below thick sand and gravel layers. Additional nested monitoring wells were drilled in a low relief area north of the Orangeville Moraine near Hwy 109 (East Garafraxa MW-2). Drilling logs show a very shallow overburden stony clay aquitard with an organic surface layer, a deeper overburden gravel and clay aquifer below a thick stony clay layer, and a grey limestone bedrock aquifer immediately below a till layer. Nested monitoring wells were drilled north of Orton in the southern corner of the study area (East Garafraxa MW-4). Drilling logs show interbedded layers of fine sand and silt to a depth of 17 m, and a shallow overburden well was screened below 2 m and a deep overburden well was screened below 11 m (borehole was filled with grout below 13 m).

The monitoring wells were sampled once in 2000. Data includes major cations and anions, hardness, total dissolved solids (TDS), some metals, and dissolved organic carbon (DOC).

Hardness exceeded non-health related ODWS (200 mg L-1) in most of the nested monitoring wells (MW-1, MW-3, MW-4). Water quality data from bedrock well MW-1 situated on the Orangeville Moraine showed several notable results: chloride was elevated (202 mg L-1), iron exceeded non-health related ODWS (0.3 mg L-1), and manganese exceeded ODWS maximum acceptable concentration (0.05 mg L-1). Water quality may be impacted by the community of Orangeville, to the east, since monitoring well MW-3 (outside the Grand River watershed) did not have comparable water quality results.

Water quality samples from the deep overburden well near Orton (MW-4) exceeded ODWS maximum acceptable concentration for dissolved organic carbon (DOC) (5.0 mg L-1) and manganese (0.05 mg L-1). Both the shallow and deep overburden wells are situated in thick deposits of sand and silt, and the fact that DOC concentrations do not exceed ODWS in the shallow well may indicate a single contamination event.

In the shallow overburden well in the low relief area near Hwy 109 (MW-2), DOC exceeded ODWS (5.0 mg L-1). This site had an organic surface layer and the DOC result may indicate organic materials are leaching from the ground surface.

Burnside (2001b) reported the Marsville municipal well to have low chloride concentrations and elevated iron concentrations (0.32 mg L-1). According to the Drinking Water Systems Regulations Annual Report for Marsville, no groundwater quality exceedances were reported in the year 2005.

Description of Capture Zones

Capture zones for Marsville's municipal supply well were modelled as a part of the regional Orangeville groundwater MODFLOW model, which encompassed the Townships of Grand Valley, East Garafraxa and Amaranth (Waterloo Hydrogeologic Inc., 2001). This model was used to develop time 2-, 5-, 10-year and steady state time of travel capture zones for the municipal well in Marsville using average pumping rates.

The resulting capture zones, illustrated on **Map 6.10**, are oriented toward the east and receive recharge water from the elevated areas of the Orangeville Moraine near the watershed divide between the Grand River and Credit River systems.

Vulnerable Areas within the 25-year Capture Zone

The first significant aquifer in the vicinity of the Marsville municipal supply well has been mapped as 'low vulnerability' using the MOE's intrinsic susceptibility index, as shown on **Map 6.9** (Burnside, 2001b).

A study is currently underway to assess the vulnerability of the bedrock municipal supply aquifer within the 25-year capture zone.

Threats within the 25-year Capture Zone

A study to inventory potential threats within the 25-year capture zone is currently underway. In August of 2006 staff from the GRCA met with Township staff to discuss high level threats to the municipal groundwater supply as summarized in **Table 6.3**.

Summary

Within the portion of the Township of East Garafraxa situated within the boundary of the Grand River watershed, only one community, Marsville, is serviced by a municipal well system. The Village of Marsville is groundwater dependant, with a source from an aquifer mapped as 'low' vulnerability. The primary threats are related to the use of private septic systems in the village and agricultural activities in the village and the surrounding rural land uses. The village has sufficient long term water supplies to address growth projections and potential reduction of existing supplies due to climate change impacts. The Township has completed a groundwater study to identify aquifer susceptibility and areas for wellhead protection and is currently assessing threats and the vulnerability of the bedrock municipal supply aquifer.

Table 6.3: High level threats in Marsville

	Groundwater
Direct Introduction	
Water treatment plant wastewater discharge	None
Sewage treatment plant effluent	Private residential septic systems
Sewage treatment plant by-passes	None
Industrial effluents	None
Landscape Activities	
Road salt application	Municipal sand dome in village is outside the WHPA Township uses pickled sand for winter operations and CaCl for dust suppression
De-icing activities	None
Snow storage	Some storage at municipal yard

Table 6.3: High level threats in Marsville

	Groundwater
Cemeteries	Old cemetery west of village
Stormwater management systems	None
Landfills	Waste transferred and hauled away
Organic soil-conditioning	None
Septage application	Some active permits (application being phased out)
Hazardous waste disposal	None
Liquid industrial waste	None
Mine tailings	Aggregate pit south of village is outside the WHPA
Biosolids application	Township has licensed sites for biosolids application
Manure application	Village is surrounded with agricultural land uses (cash crops and livestock) that require application of nutrients and pesticides
Fertilizer application	
Pesticide / herbicide application	
Historical activities – contaminated lands	None
Storage of Potential Contaminants	
Fuels / hydrocarbons	No gas stations in village
DNAPL's (dense non-aqueous phase liquids)	None
Organic solvents	None
Pesticides (of concern to drinking water)	Co-op supplies agricultural pesticides and fertilizers
Fertilizers	
Manure	Farm specific storage (check individual nutrient management plans)

Township of East Luther – Grand Valley (Grand Valley)

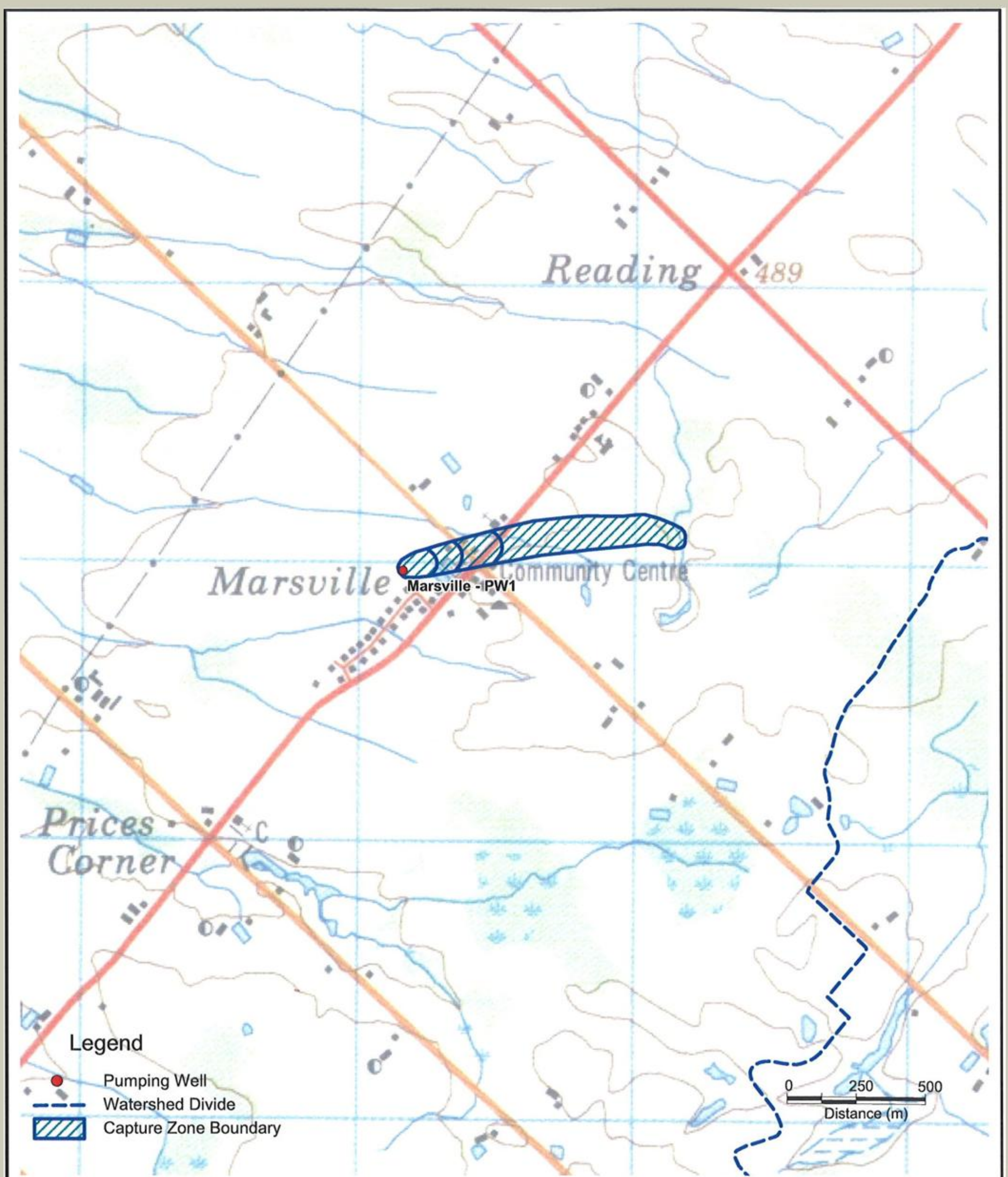
System Description and Hydrogeologic Setting

The Grand Valley water supply system consists of two pumphouses (Cooper Street and Melody Lane) with two wells per pumphouse, an elevated storage tank and a distribution system. As of 1998, the population serviced by the Grand Valley municipal system was approximately 1,600 people (Bellamy and Boyd, 2005).

Wells PW1 and PW2, located within the Cooper Street pumphouse, are drilled to depths of 86.6 m and 86.9 m respectively. Wells PW3 and PW4, located outside the Melody Lane pumphouse, are drilled to depths of 116.4 m and 56.5 m respectively. Wells PW3 and PW4 are completed in the Guelph – Amabel Formation and are located within the floodplain on the eastern side of the Grand River. Overburden in the vicinity of the wells was reported to be approximately 10 m thick. Tavistock Till and sandy glaciofluvial outwash identified by surficial Quaternary mapping predominate in the Grand Valley area.

Raw water is treated with a 12% sodium hypochlorite solution for disinfection at each pumphouse. All microbiological and physical/chemical water quality monitoring is conducted as required by provincial legislation.

Map 6.10: Wellhead Capture Zones in Marsville



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Capture Zones for the Marsville Pumping Well Orangeville and Surrounding Areas Groundwater Modeling Study

Figure 40

Date: July/2001
Checked By: DJMH

Grand River Watershed Characterization Report

Wellhead Capture Zones

Study: Orangeville and Surrounding Areas Groundwater Modelling Study
Area: Marsville Pumping Wells
Consultant(s): WHI / Burnside Environmental
Date: 2001

Groundwater Quality

As a component of the East Luther/Grand Valley Groundwater Management Study, Burnside installed nested monitoring wells north of Grand Valley at County Rd. 10 (East Luther MW-1) and west of Grand Valley (East Luther MW-2). Logs of drilling operations for MW-1 show a shallow overburden well in gravel (thin, discontinuous) below a clay cap, a deeper well in gravel below the clay layer and a coarse till layer, and a grey limestone bedrock well immediately below a thin clay and gravel layer. Logs of drilling operations for MW-2 show a shallow well in gravel and clay below layers of till and clay, and a grey limestone bedrock well immediately below a very thin clay layer. An additional monitoring well (East Luther MW-3) was drilled near the western edge of the study area, south of the mapped organic deposit. Drilling logs show a brown bedrock well covered by till and clay layers.

The monitoring wells were sampled once in 2000. Data includes major cations and anions, hardness, total dissolved solids (TDS), some metals, and dissolved organic carbon (DOC).

Hardness exceeded non-health related ODWS (200 mg L-1) in MW-3. Iron exceeded non-health related ODWS (0.3 mg L-1) in the bedrock monitoring well north of Grand Valley (MW-1). The concentrations of metals in all monitoring wells tended to be below laboratory detection limits.

The study also presented water quality data from a municipal well in the Melody Homes subdivision (the authors do not identify which well) and from the Copper Well (the authors do not discuss this well in the report). Water samples collected during the year of 2000 were analyzed for a selection of metals, nitrate, and xylene. The concentrations of metals tended to be below laboratory detection limits, the concentrations of iron were below non-health related ODWS (0.3 mg L-1), and xylene was not detected.

Description of Capture Zones

Capture zones for Grand Valley's municipal supply wells were modelled as a part of the regional Orangeville groundwater MODFLOW model, which encompassed the Townships of Grand Valley, East Garafraxa and Amaranth (Waterloo Hydrogeologic, 2001). This model was used to develop time 2-, 5-, 10-year and steady state time of travel capture zones for the municipal wells in Grand Valley using average pumping rates. The capture zones for PW 1 and PW2 are illustrated on **Map 6.11**.

Within the community of Grand Valley, the capture zones for supply wells PW-1 and PW-2 are confined to the east side of the Grand River, encompassing much of the community. This has occurred since:

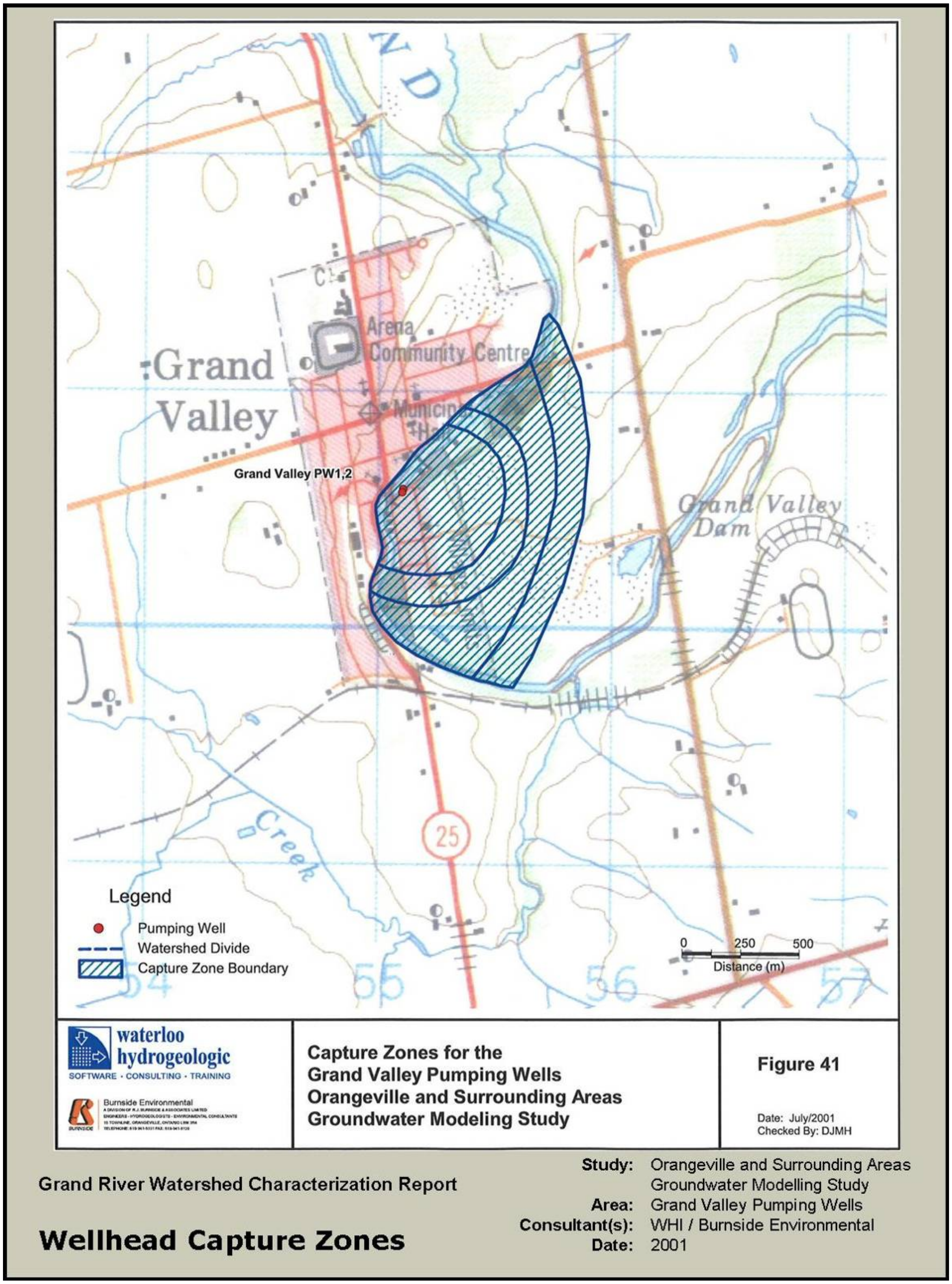
a. Vertical infiltration of surface water from the river is the major source of water for these wells, and

b. The Grand River behaves as a regional groundwater divide to the west of the wellfield.

Vulnerable Areas within the 25-year Capture Zone

The first significant aquifer in the vicinity of the Grand Valley municipal supply wells has been mapped as low and medium vulnerability using the MOE's intrinsic susceptibility index, as shown on Map 44 (Burnside, 2001c).

Map 6.11: Wellhead Capture Zones in Grand Valley



A study is currently underway to assess the vulnerability of the bedrock municipal supply aquifer within the 25-year capture zones.

Threats within the 25-year Capture Zone

A study to inventory potential threats within the 25-year capture zone is currently underway. In August of 2006 staff from the GRCA visited Dufferin County and the Village of Grand Valley to get an overview of high level threats to the municipal groundwater supply as summarized in **Table 6.4**.

Summary

Grand Valley is the only community within the Township of East Luther – Grand Valley to have a municipal groundwater supply system in place. The Village of Grand Valley is groundwater dependant and the municipal supply wells have been mapped as low and medium vulnerability. The primary threats are related to historic activities (fuel storage, spills), the use of private septic systems outside the village and agricultural activities in the surrounding rural land uses. The village has sufficient long term water supplies to address growth projections and potential reduction of existing supplies due to climate change impacts. The Township has completed a groundwater study to identify aquifer susceptibility and areas for wellhead protection and is currently assessing threats and the vulnerability of the bedrock municipal supply aquifer.

Table 6.4: High level threats in Grand Valley

	Groundwater
Direct Introduction	
Water treatment plant wastewater discharge	None
Sewage treatment plant effluent	Private residential septic systems outside the Village and sewage treatment plant in the Village with effluent discharge to the Grand River
Sewage treatment plant by-passes	None
Industrial effluents	None
Landscape Activities	
Road salt application	Municipal sand dome is outside the WHPA Township uses pickled sand for winter
De-icing activities	None
Snow storage	None
Cemeteries	Several small church cemeteries in the village
Stormwater management systems	None
Landfills	Waste transferred and hauled away
Organic soil-conditioning	None
Septage application	No active permits (application being phased out)
Hazardous waste disposal	None
Liquid industrial waste	None
Mine tailings	Aggregate pit east of village has closed
Biosolids application	Township has licensed sites for biosolids application
Manure application	Village is surrounded with agricultural land uses (cash crops and livestock) that require application of nutrients and pesticides
Fertilizer application	
Pesticide / herbicide application	
Historical activities – contaminated lands	Former Co-op is thought to have causes fuel impacts

Table 6.4: High level threats in Grand Valley

	Groundwater
Storage of Potential Contaminants	
Fuels / hydrocarbons	Nine storage locations identified
DNAPL's (dense non-aqueous phase liquids)	None
Organic solvents	None
Pesticides (of concern to drinking water)	Co-op has closed
Fertilizers	
Manure	Farm specific storage (check individual nutrient management plans)

6.3.1.3 County of Wellington

Within the portions of the County of Wellington that fall within the Grand River watershed, early-round municipal groundwater studies were completed at a municipal level across the County (Townships of Wellington North, Mapleton, Centre Wellington, Guelph–Eramosa, Erin and Puslinch). Many of these earlier groundwater studies used a mix of analytical and numerical models to generate capture zones for the municipal wells. Times of travel used to delineate Wellhead Protection Areas (WHPAs) also varied among the studies. The most recent groundwater study within the County (Golder Associates, 2006) was completed at a County-wide scale and provided consistency across the municipalities including consistent time of travel capture zones for all municipal supply wells within the County.

As a part of the County of Wellington Groundwater Protection Study, numerical groundwater flow models were developed for the Townships of Wellington North, Centre Wellington, Guelph – Eramosa and Mapleton. The numerical models were built upon previous analytical and numerical groundwater models for these areas. The County of Wellington study used both MODFLOW and FEFLOW, developed in the Guelph-Puslinch Groundwater Study (Golder Associates, 2006), to model 50-day, 2-, 10- and 25-year time of travel capture zones for each municipal supply well or well field within the County. Capture zones were modelled using anticipated future pumping rates that consider future growth within each serviced area (as identified in the County's Official Plan).

The aquifer vulnerability mapping for the County of Wellington Groundwater Protection Study was completed using a modified version of the MOE's Groundwater Intrinsic Susceptibility Index (Land Use Policy Branch, 2001). This method was modified such that vulnerability maps were produced for 'individual' aquifers rather than the uppermost aquifer only. County-wide vulnerability maps were generated for; a) the uppermost shallow aquifer, b) a deep overburden aquifer, and c) the bedrock aquifer. Only wells encountering a specific aquifer were used in the generation of the vulnerability maps. Additional assumptions made in the generation of the vulnerability maps included:

a. zones of medium to high vulnerability were propagated upwards from the bedrock aquifer, through to the deep and shallow overburden aquifers, to ensure that zones of medium to high vulnerability mapped at depth were not mapped as areas of lower vulnerability in an overlying aquifer; and

b. areas within the shallow overburden aquifer mapped as surficial sands and gravels on the Quaternary geology map were classed as highly vulnerable regardless of vulnerability scores at the wells.

WHPAs were derived from the combination of the time of travel capture zones and the vulnerability mapping for the respective aquifer pumped by the supply well. WHPAs were then classified as WHPAs 1, 2 and 3 where:

- WHPA 1 was represented by the 0-2 year capture zone area in combination with a high vulnerability rating,
- WHPA 2 was represented by the 0-2 year capture zone area in combination with a low or medium vulnerability rating AND the 2-25 year capture zone area in combination with a high vulnerability rating; and
- WHPA 3 was represented by the 2-25 year capture zone area in combination with a low or medium vulnerability rating.

Potential threat inventories were completed at the Township level during earlier municipal groundwater studies to various degrees of detail. As a component of the County of Wellington Groundwater Protection Study, these inventories were expanded, merged and mapped on a County-wide scale.

With current funding from MOE under Source Water Protection, a number of updates to the County of Wellington Groundwater Protection Study are underway. With respect to the WHPAs five-year time of travel capture zones are currently being modelled for all 37 municipal wells within the County. Additionally, a future supply well for the community of Rockwood has been identified since the completion of the County of Wellington groundwater study. Therefore new capture zones have been modelled for this well and existing capture zones in Rockwood have been modified to reflect the new pumping well.

The Townships of Mapleton and Guelph-Eramosa are updating their vulnerability mapping across the municipalities to enhance a set of maps for the ‘first significant aquifer’ and also for the deeper municipal supply aquifers. A detailed threats inventory is in the process of being completed within the 25-year capture zones for each of the municipal wells in these Townships. This inventory will include a review/compilation of existing data and a field investigation on a parcel-by-parcel basis. Additionally, groundwater issues for each municipal well and ‘preferential pathways’ will be compiled and evaluated.

The Township of Centre Wellington is currently updating the threats inventory, completing an inventory or preferential pathways and an issues assessment within the Fergus and Elora capture zones, with the most effort focused within the 2-year capture zone.

Township of Wellington North (Arthur)

System Description

Within the Township of Wellington North, the community of Arthur’s municipal water supply system consists of 3 wells, 2 pumphouses, 2 elevated water tanks and a distribution system. The municipal system supplies water to approximately 2,500 people within the community.

The municipality recently decommissioned seven wells in accordance with OWRA Reg. 903. The remaining 3 wells are completed in overburden sediments (Wells 7B and 8A/8B). The upper surficial Quaternary geology has been mapped as a clayey silt to silt till (Tavistock Till) which covers a large part of the area surrounding Arthur.

Water is treated with a 12% sodium chloride solution for disinfection and a 28% Calciquest solution for iron sequestration (Arthur Drinking Water Systems 2005 Annual Report).

Licensed operators for the Township of Wellington North regularly test the water within its overall system including the raw water at the well source, after treatment and within the distribution system of approximately 16.8 km of watermain (Arthur Drinking Water Systems 2005 Annual Report). All microbiological and physical/chemical water quality monitoring is conducted as required by provincial legislation.

Groundwater Quality

The Township of Wellington North Groundwater Management and Protection Study (Burnside, 2001) summarized a selection of cations and anions, TDS, and metals that were measured in Arthur's municipal wells. In general, the municipal wells produced hard water and iron and fluoride concentrations were commonly above Ontario Drinking Water Standards (ODWS). In Well 7B, an overburden well, chloride, sulphate, and iron concentrations were reported to be increasing over time. Organic nitrogen concentrations in the municipal wells tended to exceed the ODWS of 0.15 mg L-1, but nitrate concentrations did not exceed the ODWS.

Water quality was also measured in monitoring wells drilled for municipal pumping tests (Burnside, 2001). Within Arthur, nested wells were drilled in the shallow overburden deposits and in a sand and gravel layer above the bedrock. Southeast of Arthur, near the intersection of Hwy 6 and Hwy 109, an overburden monitoring well was drilled in a deep sand and gravel deposit. It was reported that this sand and gravel deposit may be hydraulically connected to the overburden municipal well 7B southwest of Arthur.

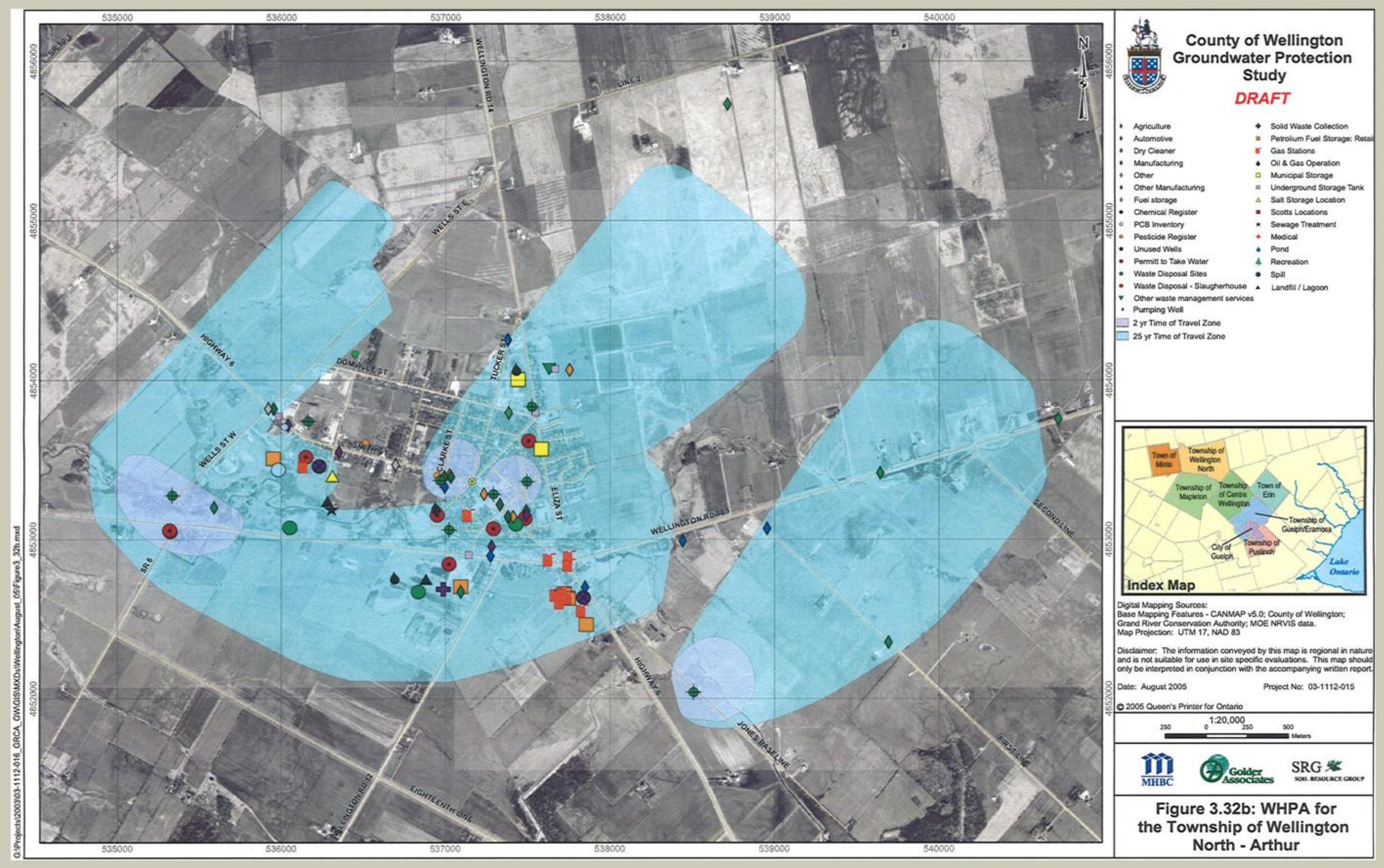
The nested overburden monitoring wells in Arthur also had hard water. The nitrate concentration in the shallow overburden well exceeded the ODWS (10 mg L-1), and the iron concentration in the deep overburden well was 7.22 mg L-1. The high nitrates in the shallow monitoring well indicate there are some impacts from surface activities. In the deep sand and gravel monitoring well near Hwy 6 and Hwy 109, water was not as hard and nitrates and iron concentrations did not exceed ODWS.

The Drinking Water Systems Regulations 2005 Annual Report for Arthur reported 6 exceedances of background bacteria during the course of 2005. The corrective action for the elevated counts was to resample. The last exceedance of microbiological parameters was on June 17th, 2005.

Description of Capture Zones

The 25-year capture zones for the community of Arthur's municipal supply wells, modelled as a part of the County of Wellington Groundwater Management Study (Golder Associates, 2005), are shown on Map . As illustrated, Wells 2, 3 and 7 merge together and extend approximately 4 km to the northeast in the upgradient direction of regional groundwater flow. The 25-year capture zone for Arthur Well 8 also extends to the northwest for approximately 3.5 km. The land use overlying the Arthur WHPA is primarily rural agricultural, although the 2-year capture zones for the decommissioned Wells 2 and 3 were within the urban footprint of Arthur.

Map 6.12: Wellhead Capture Zones and Potential Contaminants in Arthur



Grand River Watershed Characterization Report

Wellhead Capture Zones and Potential Contaminants

Study: County of Wellington Groundwater Protection Study, Draft Report
Area: Arthur
Consultant(s): Golder Associates
Date: 2005

Vulnerable Areas within the 25-year Capture Zone

The results of the WHPA mapping for the Arthur municipal wells is shown on **Map 6.13**, in the bottom half of the map. The 2-year capture zone has been mapped as a WHPA 2, indicating that the uppermost aquifer within this capture zone has been ranked as low to medium vulnerability. The 2 to 25 year capture zone has been assigned a WHPA 3, indicating that areas within this capture zone were mapped as low to medium vulnerability.

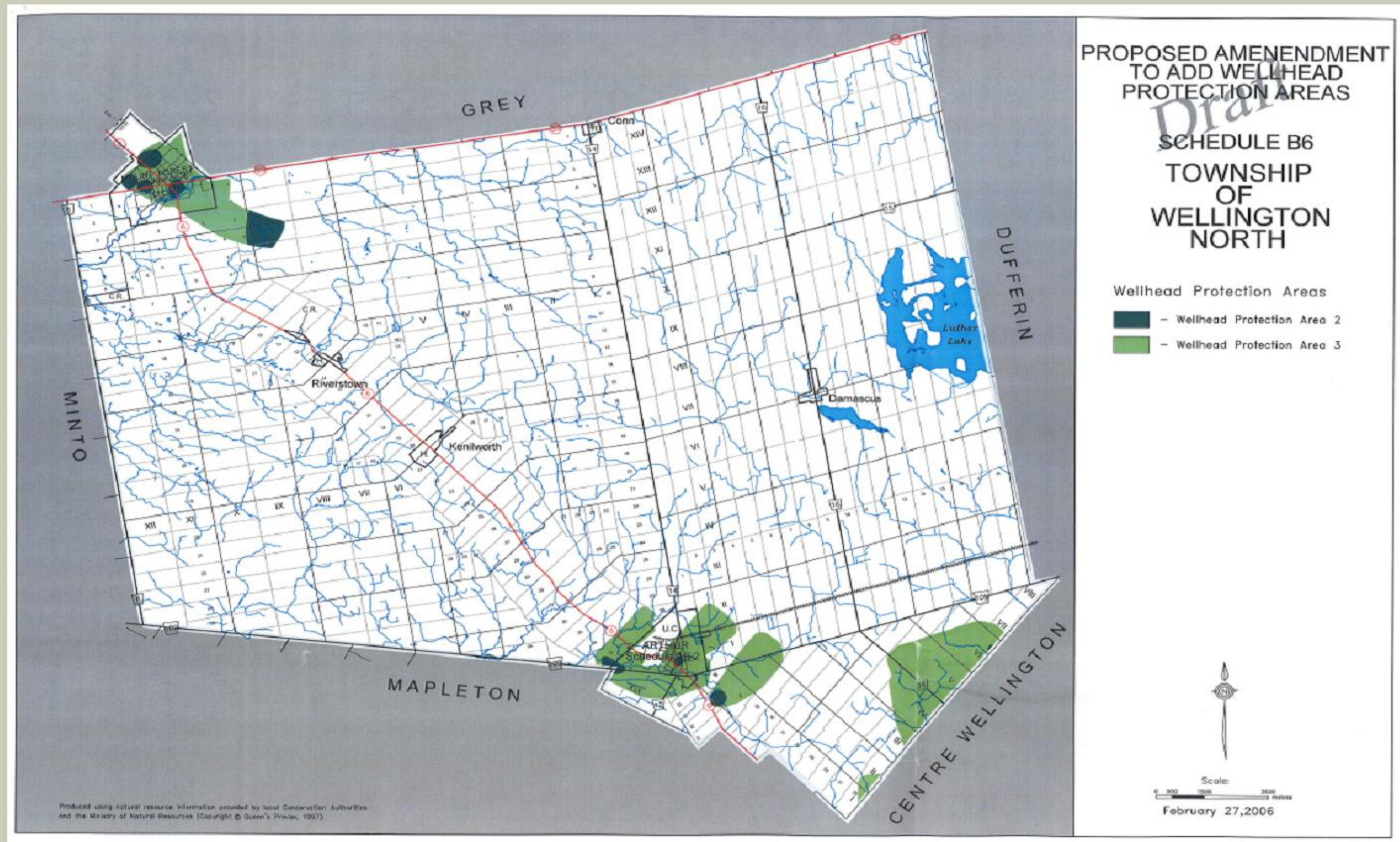
Threats within the 25-year Capture Zone

As illustrated on **Map 6.12** (Golder Associates, 2005), documented threats within Arthur's 2-year capture zones include agricultural operations, an automotive facility and one facility on the Pesticide Register. In August of 2006 staff from the GRCA met with Township staff to discuss high level threats to the municipal groundwater supply as summarized in **Table 6.5**.

Table 6.5: High Level Threats in the Town of Arthur

	Groundwater
Direct Introduction	
Water treatment plant wastewater discharge	none
Sewage treatment plant effluent	Extended aeration lagoon with seasonal UV disinfected discharge to Grand River
Sewage treatment plant by-passes	none
Industrial effluents	Auto and food processing industries pre-treat on site
Landscape Activities	
Road salt application	Salt management plan has cut salt use in half (use 5% pickled sand and 3% brine solution on stockpile)
De-icing activities	none
Snow storage	1 snow dump in Arthur (on Eliza near the lagoons)
Cemeteries	South of Arthur at Sideroad #6 and County Road #109
Stormwater management systems	Some proposed in SE corner of town as development required
Landfills	County landfill on Sideroad #5 (between Arthur & Mt. Forest)
Organic soil-conditioning	Facility in south end of town
Septage application	No septics in serviced areas (septics require a variance)
Hazardous waste disposal	None
Liquid industrial waste	None
Mine tailings	None
Biosolids application	OCWA contract biosolids handling (County desktop study)
Manure application Fertilizer application Pesticide / herbicide application	Arthur is surrounded by agricultural operations including livestock (chickens and rabbits) and crops. Typical farm handling of manure, fertilizers and pesticides
Historical activities – contaminated lands	Coates-Bell (thread manufacturing) left in 2004 Co-op was located next to Well #3 (now closed)
Storage of Potential Contaminants	
Fuels / hydrocarbons	Several gas stations
DNAPL's (dense non-aqueous phase liquids) Organic solvents	Local automotive plant (manufactures drive shafts) may have some machining/cutting fluids and/or cleaning solvents
Pesticides (of concern to drinking water)	Agricultural pharmaceutical manufacturing
Fertilizers	none (Co-op's now located in Mt. Forest, Harriston)
Manure	None

Map 6.13: Proposed Wellhead Protection Areas in the Township of Wellington North



Grand River Watershed Characterization Report

Proposed Wellhead Protection Areas

Study: County of Wellington Groundwater Protection Study, Draft Report
Area: Township of Wellington North
Consultant(s): Golder Associates
Date: 2005

Summary

Within the Township of Wellington North, Arthur is the only community located within the Grand River watershed boundary that is serviced by a municipal groundwater system. The Town of Arthur is groundwater dependant, with a source from an aquifer mapped as 'low to medium' vulnerability. New wells were recently installed to satisfy MOE regulations, however some manganese issues still need to be addressed in the new water supply. Possible threats range from a wide variety of urban activities (industry, fuel storage) within the town to rural land use issues (agricultural practices, livestock processing) in the surrounding township. The Town has identified sufficient capacity for its long term water supply in its recent Class EA process. Due to the recent upgrades to the water supply system, the Town of Arthur has not scheduled any further groundwater protection studies.

Township of Mapleton

Within the Township of Mapleton, two groundwater-based communities, Moorefield and Drayton, are located within the Grand River watershed. In August of 2006 staff from the GRCA met with Township staff to discuss high level threats to the municipal groundwater supply as summarized in **Table 6.6**.

<u>Moorefield</u>

System Description

One bedrock well provides water to the community of Moorefield.

Municipal Groundwater Quality

No information was readily available with regards to Moorefield's water quality at the time of this summary.

Description of Capture Zones

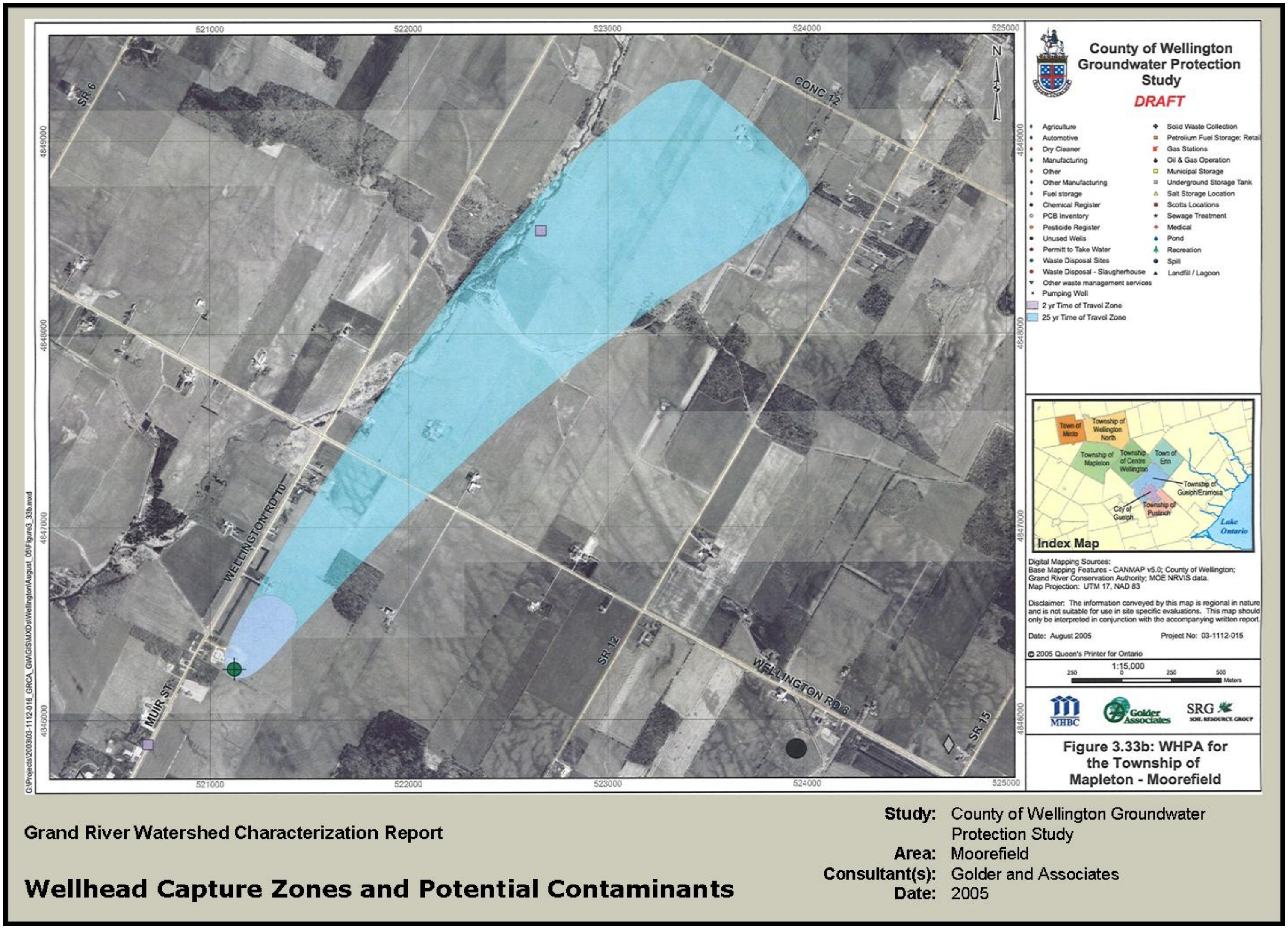
The 2- and 25-year capture zones developed for Moorefield's municipal supply well are illustrated on . The 25-year capture zone extends approximately 4 km to the northeast in the upgradient direction of regional groundwater flow in the bedrock. The overlying land use within the capture zones is entirely rural agriculture.

Vulnerable Areas within the 25-year Capture Zone

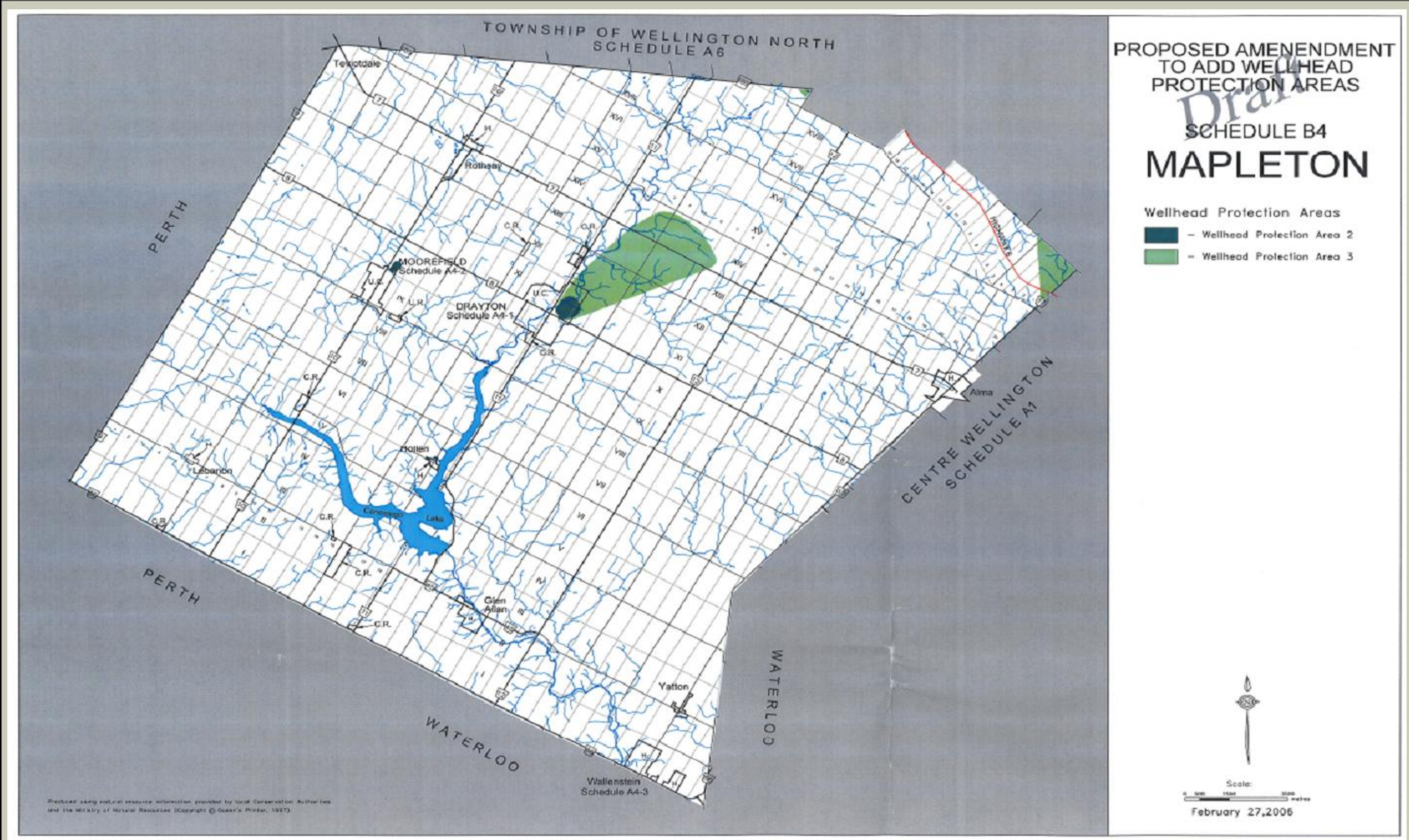
The results of the WHPA mapping for Moorefield's municipal well is shown on

Map 6.15. The 2-year capture zone has been mapped as a WHPA 2, indicating areas where the first significant aquifer within this capture zone was mapped as low to medium vulnerability. The 2 to 25 year capture zone is not shown on this figure.

Map 6.14: Wellhead Capture Zones and Potential Contaminants in Moorefield



Map 6.15: Proposed Wellhead Protection Areas in the Township of Mapleton



Grand River Watershed Characterization Report

Proposed Wellhead Protection Areas

Study: County of Wellington Groundwater Protection Study, Draft Report
Area: Township of Mapleton
Consultant(s): Golder Associates
Date: 2005

Table 6.6: High Level Threats in the Township of Mapleton

	Groundwater
Direct Introduction	
Water treatment plant wastewater discharge	none
Sewage treatment plant effluent	Drayton & Moorefield lagoons discharge to Conestogo River upstream of the Conestogo Dam
Sewage treatment plant by-passes	none
Industrial effluents	Bus wash in Drayton discharges to surface.
Landscape Activities	
Road salt application	Township uses a mix of 25%salt / 75% sand
De-icing activities	County is responsible for de-icing of major roads and bridges
Snow storage	Small amount of storage in Drayton behind the arena
Cemeteries	One active cemetery in Drayton
Stormwater management systems	One retention pond in new subdivision in Drayton
Landfills	Old landfill on County Road 7 (north-east of Drayton) closed four years ago. Waste now transferred to Rothsay, Mt. Forest & Harriston
Organic soil-conditioning	None within the WHPA
Septage application	Some sites still licensed
Hazardous waste disposal	None
Liquid industrial waste	None
Mine tailings	None
Biosolids application	Some site licensed for GTA sludge application, although most goes to North Wellington. The municipal lagoons have not been emptied (they use solar aerators).
Manure application Fertilizer application Pesticide / herbicide application	Agricultural activities (dairy farms, hog farms, chicken farms, cash crop operations) are all around Drayton & Moorefield. Dairy operation is next to the municipal lagoon.
Historical activities – contaminated lands	No industrial sites to mention. Old landfill has been tested for methane next to the Conestoga River (upstream of Drayton)
Storage of Potential Contaminants	
Fuels / hydrocarbons	Drayton Co-op has replaced in ground tanks with above ground Drayton car dealership tanks have been cleaned up Garage (in Drayton) has not removed old tanks
DNAPL's (dense non-aqueous phase liquids)	none
Organic solvents	none
Pesticides (of concern to drinking water)	Drayton Co-op has products for spraying crops
Fertilizers	Drayton Co-op has a bermed fertilizer building
Manure	Dairy operation has a 120' diameter containment tank

Threats within the 25-year Capture Zone

One underground storage tank is located within the 25-year capture zone for Moorefield's municipal well shown on **Map 6.14** (Golder Associates, 2005).

Summary

The municipal water supply for the Village of Moorefield is groundwater dependant. The main threat is related to the proximity of farming activities to the wells. The Township has recently commissioned new well facilities in the village so there is currently no data to confirm the long term water supply capacity for Moorefield, however it is expected that they have been sized appropriately to satisfy future demands. The Township is currently completing studies to update the vulnerability of existing supplies and identify threats and issues in wellhead areas.

<u>Drayton</u>

System Description

One municipal well completed in the Salina Formation supplies the community Drayton. The well services an estimated population of 1,500 people (Bellamy and Boyd, 2005).

Groundwater Quality

No information was readily available with regards to Drayton's water quality at the time of this summary.

Description of Capture Zones

Two and 25-year capture zones developed for Drayton's municipal well are shown on Map 6.16. The 25-year capture zone for Drayton's municipal well extends approximately 6 km to the northeast in the upgradient direction of regional groundwater flow within the bedrock. The land use within the capture zones is primarily rural agricultural, although the 2-year capture zone is partially overlain by the urban footprint of Drayton.

Vulnerable Areas within the 25-year Capture Zone

The results of the WHPA mapping for Drayton's municipal well are shown on **Map 6.16**. The 2-year capture zone has been mapped as a WHPA 2, indicating that areas within this capture zone were mapped as low to medium vulnerability. The 2 to 25 year capture zone has been assigned as a WHPA 3, indicating areas within this capture zone were mapped as low to medium vulnerability.

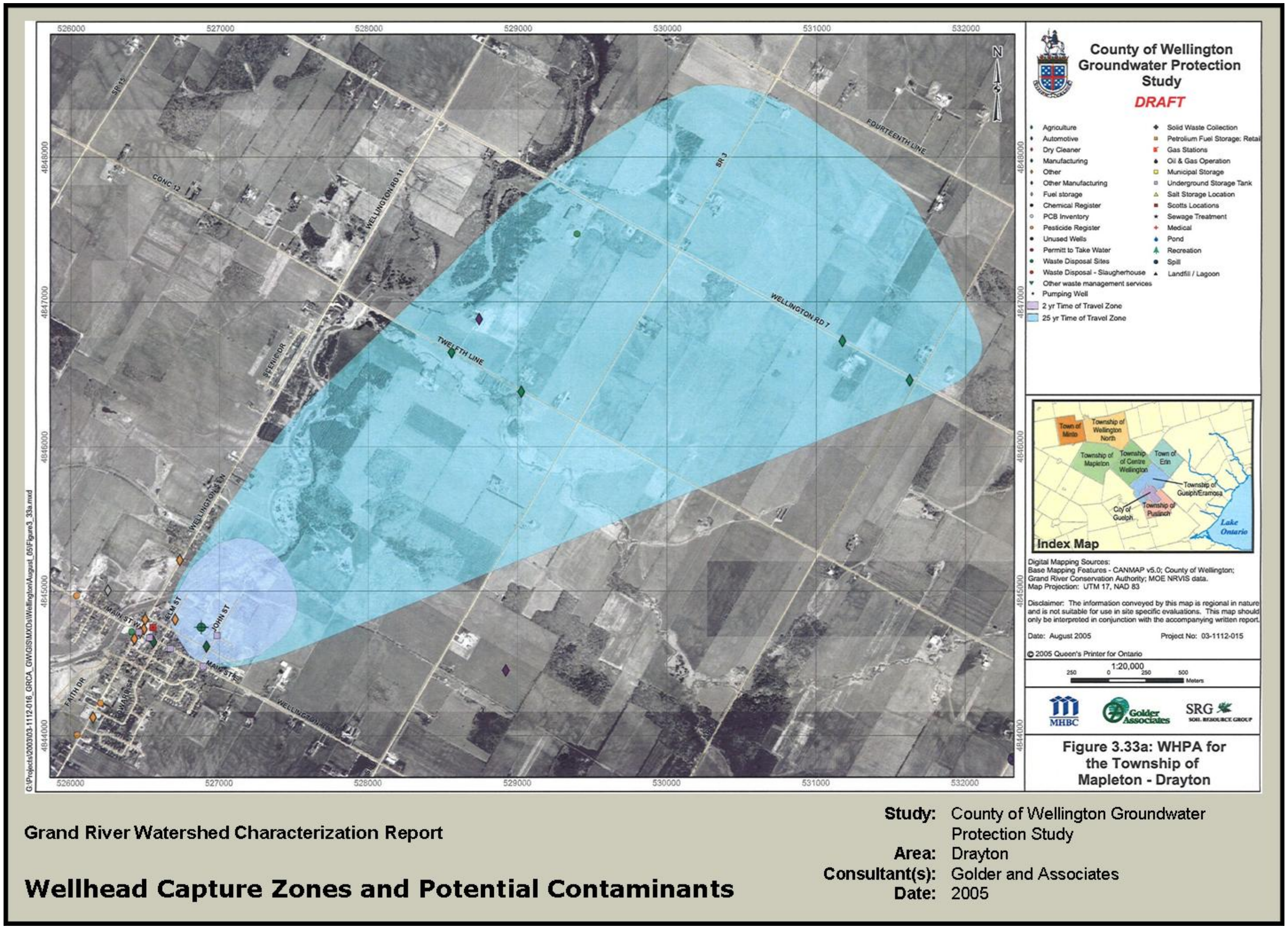
Threats within the 25-year Capture Zone

Inventoried threats within Drayton's capture zones are shown on **Map 6.16** (Golder Associates, 2005). Potential threats located within the 2-year capture zone include an underground storage tank and agricultural facilities. Within the 25-year capture zone, potential threats are generally limited to agricultural land uses and one site noted as a possible landfill or dump, located on 12th Line.

Summary

The municipal water supply for the Village of Drayton is groundwater dependant. The main threat is related to an underground storage tank; however, there are concerns about the proximity of farming activities to the well. The Township has sufficient long term water supply to meet the needs of growth projections in Drayton. The Township is currently completing studies to update the vulnerability of existing supplies and identify threats and issues in wellhead areas.

Map 6.16: Wellhead Capture Zones and Potential Contaminants in Drayton



Township of Centre Wellington (Fergus and Elora)

System Description

In 2001, the serviced population for the Town of Fergus was approximately 8,008 people (Bellamy and Boyd, 2005). The water supply system for the community of Fergus currently consists of 5 active bedrock wells (Well Nos. F1, F4, F5, F6, F7) a pump house at each well, 3 elevated water towers and a distribution system (Fergus MOE Drinking Water Systems Regulation O. Reg. 170/03, Annual Report, 2004). Well F2 is currently not in service. At each pump house, raw water is treated with chlorine gas prior to discharging to either the distribution system or underground reservoir (Fergus MOE Drinking Water Systems Regulation O. Reg. 170/03, Annual Report, 2004).

Within the community of Elora, there are currently 3 municipal wells (Well Nos. E1, E3, E4). Well E2 was recently abandoned. The 3 active wells supply drinking water to an estimated population of 4,122 people (as of 2001) within the community of Elora (Bellamy and Boyd, 2005). The 3 wells and pump houses, 2 water towers and a distribution system form the water supply system for the community. Well No. E1 is located inside a pump house, in a residential area on the north side of Elora and Well No. E3 is located at the south end of Elora in an agricultural/industrial area and Well E4 is located in an unopened road allowance in the southwest corner of Elora, surrounded by agricultural land. Raw water from all wells is treated with chlorine gas for disinfection. Treated water is discharged directly into the distribution system.

The water distribution systems for Fergus and Elora were interconnected in 2005 and now share groundwater supplies and system storage.

The uppermost bedrock unit within the 2 communities is the Guelph Formation. The Eramosa Member underlies the Guelph Formation and behaves as an aquitard. The Amabel Formation, located beneath the Eramosa Member, forms the aquifer for the Fergus and Elora municipal wells.

Groundwater Quality

As a component of the Groundwater Management Study and Protection Strategies for the Township of Centre Wellington (Blackport Hydrogeology Inc., June 2002), water quality from 5 municipal wells in Fergus and 2 municipal wells in Elora was summarized. Inorganic water quality data included chloride, sodium, nitrate, sulphate and iron.

Blackport Hydrogeology (2002) stated that sodium and chloride concentrations were variable, but some minor impacts due to road salting were evident in 2 Fergus wells. Nitrate concentrations were reported to be below ODWS. The sulphate concentrations in one Fergus well (F6) increased with increased pumping. Trichloroethylene was discovered in one Fergus well (F1) in the late 1980s and the well has been operating with an air scrubber since that time.

According to the Drinking Water Systems Regulations Annual Report, no water quality exceedances were reported for either Fergus or Elora in 2005.

Description of Capture Zones

Capture zones for the Fergus and Elora municipal wells are shown on **Map 6.17** and **Map 6.18**. The 25-year capture zones for most of the Fergus wells (refer to **Map 6.17**) merge together and extend approximately 16 km to the north. The 25-year capture zone for Well No. 5, which is located to the south of the Grand River, extends to the east for approximately 5 km. Land use within the 25-year capture zones of generally rural agricultural, although most of the urban area of Fergus also lies within the capture zone.

From **Map 6.18**, the Elora 25-year capture zones merge together and extend approximately 15 km to the north. The 25-year capture zones for the wells located to the south of the Grand River extend northward beneath the Grand River. Similar to the Fergus capture zones, land use within most of Elora's 25-year capture zones is rural agricultural, although the entire urban footprint of the community is also located within the capture zones.

Vulnerable Areas within the 25-year Capture Zone

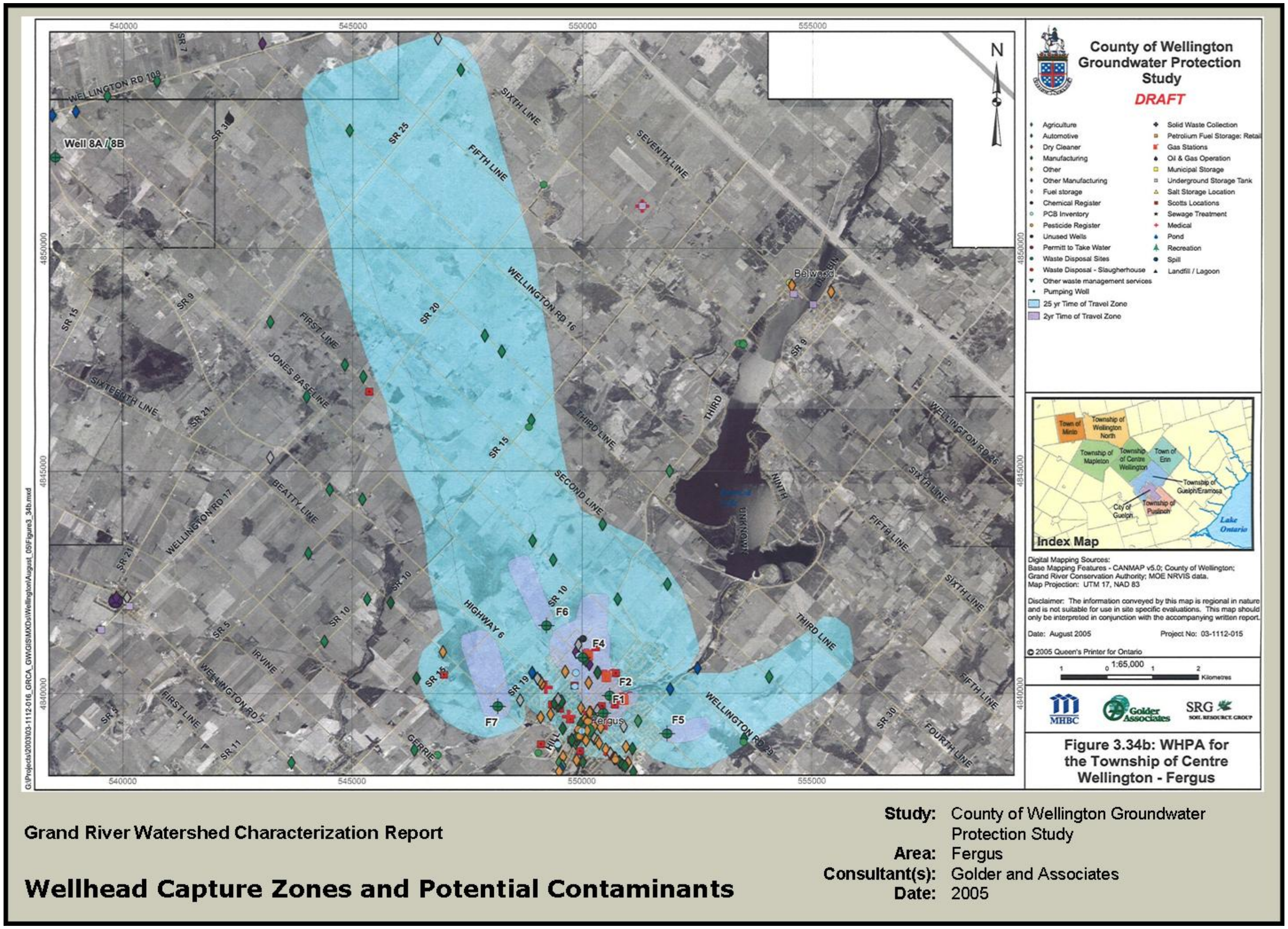
The results of the WHPA mapping for Fergus and Elora's municipal wells are shown on **Map 6.19**. Most of the WHPAs on this figure are mapped as a Protection Area 3, indicating these zones are within the 2-25 year time of travel and categorized as low to medium vulnerability. Locations mapped as a WHPA 2 are smaller in area than the WHPA 3's and located closer to the municipal wells, while areas mapped as a WHPA 1 are fairly localized to the municipal well and represent areas where the 0-2 year capture zone has been mapped as highly vulnerable.

Threats within the 25-year Capture Zone

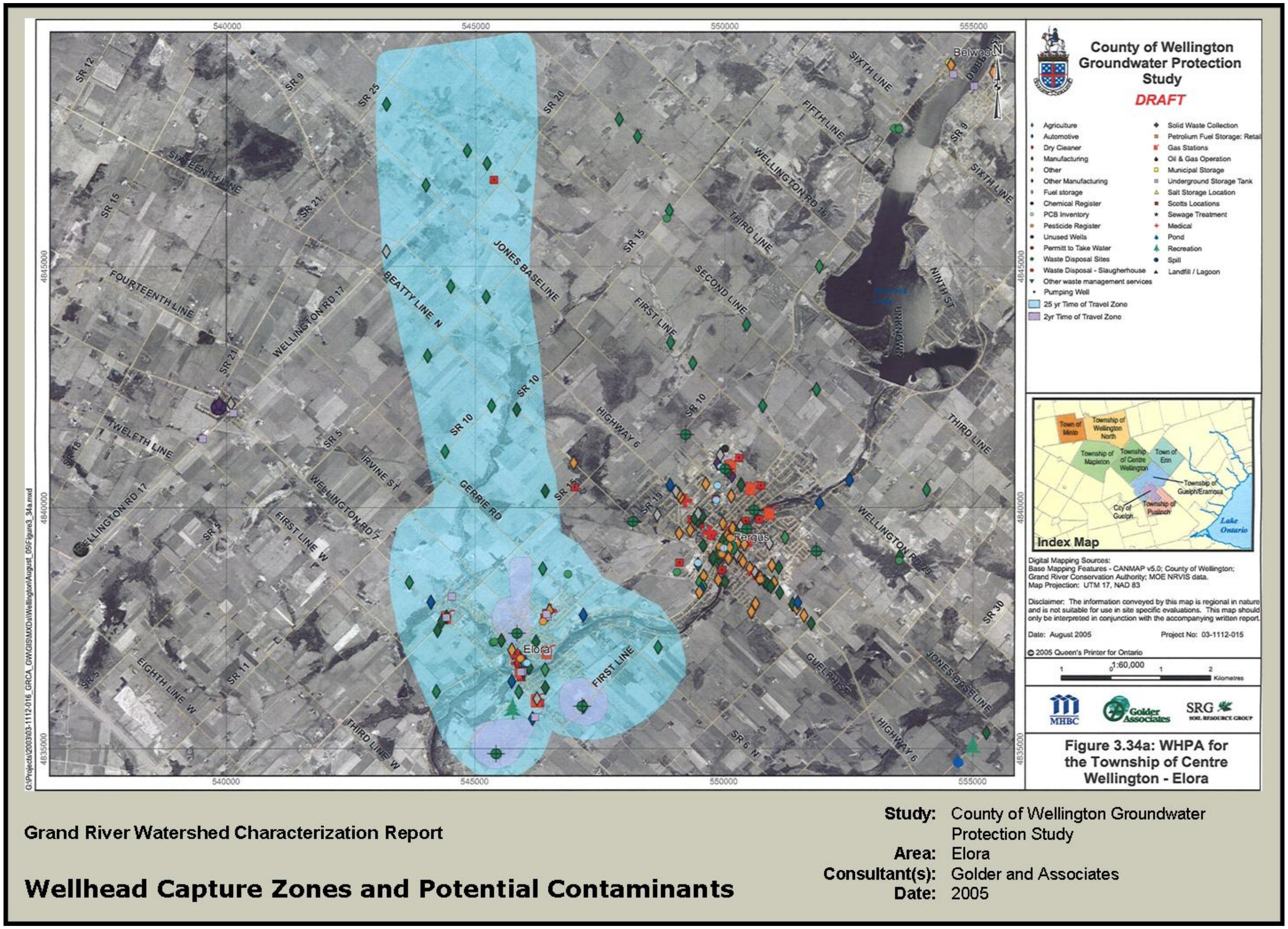
Potential contaminants, as shown on **Map 6.17** (Golder Associates, 2005), within the 2-year capture zones for Fergus include manufacturing facilities, underground fuel storage tanks, and PCB storage sites. A large number of potential contaminant sources exist within the 25-year capture zones, particularly within the urban footprint of Fergus. The potential threats include manufacturing facilities and underground fuel storage tanks. Outside of the urban area, potential contaminant sources are generally agricultural land uses and existing or former landfill sites.

As illustrated on **Map 6.18** (Golder Associates, 2005), a large number of potential contaminant sources are located within the urban area of Elora. These sites include manufacturing facilities, underground fuel storage tanks, and landfill sites. Beyond the urban areas, potential contaminant sources are primarily agricultural land uses. In June of 2006 staff from the GRCA met with the Township's consultants to discuss high level threats to the municipal groundwater supply as summarized in **Table 6.7**.

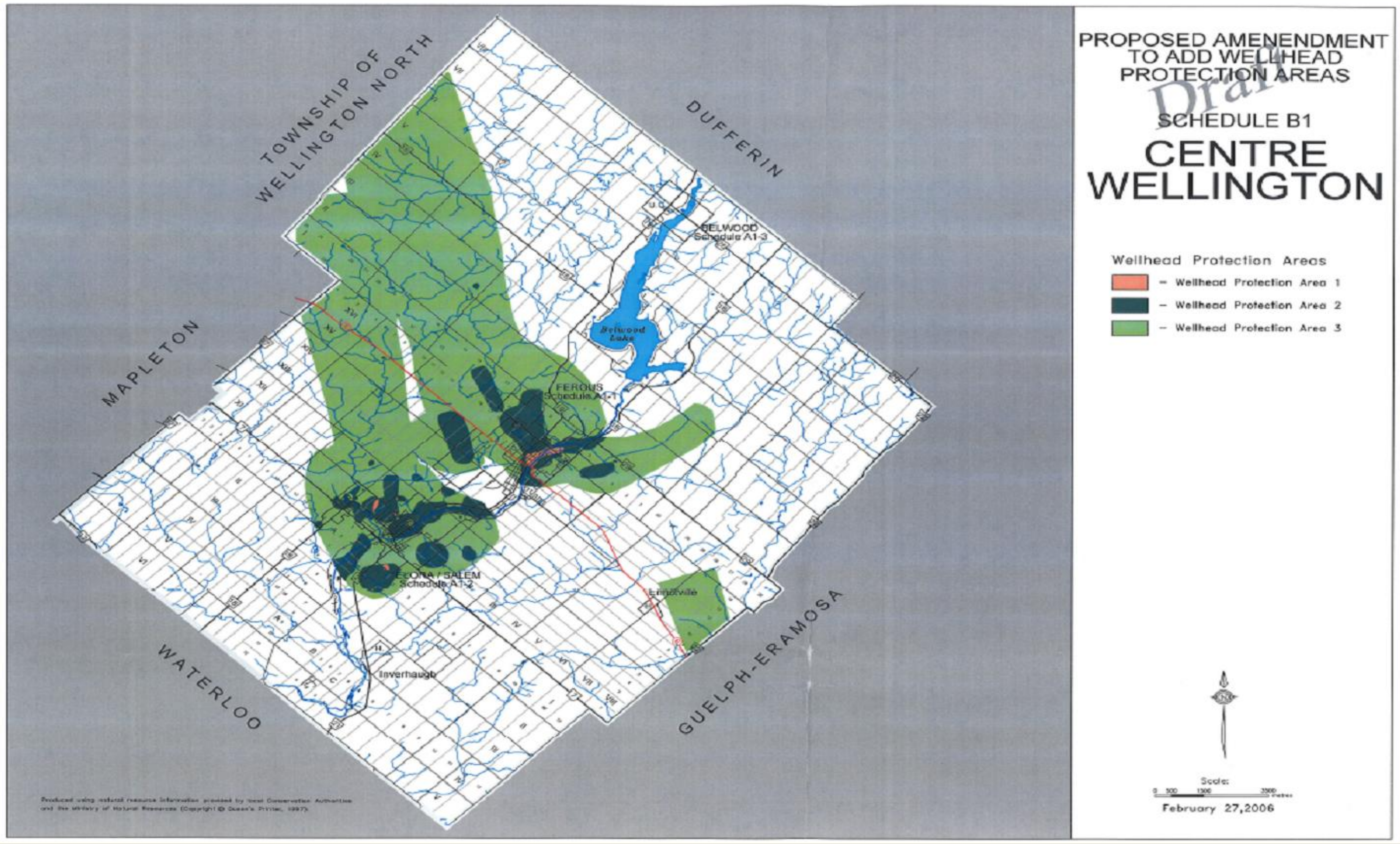
Map 6.17: Wellhead Capture Zones and Potential Contaminants in Fergus



Map 6.18: Wellhead Capture Zones and Potential Contaminants in Elora



Map 6.19: Proposed Wellhead Protection Areas in the Township of Centre Wellington



Grand River Watershed Characterization Report

Proposed Wellhead Protection Areas

Study: County of Wellington Groundwater Protection Study, Draft Report
Area: Township of Centre Wellington
Consultant(s): Golder Associates
Date: 2005

Summary

Within the Township of Centre Wellington, the communities of Fergus and Elora are supplied by an integrated municipal groundwater system. The Towns of Fergus and Elora are groundwater dependant with a source from an aquifer mapped as primarily 'low to medium' vulnerability, however, some small areas of "high" vulnerability do exist within the 2-Year time of travel zone. The majority of threats are related to a wide range of urban land use activities (industry, historical contamination, etc.), with additional concerns regarding surrounding rural land uses and rural septic services. The Township has identified the need for a Long Term Water Strategy. The Township has implemented some programs and best practices to reduce groundwater quantity and quality impacts (ie. full municipal services, tembine application). The Township along with the County of Wellington has conducted groundwater studies to quantify existing supplies and identify wellhead areas for protection and is currently completing studies to update the vulnerability of existing supplies and identify threats and issues in wellhead areas.

Table 6.7: High Level Threats in the Towns of Fergus and Elora

	Groundwater
Direct Introduction	
Water treatment plant wastewater discharge	None
Sewage treatment plant effluent	Tertiary treatment plants in Fergus and Elora discharge to the Grand
Sewage treatment plant by-passes	There have been some sewage pumping station by-passes in Elora to the Grand River and occasional by-passing of the Fergus plant during wet weather events
Industrial effluents	Well F2 (currently off-line) is GUDI and is down-gradient of the industrial park (no known issues) GSW pump & treat effluent discharges to Grand
Landscape Activities	
Road salt application De-icing activities	County uses tembine on roads and bridges Township use pickled sand for ice control
Snow storage	Future snow dump at new Township P.W. facility
Cemeteries	Fergus full, new cemetery planned for Belwood Elora cemetery buffered from the Grand
Stormwater management systems	Some detention & retention facilities in Elora & Fergus Subwatershed scale ponds planned
Landfills	Fergus closed 1978 (history of TCE disposal on site) Elora's closed 1986 (now transfer station)
Hazardous waste disposal	None
Liquid industrial waste	None
Organic soil-conditioning	None
Mine tailings	None
Septage application Biosolids application Manure application	County of Wellington identified licensed sites for septage & biosolids in 2002 Management Study OMAFRA NMA records identify storage & application
Fertilizer application	Numerous agricultural users in surrounding rural areas
Pesticide / herbicide application	Township considering municipal restrictions
Historical activities – contaminated lands	Industrial site contamination history is recorded A number of Provincial Orders are outstanding on other sites, primarily gas stations

Table 6.7: High Level Threats in the Towns of Fergus and Elora

	Groundwater
Storage of Potential Contaminants	
Fuels / hydrocarbons	Multiple sites in Fergus and Elora, inventory pending
DNAPL's (dense non-aqueous phase liquids)	Centre Wellington Hydro PCB storage next to Well F4
Organic solvents	Some industrial users
Pesticides (of concern to drinking water)	None
Fertilizers	None
Manure	None

Township of Guelph-Eramosa (Hamilton Drive and Rockwood)

System Description and Hydrogeologic Setting

The Hamilton Drive and Rockwood municipal well systems are located within the Township of Guelph-Eramosa. The community of Hamilton Drive has a serviced population of approximately 1,000 people (2001 data) and is supplied by 2 wells (Cross Creek and Huntington wells) that draw groundwater from the Guelph Formation (Bellamy and Boyd, 2005). The water supply system consists of 2 wells with pump houses and a reservoir beneath each pump house, a standpipe and distribution system. Raw water is treated with chlorine gas prior to discharge to the reservoir (Rockwood MOE Drinking Water Systems Regulation O. Reg. 170/03, Annual Report 2004).

The serviced population of Rockwood, as of 2001 was approximately 2,973 people (Bellamy and Boyd, 2005). The water supply system for Rockwood consists of 2 wells which draw from the Unsubdivided Amabel Formation, a pump house, a water tower and distribution system. Raw water is disinfected with a 12% sodium hypochlorite solution and treated with a 34.8% sodium silicate solution for iron sequestration (Rockwood MOE Drinking Water Systems Regulation O. Reg. 170/03, Annual Report 2004).

Most of the Township is underlain by a sandy silt till that acts as an aquitard, locally confining the bedrock aquifer by limiting the downward movement of water from overlying kame and outwash deposits (Gartner Lee Limited, 2004). The Guelph Formation and Unsubdivided Amabel Formation form the principal aquifers for the Township. Within the Guelph Formation, which overlies the Amabel Formation, highest well yields are typically found in the upper few metres of the Formation, which is commonly fractured and weathered (Gartner Lee Limited, 2004). The Eramosa Member of the Amabel Formation is less fractured and has a lower secondary porosity relative to the overlying Guelph Formation and the lower production zone of the Unsubdivided Amabel Formation, thus acting as a local aquitard between the two units.

Municipal Water Quality

As a part of the Guelph-Eramosa Township Regional Groundwater Characterization and Wellhead Protection Study (Gartner Lee Ltd., 2004), a map showing the probability of finding fresh water (as opposed to salty or sulphur water) in the study area was constructed using the groundwater classification from the MOE water well database. The wells generally represented the Guelph Formation, rather than the deeper Amabel Formation. An extensive area of low probability of finding fresh water was mapped from the eastern edge of the City of Guelph around the Eramosa River to the western edge around the Speed River, which may reflect the impact of road salting activities. Isolated areas of low probability were mapped in the western portion of the study area.

Water quality for the Township wells at Rockwood and Hamilton Drive were summarized from Engineers Report for the Township of Guelph-Eramosa (Burnside, 2001a and 2001b). In the Rockwood wells, where principal aquifer was identified as the Amabel Formation, concentrations of nitrate and chloride were above typical background levels and were variable. The Rockwood wells were suspected of being impacted by surficial activities. Between 1996 and 2000, turbidity and gross alpha (radionuclide) exceeded their ODWS, and hardness, total dissolved solids, and organic nitrogen have occasionally exceeded ODWS. Industrial solvents, tetrachloroethylene and trichloroethylene, were detected at concentrations below their respective health-related maximum acceptable concentrations.

Township wells at the Hamilton Drive community were considered by Burnside (2001b) to be susceptible to impacts from septic effluent, road salt, and lawn care products because of the limited overburden in the area. It was reported that turbidity occasionally exceeded the non-health related ODWS in the Cross Creek Well, and the concentrations of dissolved organic carbon and hardness occasionally exceeded their ODWS in all wells.

MOE monitoring wells are located along Hwy 7 towards Rockwood or within Rockwood. A monitoring program in Rockwood assessing the impacts from a train and vehicle accident spilling diesel fuel, battery acid, hydraulic fluid and coolant has been completed and found that diesel fuel was reported to enter the fractured bedrock below the railway. Concentrations of diesel, gas, benzene, toluene, ethylbenzene, and xylene were measured in one Rockwood municipal well and two monitoring wells. Diesel and ethylbenzene were detected below ODWS health-related MAC in two monitoring wells for one month following the accident. Benzene, toluene, ethylbenzene, and xylene were added to the analyte list for the municipal wells' monitoring program.

It was reported that steel liners were installed in two Rockwood wells (PW1 and PW2) in March 2002 to limit groundwater taking to the deeper portion of the Amabel aquifer. Gartner Lee reported that preliminary observations indicate the liners provide greater isolation from potential surface sources of contamination.

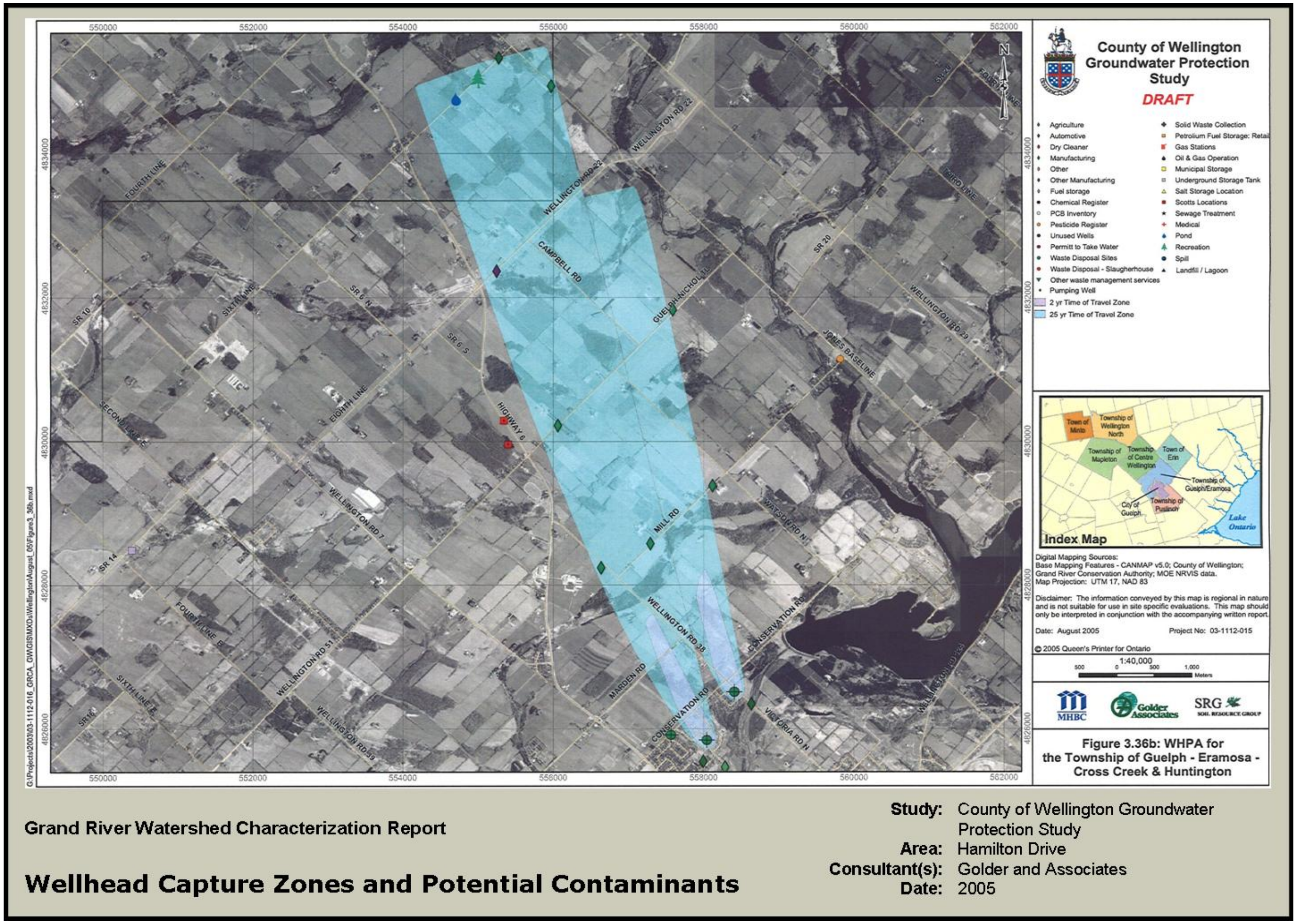
According the Drinking Water Systems Annual Report for Rockwood, fluoride concentrations exceeded the MAC of 1.5 mg/L once during the year of 2005. For the Hamilton Drive system, one occurrence of a total coliform count of 1 cfu/100ml was reported during 2005.

Description of Capture Zones

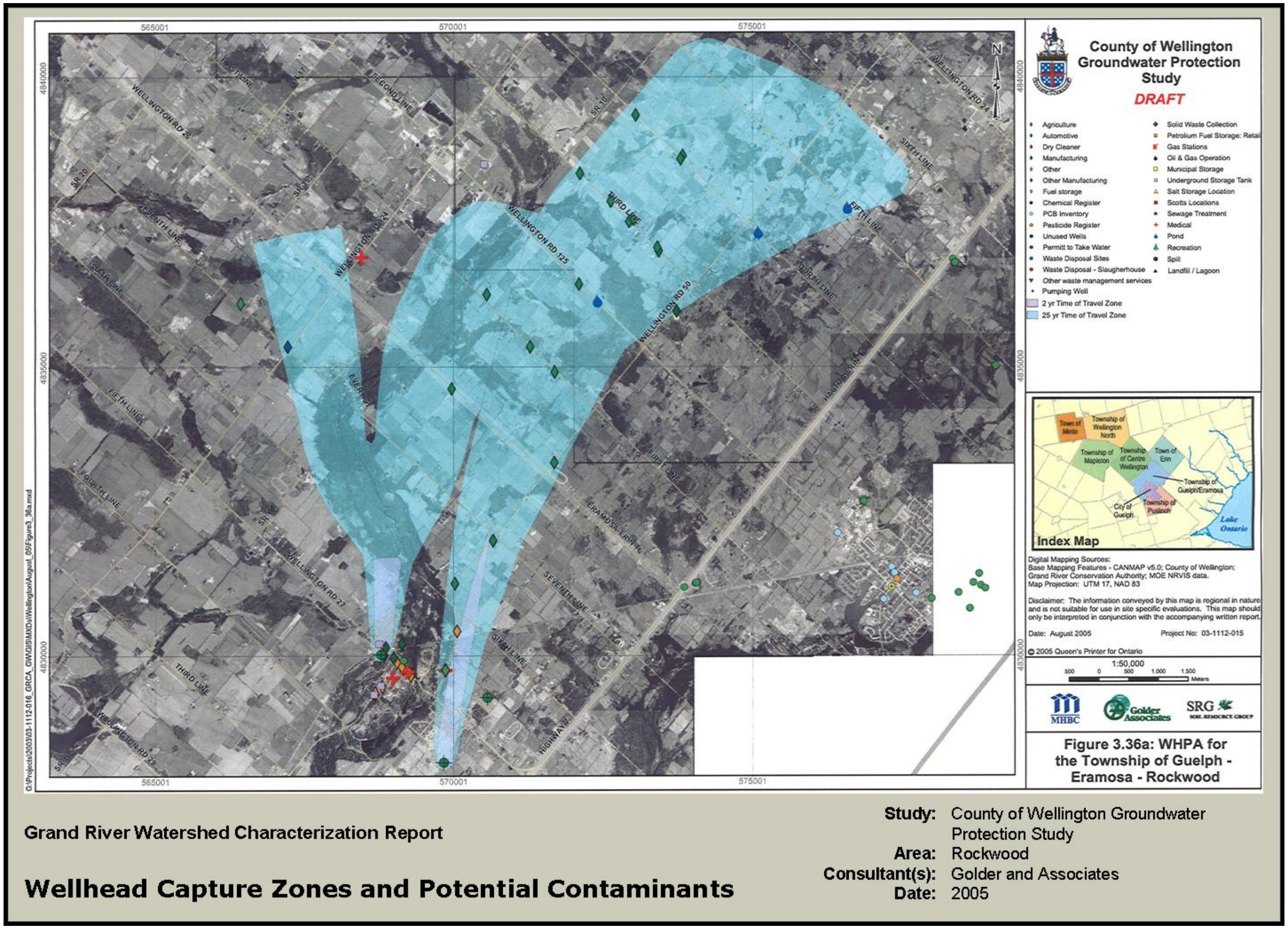
As shown on **Map 6.20**, the Hamilton Drive capture zones for the Cross Creek and Huntington Estates wells have 25-year capture zones that extend to the north-west-north for about 9 km over mainly agricultural lands. The well shown to the west of these wells with no capture zones is the Blue Forest well which has been abandoned.

The 25-year capture zones for the Rockwood wells merge together and extend approximately 13.5 km to the north and northeast in the upgradient direction of regional groundwater flow in the bedrock. This is illustrated on **Map 6.21**. The land use overlying the 25-year capture zones is almost entirely rural agricultural, although a portion of the urban area of Rockwood overlies the WHPA. Well TW2/02 does not have a capture zone, as it is no longer in use.

Map 6.20: Wellhead Capture Zones and Potential Contaminants On Hamilton Drive, Guelph



Map 6.21: Wellhead Capture Zones and Potential Contaminants in Rockwood



Vulnerable Areas Within the 25-year Capture Zone

Large portions of the Township, as shown on **Map 6.22**, have been mapped as WHPAs 2 and 3. This has resulted from the extension of the City of Guelph's capture zones into the Township. The 2-year Rockwood capture zones, located near the eastern boundary of the Township, and the Hamilton Drive 2-year capture zones, located to the west of Guelph Lake, have been mapped as a combination of WHPA 1 and 2 designations. This has resulted from areas of high (WHPA 1) and medium (WHPA 2) vulnerability being located within the 2-year capture zone.

Threats Within the 25-year Capture Zone

Mapped threat inventories for the Hamilton Drive and Rockwood areas are shown on **Map 6.20** and **Map 6.21**(Golder Associates, 2005). No threats have been located within the 2-year capture zones for the Hamilton Drive wells. Within the 25-year capture zone the overall land use is primarily rural and potential threats are related to agricultural operations.

Within the 2-year capture zones for the Rockwood wells, potential contaminant sources identified include underground storage tanks and manufacturing facilities. Outside the 2-year capture zones, potential threats are generally related to agricultural operations. In September of 2006 staff from the GRCA met with Township staff to discuss high level threats to the municipal groundwater supply as summarized in **Table 6.8**.

Summary

Within the Township of Guelph-Eramosa, two groundwater-based communities, Hamilton Drive and Rockwood, rely upon municipal water supplies. The majority of threats in Rockwood are related to urban land use activities (growth, decommissioning of old septic systems and wells, underground tanks), however there are rural land use concerns around Hamilton Drive and Rockwood about possible impacts from adjacent agricultural activities. The Township has identified the need to expand its long term water supply in Rockwood due to growth projections but is limited due to its wastewater treatment agreement with the City of Guelph. The Township and the County have conducted a number of groundwater studies to quantify existing supplies, develop new supplies and identify wellhead areas for protection.

Table 6.8: High Level Threats in Hamilton Drive and the Village of Rockwood

	Groundwater (Rockwood)	Groundwater (Hamilton Dr.)
Direct Introduction		
Water treatment plant wastewater discharge	none	none
Sewage treatment plant effluent	Wet well pumped to Guelph	Residential septic systems
Sewage treatment plant by-passes	none	none
Industrial effluents	No large industries	none
Landscape Activities		
Road salt application	MTO, County and Township apply pickled sand. The County uses brine solutions on some roads. County roads yards are 5km NE of Hamilton Dr. and 20km N of Rockwood.	
De-icing activities		
Snow storage		
Cemeteries	One active cemetery	none
Stormwater management systems	Two major wet ponds in new subdivisions	none
Landfills	County landfills and transfer sites well outside WHPA's	
Organic soil-conditioning	none	

Table 6.8: High Level Threats in Hamilton Drive and the Village of Rockwood

	Groundwater (Rockwood)	Groundwater (Hamilton Dr.)
Septage application	Applications being phased out	
Hazardous waste disposal	none	
Liquid industrial waste	Tannery in Erin Twp. at upper limit of WHPA	none
Mine tailings	none	
Biosolids application	County keeps records of permitted application sites	
Manure application	Settlement areas are surrounded by agricultural activities (primarily cash crops) requiring nutrient and pesticide applications	
Fertilizer application		
Pesticide / herbicide application		
Historical activities – contaminated lands	Former mill and candy factory	none
Storage of Potential Contaminants		
Fuels / hydrocarbons	One existing gas station (one more in for site plan review)	Strictly residential land uses
DNAPL's (dense non-aqueous phase liquids)	none	
Organic solvents		
Pesticides (of concern to drinking water)		
Fertilizers		
Manure		

6.3.1.4 County of Perth

Within the portion of the County of Perth situated within the boundary of the Grand River watershed, only one community, Milverton, is serviced by a municipal well system.

Township of Perth East (Milverton)

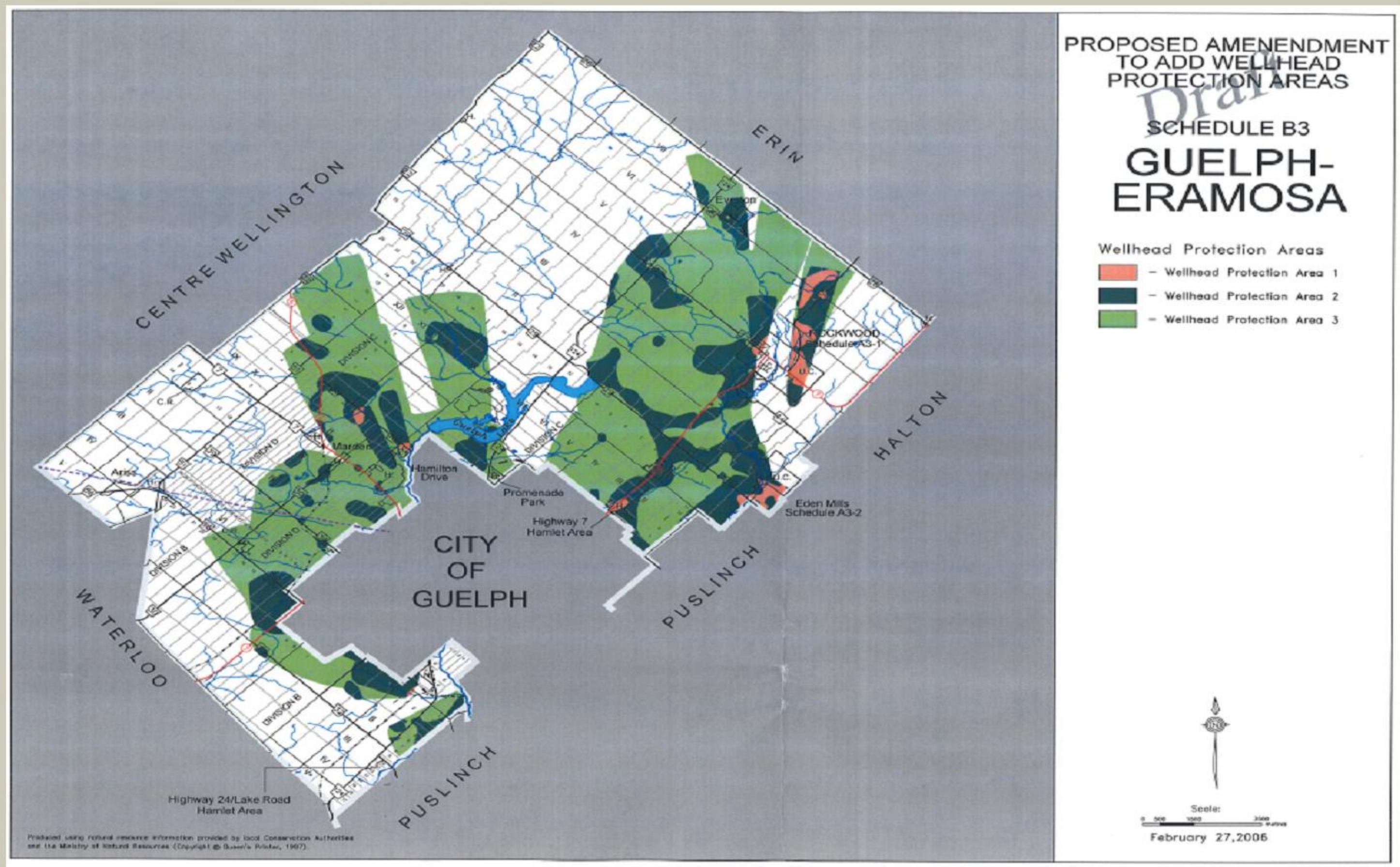
System Description

Milverton, located in the Township of Perth-East, had an estimated serviced population of 1,740 people in 2004 (Milverton 2004 Annual Drinking Systems Report). The drinking water system for the community consists of 3 wells with 3 associated pumphouses and an underground reservoir. Two of the wells which supply the community are completed in bedrock: Well 4, drilled in 1962 and Well 5, drilled in 1965. Both wells are screened in the Amherstburg Formation where Well 4 is 48 m deep and Well 5 is 46 m deep. Well 6, a 66.4 m deep well, was also brought on-line in June, 2004. Raw water is treated with sodium silicate for iron removal and sodium hypochlorite for disinfection. The surficial Quaternary geology surrounding Milverton is predominantly Elma Till, a silty to sandy till unit, and lacustrine clay.

Municipal Water Quality

No exceedances were reported in the Drinking Water Systems Regulations 2004 Annual Report for Milverton.

Map 6.22: Proposed Wellhead Protection Areas in the Township of Guelph-Eramosa

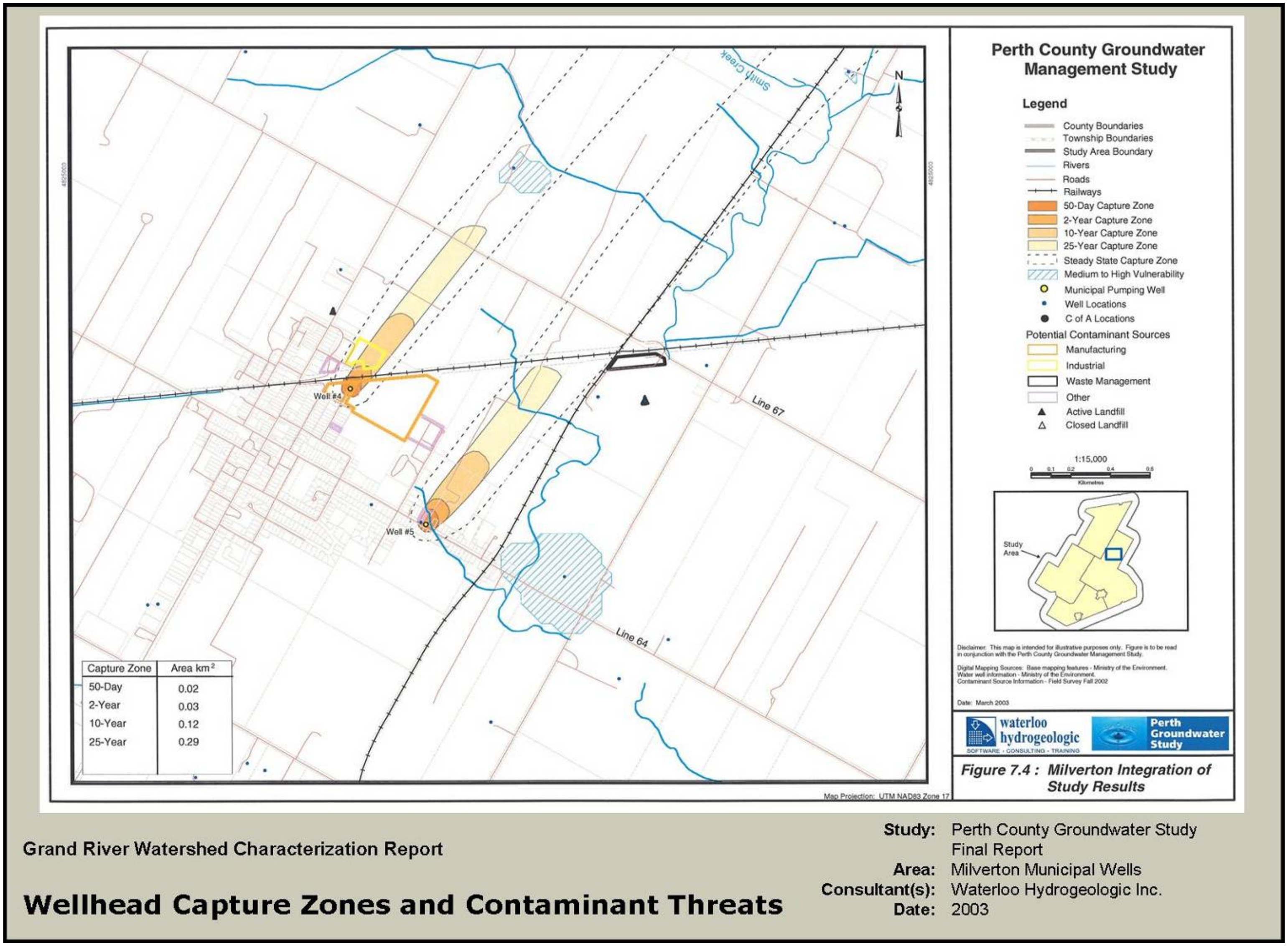


Grand River Watershed Characterization Report

Proposed Wellhead Protection Areas

Study: County of Wellington Groundwater Protection Study, Draft Report
Area: Township of Guelph-Eramosa
Consultant(s): Golder Associates
Date: 2005

Map 6.23: Wellhead Capture Zones and Contaminants Threats in Milverton



Description of Capture Zones

The Perth County Groundwater Study (Waterloo Hydrogeologic, 2003b) used MODFLOW to develop capture zones for municipal wells within the County. For Milverton, 50-day, 2-, 10-, and 25-year time of travel capture zones were modelled using backward particle tracking in MODPATH. The pumping rates used for capture zone delineation were determined by scaling the current pumping rates with the expected growth in the serviced population over the next 15 years.

Uncertainty analysis in the modelled capture zones was performed by using a range of "high" and "low" parameters for hydraulic conductivity, recharge rate, porosity values, and boundary conditions. The ranges used were considered to represent plausible conditions.

The capture zones, as presented on **Map 6.23**, for Wells 4 and 5 are narrow, linear, and short, extending about 1 km to the northeast. Steady-state capture zones are also shown, which extend about 6 km to the north-east, curving noticeably towards the east. A new well (Well 6) was to be brought on-line as of June, 2004 (Ontario Drinking Water Systems Report for Milverton, 2004). It is unknown at the time of this report whether a capture zone has been developed for this new well.

Vulnerable Areas Within the 25-year Capture Zone

Areas of medium to high vulnerability for the bedrock aquifer are shown superimposed over Milverton's capture zones on **Map 6.23**. One vulnerable zone is located within Well 4's steady state capture zone, and a second vulnerable zone is located to the southeast of Well 5. A study is currently underway to update the vulnerability of the municipal supply wells.

Threats within the 25-year Capture Zone

Inventoried potential contaminant sources within the vicinity of Milverton's municipal wells are shown on **Map 6.23** (Waterloo Hydrogeologic Inc., 2003b). Two manufacturing facilities are located within Well 4's 50-day capture zone, an industrial site is located within Well 4's 10-year capture zone and an active landfill is located to the northwest of Well 4's capture zones. A second active landfill is located to the northeast of Well 5's capture zones. A study to complete the inventory of potential threats within the capture zones is currently underway. In September of 2006, staff from the GRCA met with Perth East staff to discuss high level threats to the municipal groundwater supply as summarized in **Table 6.9**.

Table 6.9: High Level Threats in the Village of Milverton

	Groundwater
Direct Introduction	
Water treatment plant wastewater discharge	none
Sewage treatment plant effluent	Lagoon system with outlet to Upper Thames tributary
Sewage treatment plant by-passes	none
Industrial effluents	Several industrial sites located in Well #4 WHPA
Landscape Activities	
Road salt application	Township applies pickled sand in village Sand stored at County yard in North Easthope
De-icing activities	County operations
Snow storage	Some snow stored at PW building on Mill Street
Cemeteries	One just east of Well #5
Stormwater management systems	none

Table 6.9: High Level Threats in the Village of Milverton

	Groundwater
Landfills	County landfill is in Ellis Township outside WHPA
Organic soil-conditioning	none
Septage application	Not accepted in Perth East
Hazardous waste disposal	Municipality has a contracted HHW event once in 3yrs
Liquid industrial waste	none
Mine tailings	none
Biosolids application	Lagoons cleaned once in 5 years
Manure application	Normal agricultural practices used for nutrient and pesticides Farms produce cash crops and livestock (horses)
Fertilizer application	
Pesticide / herbicide application	
Historical activities – contaminated lands	none
Storage of Potential Contaminants	
Fuels / hydrocarbons	Village has a Co-op
DNAPL's (dense non-aqueous phase liquids)	Several industrial sites located in Well #4 WHPA
Organic solvents	
Pesticides (of concern to drinking water)	Co-op supplies agricultural pesticides and fertilizers
Fertilizers	
Manure	Farm specific storage (check individual nutrient management plans)

Summary

Within the portion of the Perth County situated within the boundary of the Grand River watershed, only one community, Milverton, is serviced by a municipal well system. The Village of Milverton, in the Township of Perth East, is groundwater dependant. While the village straddles the Grand/Upper Thames watershed divide, the ground water is sourced from the Upper Nith watershed. Groundwater susceptibility to contamination has been mapped as primarily low vulnerability with zones of higher vulnerability just outside the 25-year capture zone. The primary threats are related to urban land use activities (industry and fuel storage) as well as rural land use activities (agricultural farming practices) surrounding the village. The Township of Perth East has completed a water supply Class EA that should address future growth projections in the village. The County has also conducted a groundwater study to identify aquifer susceptibility, preliminary threats and areas for wellhead protection and is currently assessing threats and updating the vulnerability of the municipal supply wells.

6.3.1.5 City of Guelph

The City of Guelph and Township of Puslinch have recently completed the Guelph-Puslinch Groundwater Protection Study (Golder Associates, 2006). Components of this study included the development of a regional FEFLOW groundwater flow model, vulnerability mapping for the four identified aquifers in the area, and a potential contaminant sources inventory.

A second study funded through the MOE under source water protection is currently underway to update the City's capture zones using the FEFLOW groundwater model developed by Golder Associates (2006). The model will be modified by increasing existing municipal extractions, in addition to the inclusion of additional municipal supply wells, as per the City of Guelph Master Water Supply Plan. Other components of this study include:

- Assigning vulnerability scoring to the City's 25-year WHPAs,
- Completing surface to well advection times (SWAT) estimates for the City's wells,
- Identifying and inventorying threats in vulnerable areas around each municipal supply well and providing a hazard rating for each threat,
- Completing an issues evaluation based on a review of water quality data and specific land use, and,
- Completing a preferential pathways study.

Guelph and Gazer-Mooney Subdivision

System Description and Hydrogeologic Setting

In 2002, the population serviced by the City of Guelph water supply system was estimated to be 125,416 people (Bellamy and Boyd, 2005), with nearly 100% of the population supplied by the municipal water supply system. The source of the City's drinking water supply is from 23 groundwater wells (19 wells in service) and a shallow groundwater collector system. **Table 6.10** summarizes the City's wells and treatment facilities. The City's water supply and distribution system is comprised of 6 km of water supply aqueduct, 5 underground storage reservoirs, 3 water towers and a distribution system (City of Guelph Provincial Regulation 170/03, Annual Report, 2004).

Table 6.10: Summary of the City of Guelph's Wells and Treatment Facilities

Wellfield Name	Description	Disinfection
Arkell Artificial Recharge System	-surface water -consists of infiltration basin and trenches	-disinfection at F.M. Woods
Arkell Springs	-GUDI with effective insitu filtration -consists of a series of small diameter collector pipes capturing shallow groundwater and discharging to F.M. Woods Station via an aqueduct	-disinfection at F.M. Woods
Arkell Wellfield	Well 1 (Well PW1/66) – GUDI with effective insitu filtration -300 mm diameter, 14.2 m deep groundwater production well located in the Arkell Spring Grounds and discharging to F.M. Woods Station via an aqueduct	-disinfection at F.M. Woods
	Well 6 (Well PW6/63) -300 mm diameter, 44.2 m deep groundwater production well located in the Arkell Spring Grounds and discharging to F.M. Woods Station via an aqueduct	
	Well 7 (Well PW7/63) -300 mm diameter, 43.8 m deep groundwater production well located in the Arkell Spring Grounds and discharging to F.M. Woods Station via an aqueduct	
	Well 8 (Well PW6/63) -300 mm diameter, 42.1 m deep groundwater production well	

Table 6.10: Summary of the City of Guelph's Wells and Treatment Facilities

Wellfield Name	Description	Disinfection
	located in the Arkell Spring Grounds and discharging to F.M. Woods Station via an aqueduct	
Burke Well	Burke Well (PW2/66) – 300 mm diameter, 78.9 m deep groundwater production well located at 164 Arkell Road in the City of Guelph -discharges to an on-site underground reservoir	-sodium hypochlorite
Calico Well	Calico Well (PW4/76) – a 305 mm diameter, 64.3 m deep groundwater production well located in the Township of Guelph-Eramosa -discharges to an on-site underground reservoir	-sodium hypochlorite
Carter Wellfield	Carter Well 1 – GUDI with effective insitu filtration -a 250 mm diameter, 20.1 m deep drilled groundwater production well -discharges to the Scout Camp valve chamber and discharging to F.M. Woods Station via an aqueduct	-disinfection at F.M. Woods
	Carter Well 2 – GUDI with effective insitu filtration -a 250 mm diameter, 20.7 m deep drilled groundwater production well -discharges to the Scout Camp valve chamber and discharging to F.M. Woods Station via an aqueduct	
Clythe Creek Booster Pumping Station	-consists of a 250 mm reservoir fill line from the distribution system and an underground reservoir with a storage volume of 672 m^3 -the pumphouse is located above the reservoir which houses the well pump and 2 vertical turbine high lift pumps	-sodium hypochlorite
Dean Ave Well	Dean Ave Well (PW1/58) – 330 mm diameter, 57.2 m deep drilled groundwater production well located at 103 Dean Avenue in the City of Guelph -discharges to an on-site underground reservoir	-sodium hypochlorite
Downey Well	Downey Well (PW5/67) – a 300 mm diameter, 73.8 m deep drilled groundwater production well located at 28 Downey Road in the City of Guelph -discharges to an on-site underground reservoir	-sodium hypochlorite
Emma Well	Emma Well (PW1/31) – a 457 mm diameter, 47.2 m deep drilled groundwater production well located at 93 Emma Street in the City of Guelph	–one ultraviolet disinfection unit and a sodium hypochlorite disinfection system
F.M. Woods Pumping Station and Reservoir	– receives raw water from 5 systems: Arkell well field, Arkell spring collector system, the Arkell artificial recharge system and the Carter well field -located at 29 Waterworks Place in the City of Guelph -houses treatment, storage and control facilities which includes 3 underground reservoirs, 5 high lift, vertical turbine pumps, 1 low lift pump, and a sodium hypochlorite disinfection system	-sodium hypochlorite
Helmar Well	Helmar Well (PW6/66) – a 305 mm diameter, 77.7 m deep drilled groundwater production well located at 673 Woodlawn Road in the City of Guelph -discharges to an on-site underground reservoir	-sodium hypochlorite and sodium silicate

Table 6.10: Summary of the City of Guelph's Wells and Treatment Facilities

Wellfield Name	Description	Disinfection
Membro Well	Membro Well (PW1/53) – a 200 mm diameter, 75 m deep drilled groundwater production well located at 290 Water Street in the City of Guelph -discharges to an on-site underground reservoir	-sodium hypochlorite
Paisley Well	Paisley Well (PW4/59) – a 305 mm diameter, 71.9 m deep drilled groundwater production well located at 810 Paisley Road in the City of Guelph - discharges to an on-site underground reservoir	-sodium hypochlorite
Park Wellfield	Park Well #1 – a 508 mm diameter, 56.3 m deep drilled well Park Well #2 – a 508 mm diameter, 57.9 m deep drilled well	-sodium hypochlorite
Queensdale Well	Queensdale Well (PW1/70) – a 305 mm diameter, 64 m drilled groundwater production well located at 69 Queensdale Crescent in the City of Guelph - discharges to an on-site underground reservoir	-sodium hypochlorite and sodium silicate
Robertson Booster Pumping Station	– 3 centrifugal in-line booster pumps	-sodium hypochlorite
University of Guelph Well	UoG Well (PW1/73) – a 305 mm diameter, 64 m deep drilled well located at 420 Edinburgh Road in the City of Guelph - discharges to an on-site underground reservoir	-sodium hypochlorite
Water St Well	Water St Well (PW3/53) – a 305 mm diameter, 64 m deep drilled well located at 200 Water Street in the City of Guelph	-sodium hypochlorite
Gazer Mooney Subdivision Distribution System	-serves 76 homes and approximately 200 residents in Guelph-Eramosa Township -the distribution system is a part of the City of Guelph's water supply -the average water flow rate is approximately 90 L/min -the peak flow rate is approximately 372 L/min	- disinfection at Guelph well supply point

The wells that supply the City's water are completed within both overburden sediments (1 well), and the underlying Guelph and/or Amabel Formations (22 wells). At Arkell, which is located just outside the City, the groundwater supply is supplemented by an artificial recharge system.

Municipal Water Quality

The City of Guelph summarized adverse water quality results in the Provincial Regulation 170/03 Annual and Summary Report for the period January 1 to December 2005 (City of Guelph, 2006). These results, as summarized in the report, as presented below in **Table 6.11**. In all cases, resampling did not confirm the initial adverse test result.

Description of Capture Zones

Thirteen municipal pumping wells are located within the City of Guelph's boundaries, however, the City uses an additional well just outside the north-west city limits in the Township of Guelph-Eramosa and six wells within the Township of Puslinch. The Glen Collector System is comprised of a series of lateral collector pipes installed in the overburden below the groundwater table. These pipes drain via gravity to the original aqueduct that follows the Eramosa River to the Woods Pumping Station (Golder, 2006a).

The Guelph – Puslinch Groundwater Protection Study (Golder, 2006a) used a regional FEFLOW model to delineate capture zones for wells within the City of Guelph and the Township of Puslinch (previously discussed). Within the City of Guelph, base case pumping rates used to delineate the capture zones were derived from annual average pumping rates based on 2002 data (Golder, 2006a). The uncertainty in capture zone delineation was addressed by the use of 2 correction factors; an expansion of the capture zone by 5 degrees from the centerline and an increase of 20% from the centerline of the capture zone. **Map 6.24** shows the capture zones for the City of Guelph's supply wells.

Table 6.11: Summary of adverse test results and corrective actions for the City of Guelph's water supply system

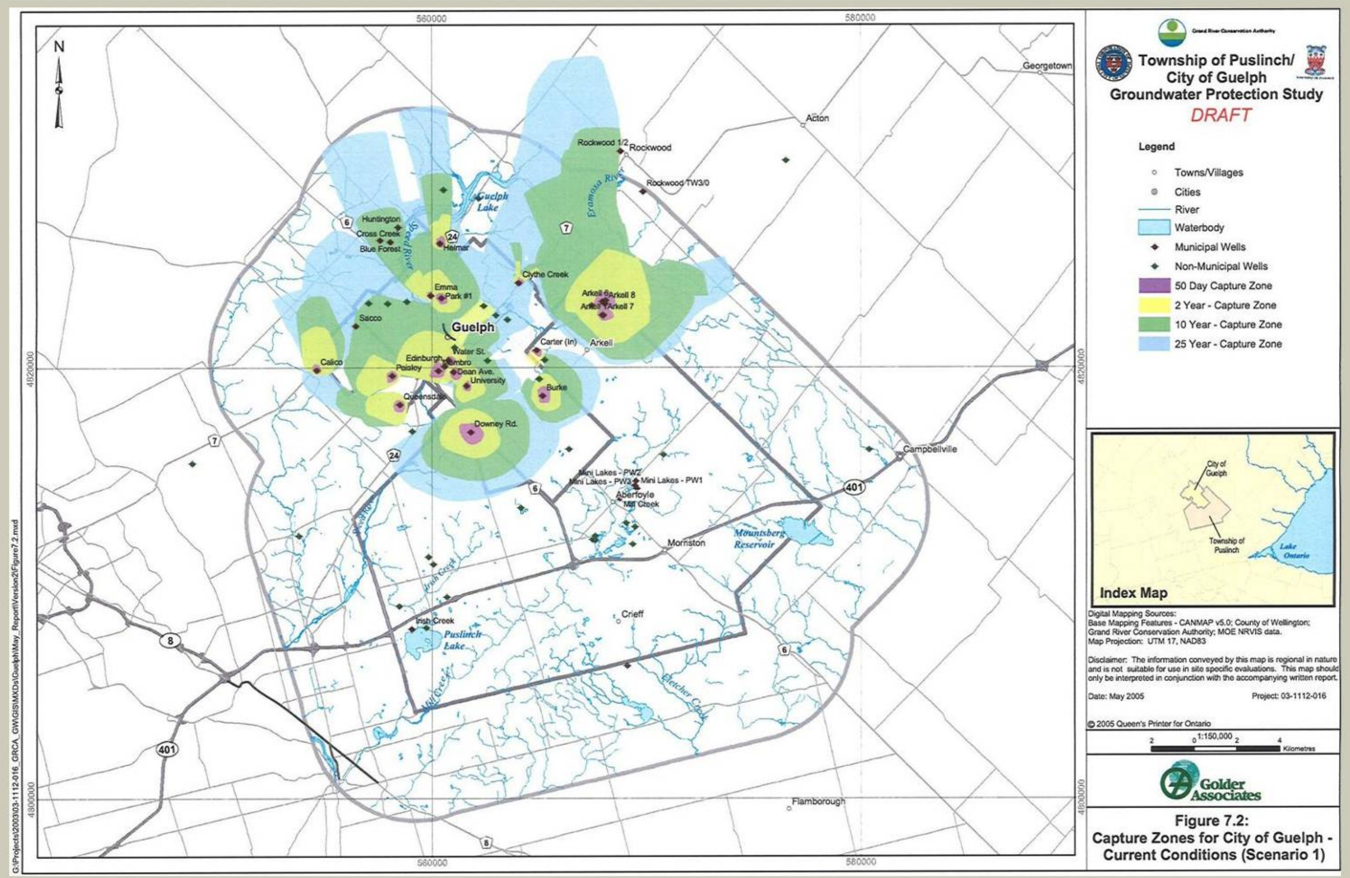
Date	Location	Description	Corrective Action	Resample Results Good
Feb 1	Queensdale	Sodium above 20mg/l (Max ODWS = 20 mg/L)	Health Unit and MOE notified - Resampled	Yes
April 27	Eramosa 7/11	Background >200cfu/100ml (Max ODWS =200cfu/200ml)	Health Unit and MOE notified - Resampled	Yes
June 3	Gordon Lift Station	Background >200cfu/100ml (Max ODWS =200cfu/200ml)	Health Unit and MOE notified - Resampled	Yes
July 14	West End Rec. Centre	Background >200cfu/100ml (Max ODWS =200cfu/200ml)	Health Unit and MOE notified - Resampled	Yes
July 27	Guelph WWTP	Background >200cfu/100ml (Max ODWS =200cfu/200ml)	Health Unit and MOE notified - Resampled	Yes
Aug 24	Speedvale tower	3 Total Coliform (Max ODWS = 0 cfu)	Health Unit and MOE notified - Resampled	Yes
Aug 26	Marksam	Unsanitary Conditions – soil entry into watermain break	Health Unit and MOE notified - Flushed, disinfected, resampled	Yes

(City of Guelph, 2006)

Most of the City of Guelph is underlain by the capture zones of its supply wells. Approximately 28 percent of the total area of the City of Guelph is underlain by the 0 to 2 year capture zones, which increases to about 84 percent for the 0 to 25 year capture zones.

The capture zones for some of the municipal wells are located or extend beyond the City limits, into surrounding Townships (Guelph-Eramosa and Puslinch) and Halton Region. These capture zones are influenced by the presence of several larger scale private water takings within the City (Golder, 2006a). While these wells affect the initial capture zones developed around nearby municipal wells (e.g. Emma and Park wells), the impact on the final capture zones is counteracted somewhat by the uncertainty analysis.

Map 6.24: Wellhead Capture Zones in the City of Guelph and Puslinch Township



Grand River Watershed Characterization Report

Wellhead Capture Zones

Study: Guelph-Puslinch Groundwater Protection Study
Area: Guelph and Puslinch
Consultant(s): Golder Associates Ltd.
Date: 2005

Vulnerable Areas within the 25-year Capture Zone

Aquifer vulnerability mapping for the City of Guelph was completed as a component of the Guelph – Puslinch Groundwater Protection Study (Golder, 2006a). Vulnerability mapping was carried out using a modified version of the MOE's Groundwater Intrinsic Susceptibility Index (GwISI) outlined in the MOE Technical Terms of Reference (Land Use Policy Branch, 2001). Listed below are the key modifications to the aquifer vulnerability mapped determined as a part of this study;

- GwISI scores at individual wells classified each aquifer as overburden, bedrock or contact where the latter is defined as an aquifer within 2 m of the bedrock surface, whether in bedrock or overburden;

- Only wells encountering a specific aquifer were used in creating the maps;

- Vulnerability maps were completed for individual aquifers; the shallow overburden aquifer, intermediate to deep overburden aquifer, the Guelph Formation aquifer and the Amabel Formation aquifer;

- Zones of medium to high vulnerability were propagated upwards from the bedrock aquifer, through the intermediate aquifer, to the shallow overburden aquifer to ensure that zones of medium to high vulnerability mapped at depth were not mapped as low vulnerability in an overlying aquifer;

- For the shallow overburden aquifer map, areas mapped as surficial sands and gravels on the Quaternary geology map were classified as highly vulnerable regardless of vulnerability scores;

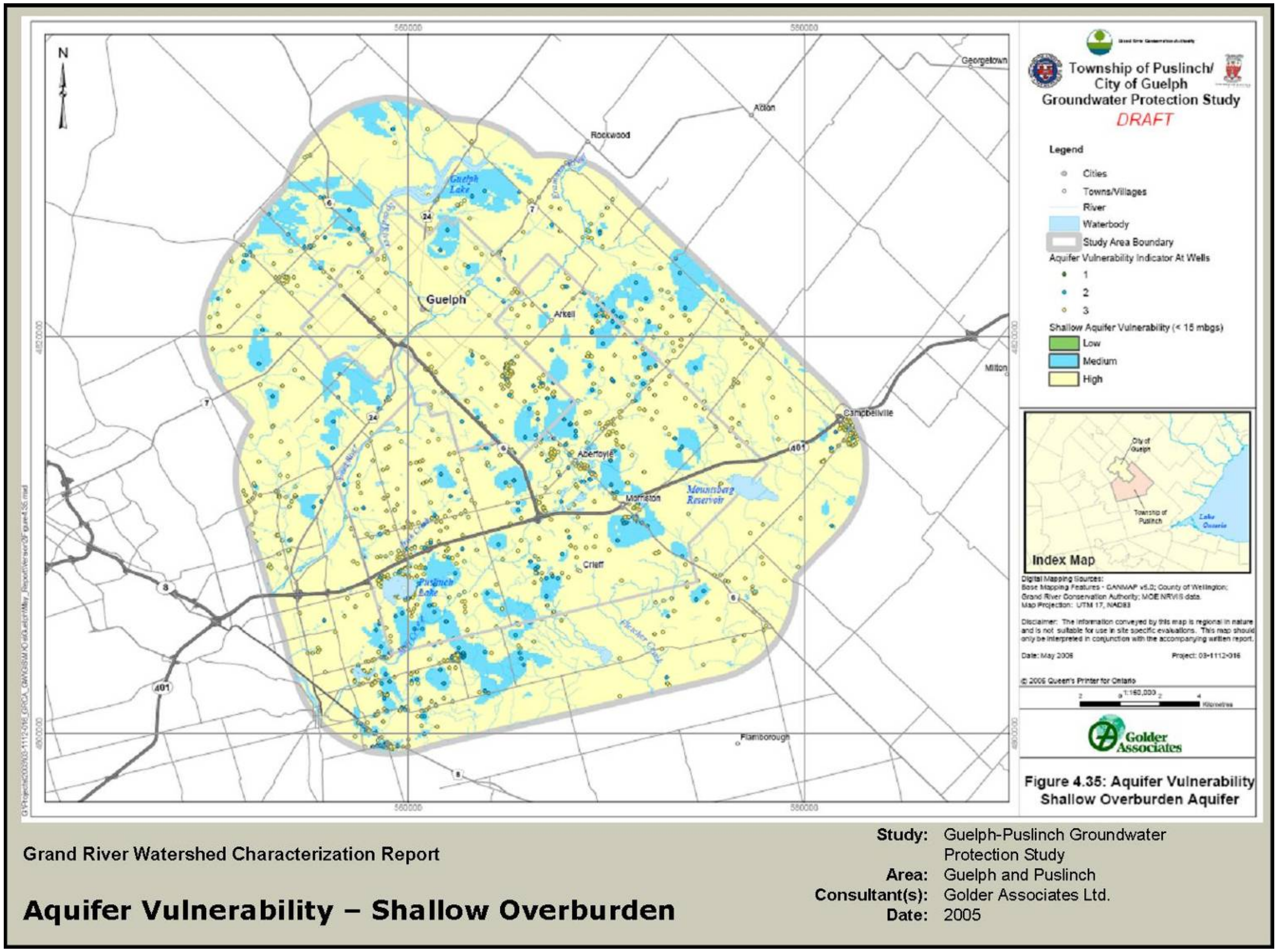
A low vulnerability score was assigned to areas where the Amabel Formation was overlain by both the Eramosa Member and the Guelph Formation.

The resulting maps, shown on **Map 6.25, Map 6.26, Map 6.27** and **Map 6.28** illustrate the vulnerability for the shallow overburden aquifer, deep overburden aquifer, Guelph Formation aquifer and Amabel Formation aquifer respectively.

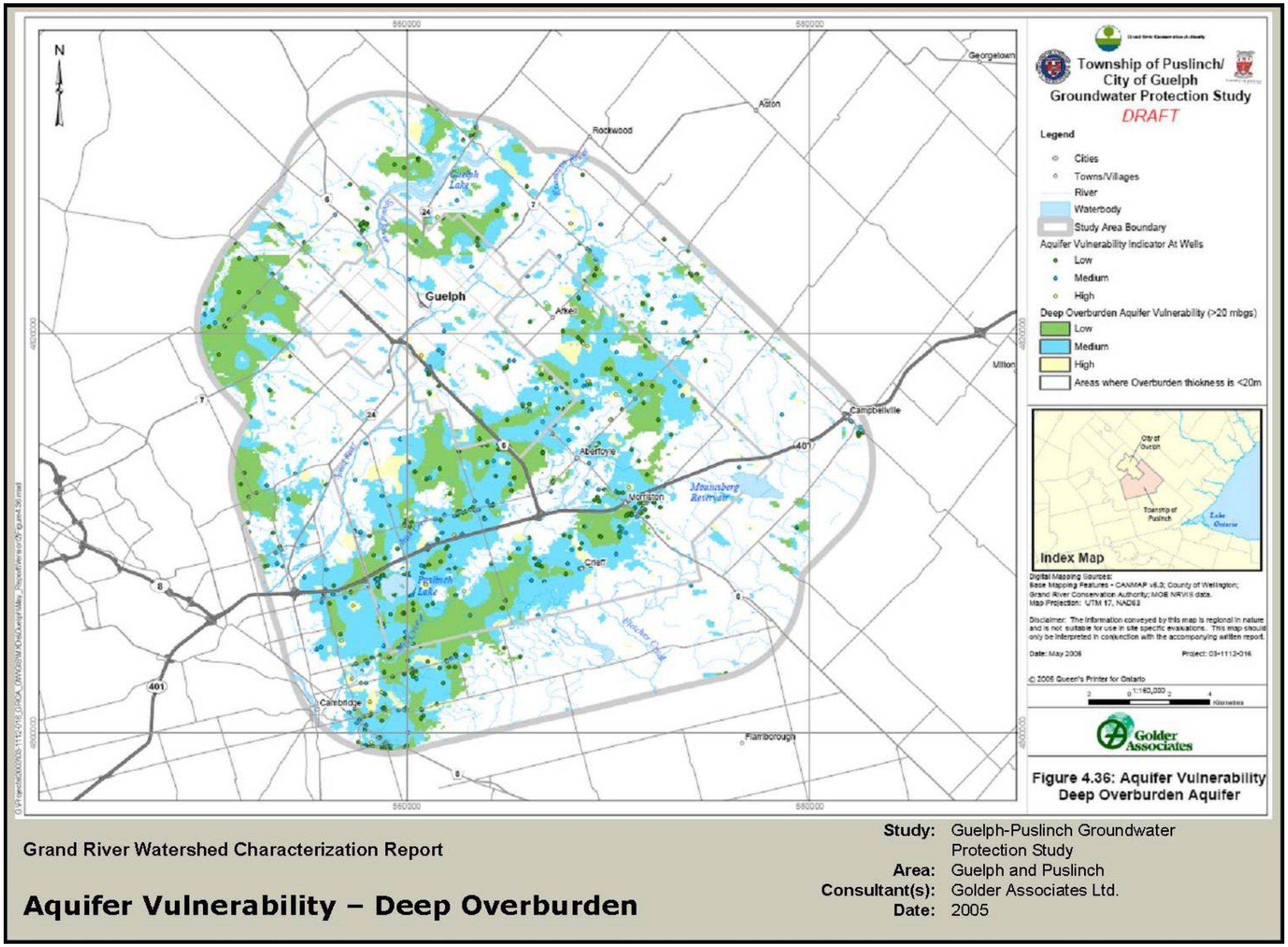
The shallow overburden aquifer was defined as an overburden or contact aquifer of at least 1 m thickness, encountered within 20 m of ground surface. The vulnerability for this aquifer (Map 60) is predominantly high, with a few areas of medium vulnerability along the trend of the Paris and Galt Moraines and in scattered areas north of the Speed River where the surficial deposits are mapped as till. The shallow overburden aquifer may be used for local domestic water supply through sandpoints or shallow dug wells, and also tends to play an important role in supplying baseflow to local streams and wetlands and water for shallow rooting vegetation.

The deeper overburden aquifer was defined as an overburden or contact aquifer of at least 1 m in thickness, encountered at more than 20 m below ground surface. This aquifer exists only in those areas where the total overburden thickness is at least 20 m, and as such is restricted to the Paris and Galt moraines, and areas of thick overburden in the northern portion of the study area. The vulnerability of the deeper overburden aquifer (**Map 6.26**) is predominantly medium to low, with only limited areas of high vulnerability along the north side of the Paris moraine.

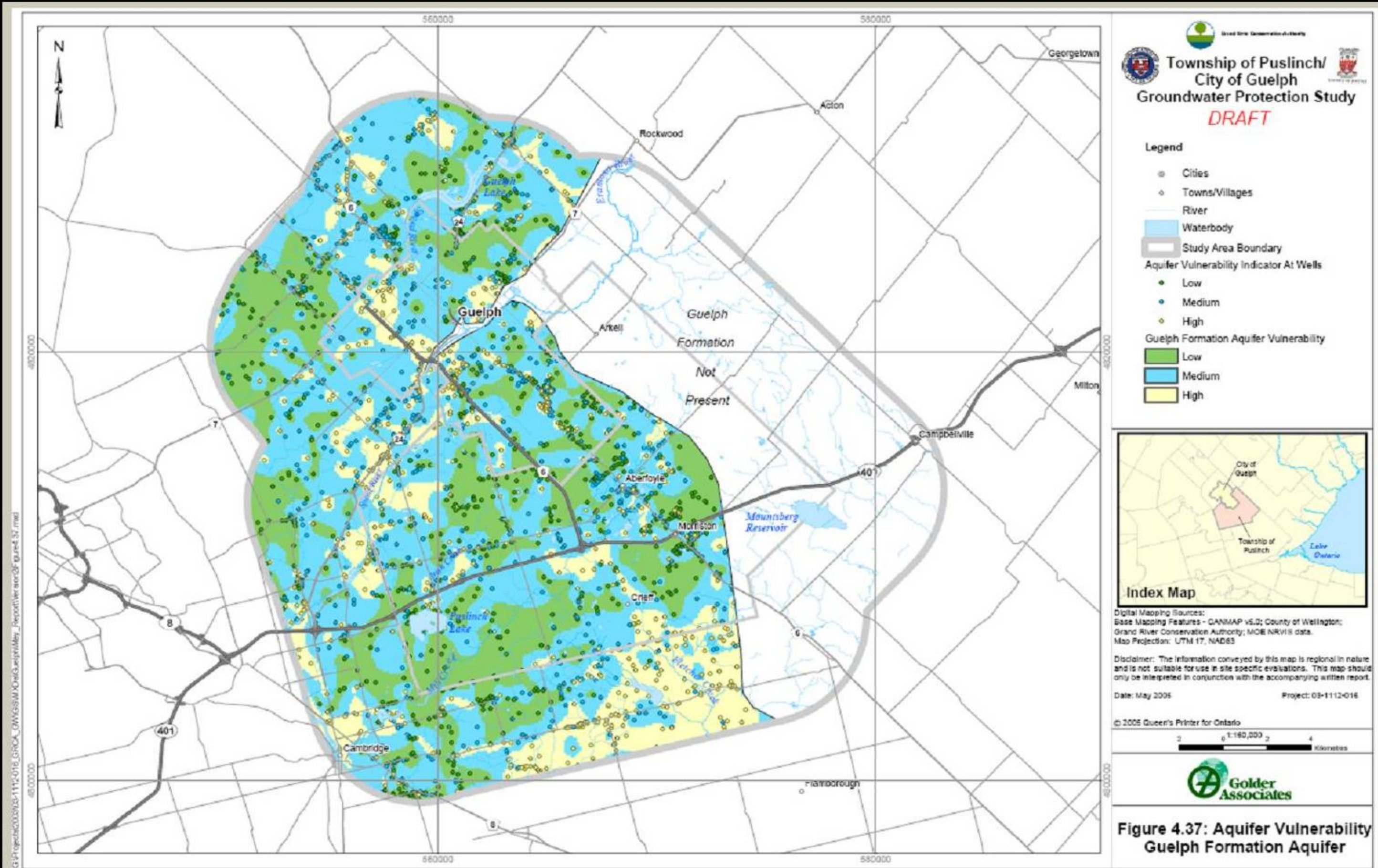
Map 6.25: Shallow Overburden Aquifer Vulnerability, Guelph and Puslinch



Map 6.26: Deep Overburden Aquifer Vulnerability, Guelph and Puslinch



Map 6.27: Guelph Formation Aquifer Vulnerability, Guelph and Puslinch

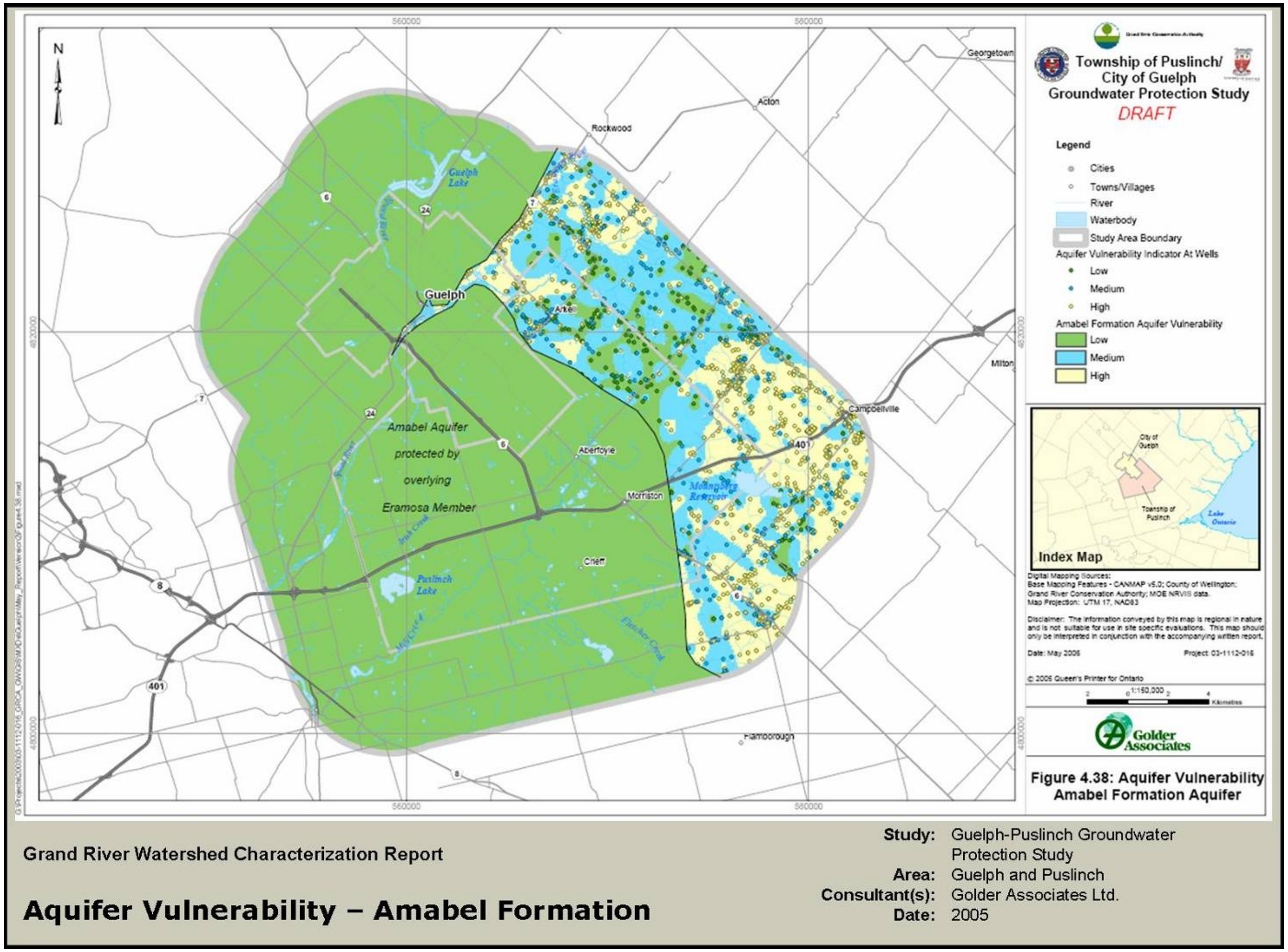


Grand River Watershed Characterization Report

Aquifer Vulnerability – Guelph Formation

Study: Guelph-Puslinch Groundwater Protection Study
Area: Guelph and Puslinch
Consultant(s): Golder Associates Ltd.
Date: 2005

Map 6.28: Amabel Formation Aquifer Vulnerability, Guelph and Puslinch



The Guelph Formation aquifer vulnerability was determined from the vulnerability scores for the bedrock and contact aquifers within the mapped area of the formation. The vulnerability of the Guelph Formation aquifer (**Map 6.27**) is generally low or medium, except in areas of thin overburden along the Speed and Eramosa Rivers and on the Flamborough Plain.

The Amabel Formation aquifer vulnerability was determined from the vulnerability scores for bedrock and contact aquifers within the mapped subcrop/outcrop area of the formation. The vulnerability of the Amabel Formation aquifer (**Map 6.28**) is generally low or medium, except in areas of thin overburden along the Speed and Eramosa Rivers and on the Flamborough Plain.

Threats within the 25-year Capture Zone

A potential contaminant sources inventory was completed as a component of the Guelph-Puslinch Groundwater Protection Study (Golder Associates, 2006a) using a variety of public and commercial datasets. Results of the inventory within the City of Guelph are shown on **Map 6.29.** For the purpose of explaining the relative threats to the Guelph water supply system, the municipality has been divided into four water supply quadrants (NE, NW, SW & SE). The following initial threats assessments have been compiled from a desk top review of groundwater reports and a staff interview in June of 2006. The Threats Inventory will be updated as part of an ongoing MOE-funded source protection study.

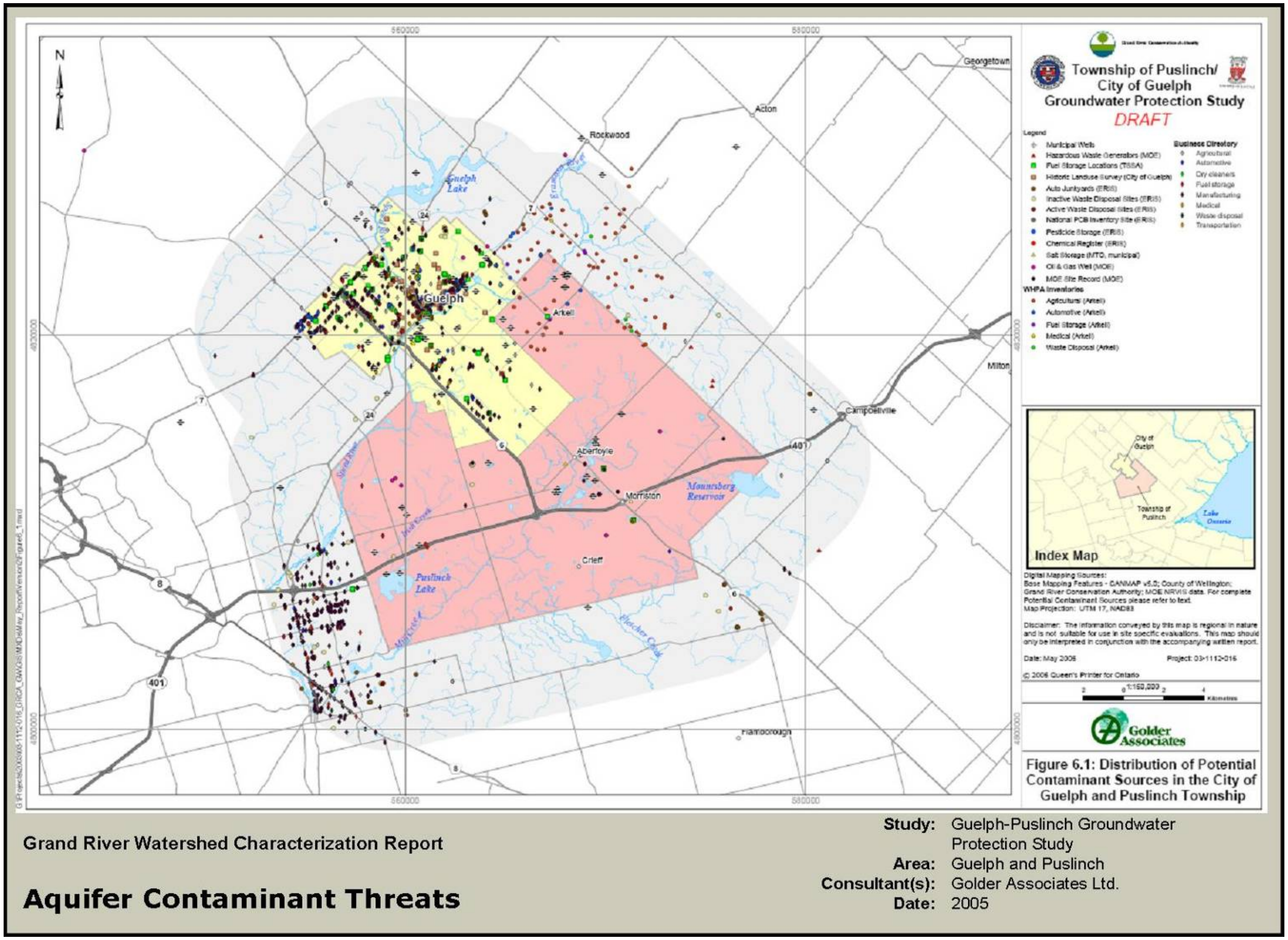
Northeast Quadrant (north of the Eramosa River and east of the Speed River)
Park (1&2), Emma Street, Helmar & Clythe Creek Wells

The northeast quadrant is the site of 5 wells accounting for about 25% of the city's groundwater supply, approximately 3/4 of which comes from the Park and Emma wells. While the Clythe Creek well is currently inactive due to natural water quality issues, the remaining wells, situated in residential neighbourhoods, are fully functioning. The quadrant is characterized as predominantly residential, however the older sections have a history of industrial activity, much of which still remains or is establishing adjacent to the Speed and Eramosa Rivers accounting for about 25% of known manufacturing and fuel storage sites. Land uses directly to the east of the city are predominantly agricultural. The quadrant is also the site of the city's main hospital, municipal waste transfer and recycling facility, former landfill (closed in 2003), a number of historic waste disposal sites, several dry cleaning establishments and a number of automotive businesses. A variety of brownfield sites exist that have been the subject of ongoing cleanup activities to address spills, chemical and fuel storage and foundry waste.

Northwest Quadrant (north and west of the Speed River)
Paisley Road, Queensdale, Smallfield, Sacco & Calico Wells

The northwest quadrant, while the site of 5 wells, is the source for only about 5% of the city's groundwater supply. While some wells are currently inactive due to man-made water quality issues, two active wells are situated within residential land uses and one is located just outside the City boundary in a rural/agricultural setting. The quadrant includes a large proportion of the city's industrial and commercial land use inventory, accounting for about 60-65% of known manufacturing and fuel storage sites. The quadrant is also the location for the majority of Guelph's dry cleaners, automotive sales outlets and medical institutions and clinics. A number of brownfield sites exist within the quadrant many of which are undergoing cleanups of spills, VOCs, PRCs, coal tar, metals, chlorides and PCBs. Other potential threats in the quadrant include a waste transfer facility and a number of inactive waste disposal sites.

Map 6.29: Aquifer Contaminant Threats, Guelph and Puslinch



Southwest Quadrant (south of the Speed River and west of Gordon Street)
Dean Avenue, Downey Road, Edinburgh, Water Street, Membro & University of Guelph Wells

The southwest quadrant is the site of 6 wells accounting for about 15% of the city's groundwater supply, approximately 2/3 of which comes from the Downey well in the Kortright subdivision. One well is currently inactive due to water quality issues, although some work is being done to site a new water supply source in the quadrant. The quadrant is characterized as a relatively new mix of residential, institutional, industrial, commercial and open space land use in the rapidly expanding south. Residential subdivisions in the south end of Guelph have been developed using a wide range of stormwater management retention and recharge facilities to enhance runoff quality and groundwater recharge. Significant expansions are underway to the Techno Business Park adjacent to the University of Guelph and the Hanlon Business Park adjacent to the Hanlon Parkway, accounting for about 15-20% of known manufacturing and fuel storage sites. The quadrant is also the site of the city's main Public Works yard and salt storage domes, the Hydro works yard, a hazardous waste disposal business, several dry cleaning establishments, a number of medical clinics and a historic quarrying operation with significant dewatering activity.

Southeast Quadrant (south of the Eramosa River and east of Gordon Street)
Arkell Springs (1, 6, 7, & 8), Scout Camp, Carter (1&2) & Burkes Wells

The southeast quadrant is the site of 7 wells and the source of about 55% of the city's groundwater supply, the majority of which comes from the Arkell Spring Grounds just outside the City boundary. The Spring Grounds are situated within about 350ha of undeveloped lands owned by the City. The remaining wells are situated within relatively undisturbed settings adjacent to natural heritage lands. The quadrant is characterized as a mix of residential, commercial, institutional, agricultural, recreational and open space land uses. Land uses directly to the east of the city are predominantly agricultural. Residential subdivisions in the south end of Guelph have been developed using a wide range of stormwater management retention and recharge facilities to enhance runoff quality and groundwater recharge. The quadrant is also the site of several automotive operations, fuel storage, fertilizer and pesticide handling sites.

Overall the City of Guelph has conducted a range of studies to ascertain the status of its ground water quantity and quality, and continues to work with a range of partners to identify issues and eliminate specific threats. Current issues relate to the source and quantity of contaminants (i.e. VOCs, nitrates, chlorides, etc.) that have forced the closure of some wells and the need to maintain close surveillance of all other water sources. However, while much has been identified already, some questions remain unanswered regarding threats at certain existing and historic land uses. The City will continue to work to collect data at the level of detail necessary to ensure protection of its groundwater supply.

Summary

The City of Guelph is predominantly groundwater dependant. Water supplies are augmented with Eramosa River recharge at the Arkell Spring Grounds. The majority of threats are related to urban land use activities (industry, higher population density, municipal winter operations, etc.), however there are rural land use issues with some wells. The City has identified the need to expand its long term water supply due to growth projections and potential loss of existing supplies to contamination or climate change impacts. The City has implemented programs to enhance surface recharge and to protect the quality of recharge through SWM best practices. The City has also conducted a wide range of groundwater studies to quantify existing supplies, develop new supplies and identify wellhead areas for protection.

6.3.1.6 Regional Municipality of Waterloo

The Regional Municipality of Waterloo (Region) operates a total of eighteen (18) municipal drinking water systems that serve a population of approximately 500,000. The Integrated Urban System (IUS) – a complex network of wells, reservoirs, pumping stations and trunk water mains – supplies water to people living in Cambridge, Kitchener, Waterloo, Elmira, and St. Jacobs. Seventeen (17) smaller water supply systems provide water to some settlement areas in the four townships. In all, groundwater is extracted from 115 wells throughout the Region and surface water is obtained from an intake at the Grand River (Hidden Valley Intake) in Kitchener. Together these sources of water supply approximately 260,000 cubic metres of water a day.

In 1993 the Region implemented a comprehensive Water Resources Protection Strategy (WRPS) to minimize the risk of historic, existing and future land uses on municipal water supplies. The cornerstone of the WRPS was the delineation of Wellhead Protection Areas (WHPAs) for the Region's groundwater drinking water systems. This involved a multiple-component process, including 2D analytical and 3D numerical groundwater flow modeling. Sensitivities were assigned to WHPAs based on the relative sensitivity of the wells to activities on the surface. In 2000, the WHPAs were incorporated in the Regional Official Policies Plan (ROPP).

The Region has also developed a Threats Inventory Database (TID) which is a collection of information on land-use activities that have potential to affect the quality of surface and groundwater in the Region (RMOW, 2006). The TID includes information on past and present industries, landfills, chemical and fuel storage sites, and other urban land use activities throughout the Region of Waterloo, all ranked according to the level of potential threat each poses to the surface and groundwater. A threat is defined as a past, present or future (proposed) activity or condition that is impacting or has the potential to impact a drinking water source.

The Region in partnership with the GRCA has implemented programs to protect water quality such as the Business and Rural Water Quality Programs. These programs provide incentives to businesses and farmers to upgrade current practices and develop plans to protect water quality. The Region in partnership with the local municipalities has implemented a Winter Maintenance Policy and Procedures to reduce the amount of winter salt applied to roads across the Region. The Region is recognized internationally as a leader in the implementation of municipal groundwater source protection programs.

The Region has conducted a wide range of groundwater studies to quantify existing supplies, develop new supplies, and has implemented a region-wide groundwater monitoring program. In all a significant body of scientifically-defensible hydrogeologic information has been produced and is used as the basis for the Region's groundwater management activities.

In 2003 the Region in partnership with the GRCA was awarded funding for the MOE's 2001 Municipal Groundwater Studies Grant Program to complete a number of tasks, including development of a new ten-year implementation plan for the WRPS. The WRPS update includes an approach for ranking threats and assessing risk-reduction measures for a number of threat categories in each WHPA. Based on this approach risk-reduction measures were proposed in each WHPA. An approach to prioritizing risk management activities was also proposed. The WRPS (2007) is considered an interim plan as the extent to which risk reduction measures are implemented will ultimately be influenced by regulations under the Clean Water Act (2006) which have yet to be developed. The WRPS update is presented in Council Report E-07-052.

Vulnerability mapping using the Intrinsic Susceptibility Index (ISI) and Aquifer Vulnerability Index (AVI) was also completed as part of the 2001 Municipal Groundwater Studies and will be updated by future work. The Region is currently developing a FEFLOW™ groundwater/surface water 3D numerical flow model with plans to update its WHPAs and undertake SWAT vulnerability analysis for each of its groundwater drinking water systems.

In 2006 the Region was awarded funding for the MOE's 2006 Source Protection Technical Studies Grant Program to update existing work, fill data gaps, and participate in the development of the Assessment Report for the Lake Erie Source Protection Region. The Region intends to complete a wide range of work as part of the recent technical studies program, including:

- WHPA and SWAT Mapping to include the 25-year TOT;
- Groundwater Vulnerability Scoring and Analysis;
- Surface and Groundwater Uncertainty Analysis;
- Inventory and Prioritization of Drinking Water Issues;
- Drinking Water Threats Inventory;
- Hazard Rating;
- Constructed Preferential Pathways Identification and Inventory; and,
- Water Quality Risk Assessment.

Integrated Urban System (IUS) – Cambridge, Kitchener, Waterloo, Elmira, and St. Jacob's

System Description and Hydrogeologic Setting

The RMOW is responsible for water supply, storage and the operation of the trunk distribution system (including maintenance of pressure zones), while the lower tier municipalities are responsible for local distribution and customer billing. The Integrated Urban System (IUS) is a complex network of wells, reservoirs, pumping stations and trunk water mains serving Cambridge, Kitchener, Waterloo, parts of Elmira and St. Jacobs in the Township of Woolwich, and parts of Wilmot Township (approximately 325,000 persons). Fully treated and disinfected water from the Mannheim Water Treatment Plant (WTP) is introduced to the IUS in Kitchener combined with treated water from a variety of groundwater sources and then distributed via reservoirs and trunk watermains to the lower tier municipalities for consumption. During the seasons of lower demand, fully treated water is injected via ASR wells at the Mannheim WTP for storage and pumped out for use during high demand periods.

The IUS comprises 67 wells, the Mannheim WTP, four groundwater WTPs providing iron/manganese removal and disinfection, eight reservoir/pump stations providing disinfection or rechlorination/chloramination, one reservoir providing ammoniation, two elevated tanks with re-chlorination/ammoniation facilities, and a fluoridation facility. **Table 6.12** provides a summary of the IUS wells and treatment facilities.

Table 6.12: Summary table of the Region's IUS wells and treatment facilities

System	Description	Disinfection
Cambridge (Map 6.30)		
Galt Well System	Galt Well G4 – 305 mm diameter, 61.0 m deep drilled groundwater production well discharging to distribution system	UV primary disinfection and sodium hypochlorite secondary disinfection
	Galt Well G5 – 305 mm diameter, 24.1 m deep drilled groundwater production well discharging to distribution system	
	Galt Well G9 – 305 mm diameter, 78.3 m deep drilled groundwater production well discharging to distribution system	
	Galt Well G6 – 305 mm diameter, 82.6 m deep drilled groundwater production well discharging to distribution system	Sodium hypochlorite
Hespeler Well System	Hespeler Well H3 – 254 mm diameter, 63.6 m deep drilled groundwater production well discharging to distribution system	UV primary disinfection and sodium hypochlorite secondary disinfection
	Hespeler Well H4 – 305 mm diameter, 51.2 m deep drilled groundwater production well discharging to distribution system	
	Hespeler Well H5 – 305 mm diameter, 68.9 m deep drilled groundwater production well discharging to distribution system	Sodium hypochlorite
Middleton Well System	Middleton G1 – 356 mm diameter, 59.4 m deep drilled groundwater production well discharging to Middleton Reservoir then to distribution system	Sodium hypochlorite at Middleton Reservoir
	Middleton G1A – 356 mm diameter, 60.1 m deep drilled groundwater production well discharging to Middleton Reservoir then to distribution system	
	Middleton G2 – 356 mm diameter, 49.7 m deep drilled groundwater production well discharging to Middleton Reservoir then to distribution system	
	Middleton G3 – 508 mm diameter, 51.8 m deep drilled groundwater production well discharging to Middleton Reservoir then to distribution system	
	Middleton G14 – 508 mm diameter, 54.9 m deep drilled groundwater production well discharging to Middleton Reservoir then to distribution system	
	Middleton G15 – 508 mm diameter, 51.8 m deep drilled groundwater production well discharging to Middleton Reservoir then to distribution system	
Pinebush Road	Pinebush Well P10 – 203 mm diameter, 64.3 m deep drilled groundwater production well discharging to Pinebush WTP then to Rahmans reservoir and/or distribution system	Sodium hypochlorite at Pinebush WTP
	Pinebush Well P11 – 254 mm diameter, 83.8 m deep drilled groundwater production well discharging to Rahmans reservoir and/or distribution system	
	Pinebush Well P17 – 304 mm diameter, 110.6 m deep drilled groundwater production well discharging to Rahmans reservoir and/or distribution system	

Table 6.12: Summary table of the Region's IUS wells and treatment facilities

System	Description	Disinfection
Preston Well System	Preston Well P6 – 254 mm diameter, 80.2 m deep drilled groundwater production well discharging to distribution system	Sodium hypochlorite
	Preston Well P16 – 254 mm diameter, 38.7 m deep drilled groundwater production well discharging to distribution system	UV primary disinfection and sodium hypochlorite secondary disinfection
Rahmans Well System	Rahmans Well P9 – 254 mm diameter, 80.2 m deep drilled groundwater production well discharging to Rahmans reservoir/and or distribution system	Sodium hypochlorite
	Rahmans Well P15 – 254 mm diameter, 74.1 m deep drilled groundwater production well discharging to Rahmans reservoir and/or distribution system	
Shades Mill	Shades Mill Well G7 – 406 mm diameter, 17.7 m deep drilled groundwater production well discharging to Shades Mill WTP then to distribution system	UV primary disinfection at Shades Mill WTP and sodium hypochlorite secondary disinfection
	Shades Mill Well G8 – 406 mm diameter, 17.7 m deep drilled groundwater production well discharging to Shades Mill WTP then to distribution system	
	Shades Mill Well G38 GUDI – 356 mm diameter, 39.6 m deep drilled groundwater production well discharging to Shades Mill WTP then to distribution system	
	Shades Mill Well G39 GUDI – 356 mm diameter, 43.4 m deep drilled groundwater production well discharging to Shades Mill WTP then to distribution system	
Turnbull Well System	Turnbull Well G16 – 304 mm diameter, 100.0 m deep drilled groundwater production well discharging to Turnbull WTP then to distribution system	Sodium hypochlorite at Turnbull WTP
	Turnbull Well G17 – 304 mm diameter, 120.7 m deep drilled groundwater production well discharging to Turnbull WTP then to distribution system	
	Turnbull Well G18 – 203 mm diameter, 92.7 m deep drilled groundwater production well discharging to Turnbull WTP then to distribution system	

Kitchener
(

Greenbrook Well System	Well K1 – 457 mm diameter, 48.0 m deep drilled groundwater production well discharging to Greenbrook WTP then to distribution system	Sodium hypochlorite and ammonium sulphate at Greenbrook WTP
	Well K2 – 457 mm diameter, 48.8 m deep drilled groundwater production well discharging to Greenbrook WTP then to distribution system	
	Well K5A – 406 mm diameter, 42.8 m deep drilled groundwater production well discharging to Greenbrook WTP then to distribution system	
	Well K8 – 305 mm diameter, 61.9 m deep drilled groundwater production well discharging to Greenbrook WTP then to distribution system	
	Well K4B – 406 mm diameter, 37.5 m deep drilled groundwater production well discharging to distribution system then to Greenbrook	Sodium hypochlorite

Table 6.12: Summary table of the Region's IUS wells and treatment facilities

System	Description	Disinfection
	WTP	
Kitchener Well System	Well K18 – 305 mm diameter, 37.5 m deep drilled groundwater production well discharging to distribution system	Sodium hypochlorite
	Well K19 – 355 mm diameter, 37.8 m deep drilled groundwater production well discharging to distribution system	
	Well K34 – 406 mm diameter, 35.1 m deep drilled groundwater production well discharging to distribution system	Sodium hypochlorite and ammonium sulphate
	Well K36 – 305 mm diameter, 50.6 m deep drilled groundwater production well discharging to distribution system	UV primary disinfection and sodium hypochlorite secondary disinfection
Mannheim Well System (Group 1 – Mannheim East)	Well K21 – 457 mm diameter, 57.9 m deep drilled groundwater production well discharging to distribution system then to Mannheim Reservoir	Sodium hypochlorite
	Well K25 – 406 mm diameter, 50.0 m deep drilled groundwater production well discharging to distribution system then to Mannheim Reservoir	
	Well K29 – 305 mm diameter, 51.5 m deep drilled groundwater production well discharging to distribution system then to Mannheim Reservoir	
Mannheim Well System (Group 3 - Peaking)	Well K91 – 305 mm diameter, 65.5 m deep drilled groundwater production well discharging to Mannheim Reservoir then to distribution system	Sodium hypochlorite
	Well K92 – 305 mm diameter, 66.5 m deep drilled groundwater production well discharging to Mannheim Reservoir then to distribution system	
	Well K93 – 305 mm diameter, 75.3 m deep drilled groundwater production well discharging to Mannheim Reservoir then to distribution system	
	Well K94 – 305 mm diameter, 71.6 m deep drilled groundwater production well discharging to Mannheim Reservoir then to distribution system	
Mannheim Well System (Mannheim Artificial Recharge Facility)	Well ASR1 – 442 mm dia. (with a 406 mm dia. screen), 72.2 m deep drilled groundwater recharge/recovery well discharging to treated water reservoir at the Mannheim WTP	Chlorine and anhydrous ammonia at Mannheim WTP
	Well ASR2 – 442 mm dia. (with a 406 mm dia. screen), 65.5 m deep drilled groundwater recharge/recovery well discharging to treated water reservoir at the Mannheim WTP	
	Well ASR3 – 442 mm dia. (with a 406 mm dia. screen), 63.1 m deep drilled groundwater recharge/recovery well discharging to treated water reservoir at the Mannheim WTP	
	Well ASR4 – 442 mm dia. (with a 406 mm dia. screen), 72.5 m deep drilled groundwater recharge/recovery well discharging to treated water reservoir at the Mannheim WTP	
	Well RCW1 – 442 mm dia. (with a 406 mm dia. screen), 82.7 m deep drilled groundwater recovery well discharging to treated water reservoir at the Mannheim WTP	

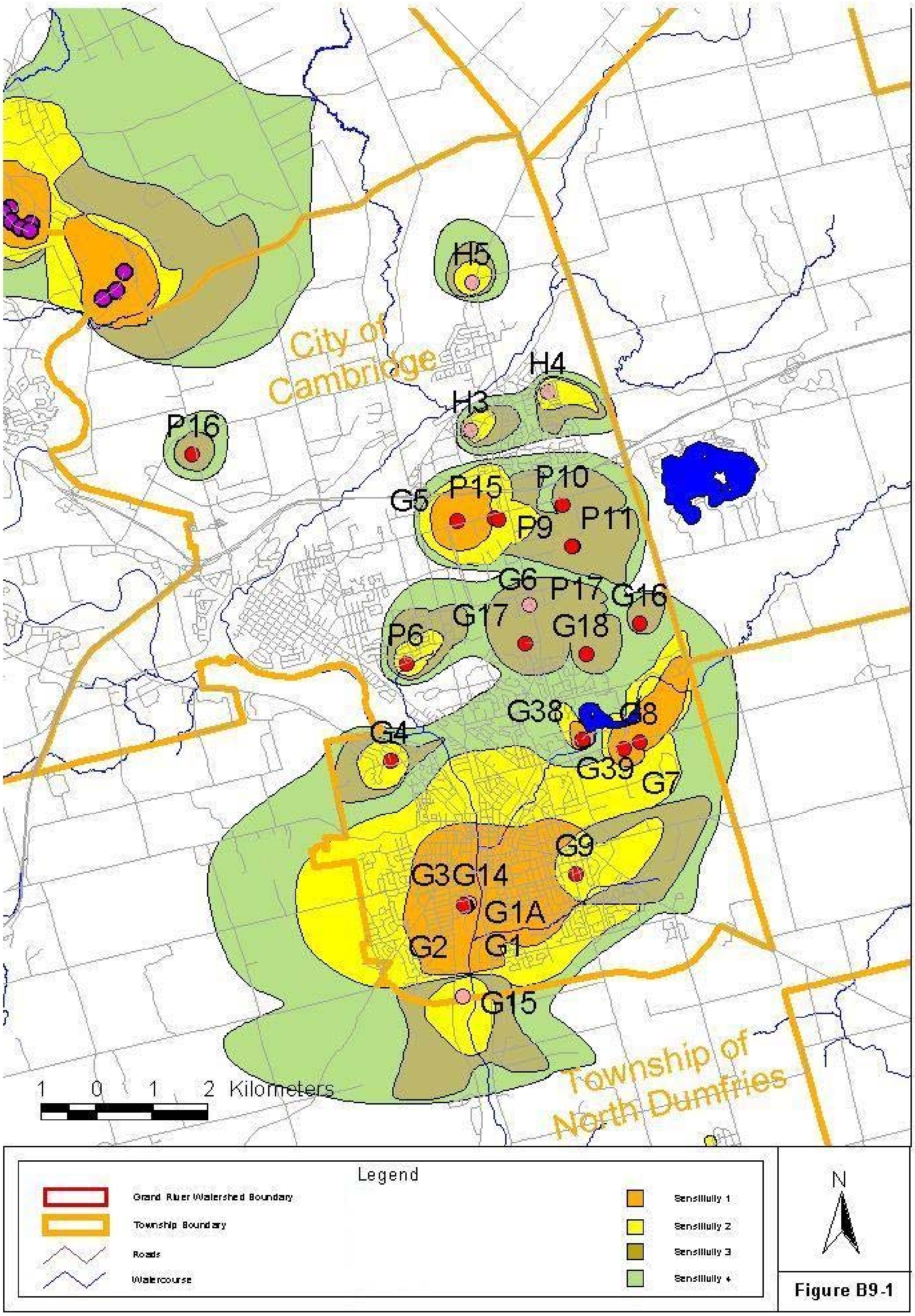
Table 6.12: Summary table of the Region's IUS wells and treatment facilities

System	Description	Disinfection
	Well RCW2 – 442 mm dia. (with a 406 mm dia. screen), 78.8 m deep drilled groundwater recovery well discharging to treated water reservoir at the Mannheim WTP	
Parkway	Well K31 – 406 mm diameter, 33.4 m deep groundwater production well discharging to Parkway Reservoir then to distribution system	Sodium hypochlorite and ammonium sulphate at Parkway Reservoir
	Well K33 – 406 mm diameter, 28.0 m deep drilled groundwater production well discharging to Parkway Reservoir then to distribution system	
	Well K32 – 406 mm diameter, 25.6 m deep drilled groundwater production well discharging to Parkway Reservoir then to distribution system	
Strange Street	Well K10A – 305 mm diameter, 21.2 m deep drilled groundwater production well discharging to distribution system then to Strange St. Reservoir	Sodium hypochlorite
	Well K13 – a 356 mm diameter, 33.5 m deep drilled groundwater production well discharging to distribution system then to Strange St. Reservoir	
	Well K11 – 356 mm diameter, 35.8 m deep drilled groundwater production well discharging to distribution system then to Strange St. Reservoir	
Woolner	Well K80 GUDI – a 610 mm diameter, 6.1 m deep horizontal groundwater collector discharging to distribution system	Sodium hypochlorite primary disinfection and UV & ammonium sulphate secondary disinfection
	Well K81 GUDI – 610 mm diameter, 6.1 m deep horizontal groundwater collector discharging to distribution system	
	Well K82 GUDI – a 610 mm diameter, 9.1 m deep horizontal groundwater collector discharging to distribution system	
	Waterloo (Map 6.31)	
Waterloo Well System	Well W10 GUDI – a 387 mm diameter, 18.3 m deep drilled groundwater production well discharging to distribution system	UV primary disinfection and sodium hypochlorite secondary disinfection
William Street	Well W1B – 356 mm diameter, 31.1 m deep drilled groundwater production well discharging to the William St. Reservoir then to distribution system	Sodium hypochlorite at William St. Reservoir
	Well W3 – 254 mm diameter, 103.9 m deep drilled groundwater production well discharging to the William St. Reservoir then to distribution system	
	Well W1C – 305 mm diameter, 35.2 m deep drilled groundwater production well discharging to distribution system then to the William St. Reservoir	Sodium hypochlorite
	Well W2 – 406 mm diameter, 33.0 m deep drilled groundwater production well discharging to distribution system then to the William St. Reservoir	

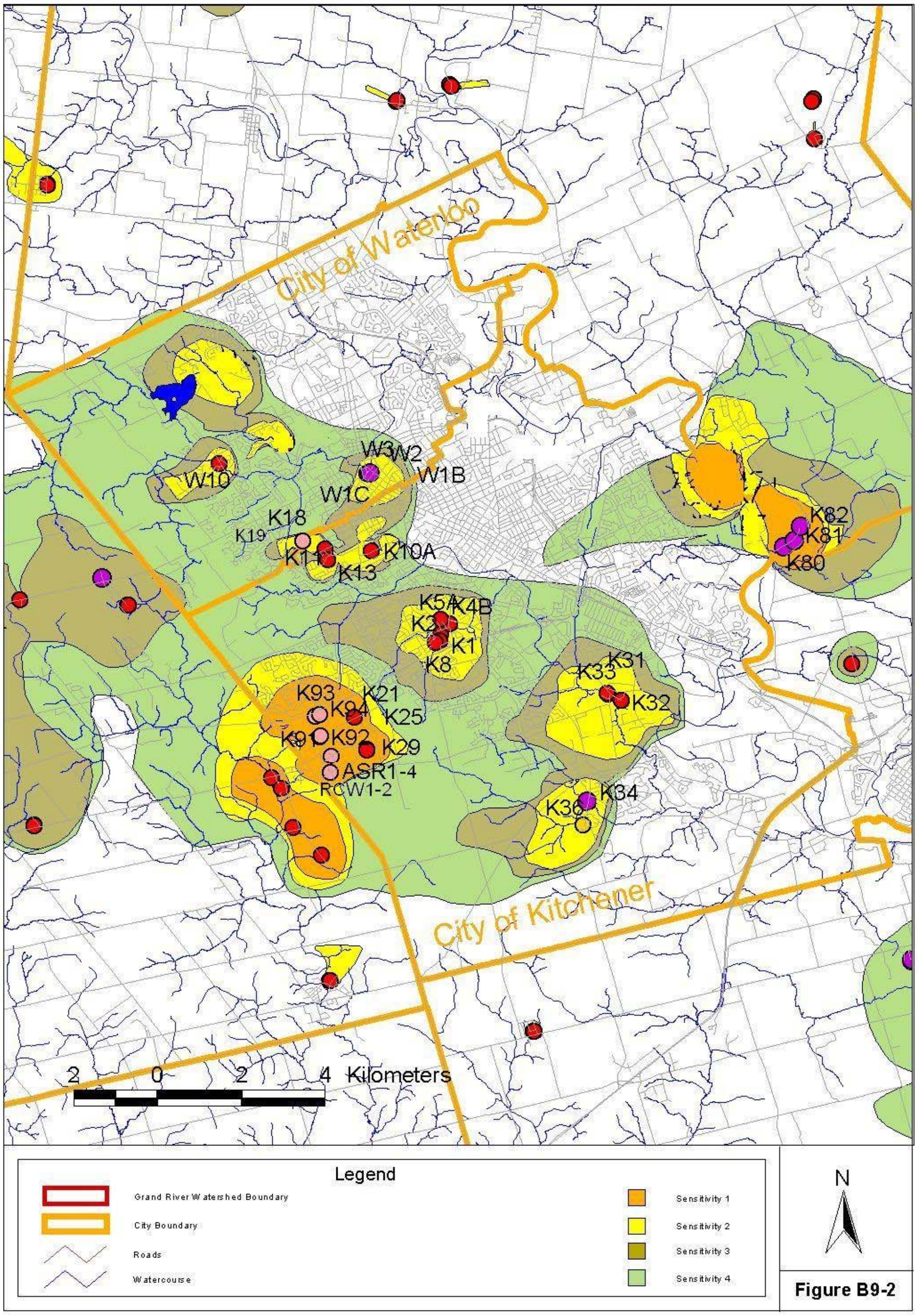
Table 6.12: Summary table of the Region's IUS wells and treatment facilities

System	Description	Disinfection
Wilmot (Map 6.32)		
Erb Street	Well W6A – 305 mm diameter, 55.5 m deep drilled groundwater production well discharging to distribution system then to the Erb St. Reservoir	Sodium hypochlorite
	Well W6B – 305 mm diameter, 54.5 m deep drilled groundwater production well discharging to distribution system then to the Erb St. Reservoir	
	Well W7 – 406 mm diameter, 42.1 m deep drilled groundwater production well discharging to distribution system then to the Erb St. Reservoir	
	Well W8 – 387 mm diameter, 42.1 m deep drilled groundwater production well discharging to distribution system then to the Erb St. Reservoir	
Mannheim Well System (Group 2 – Mannheim West)	Well K22A GUDI – 457 mm diameter, 28.0 m deep drilled groundwater production well discharging to distribution system then to Mannheim Reservoir	UV primary disinfection and sodium hypochlorite secondary disinfection
	Well K23 GUDI – 457 mm diameter, 26.2 m deep drilled groundwater production well discharging to distribution system then to Mannheim Reservoir	
	Well K24 – 457 mm diameter, 33.8 m deep drilled groundwater production well discharging to distribution system then to Mannheim Reservoir	
	Well K26 – 457 mm diameter, 38.1 m deep drilled groundwater production well discharging to distribution system then to Mannheim Reservoir	
Wilmot Centre	Well K50 – 406 mm diameter, 39.9 m deep drilled groundwater production well discharging to distribution system then to Mannheim Reservoir and/or Baden-New Hamburg distribution system	Sodium hypochlorite
	Well K51 – 457 mm diameter, 39.6 m deep drilled groundwater production well discharging to distribution system then to Mannheim Reservoir and/or Baden-New Hamburg distribution system	
Woolwich (Map 6.33)		
Elmira	Well E10 – 305 mm diameter, 53.7 m deep drilled groundwater production well discharging to distribution system	Sodium hypochlorite & ammonium sulphate

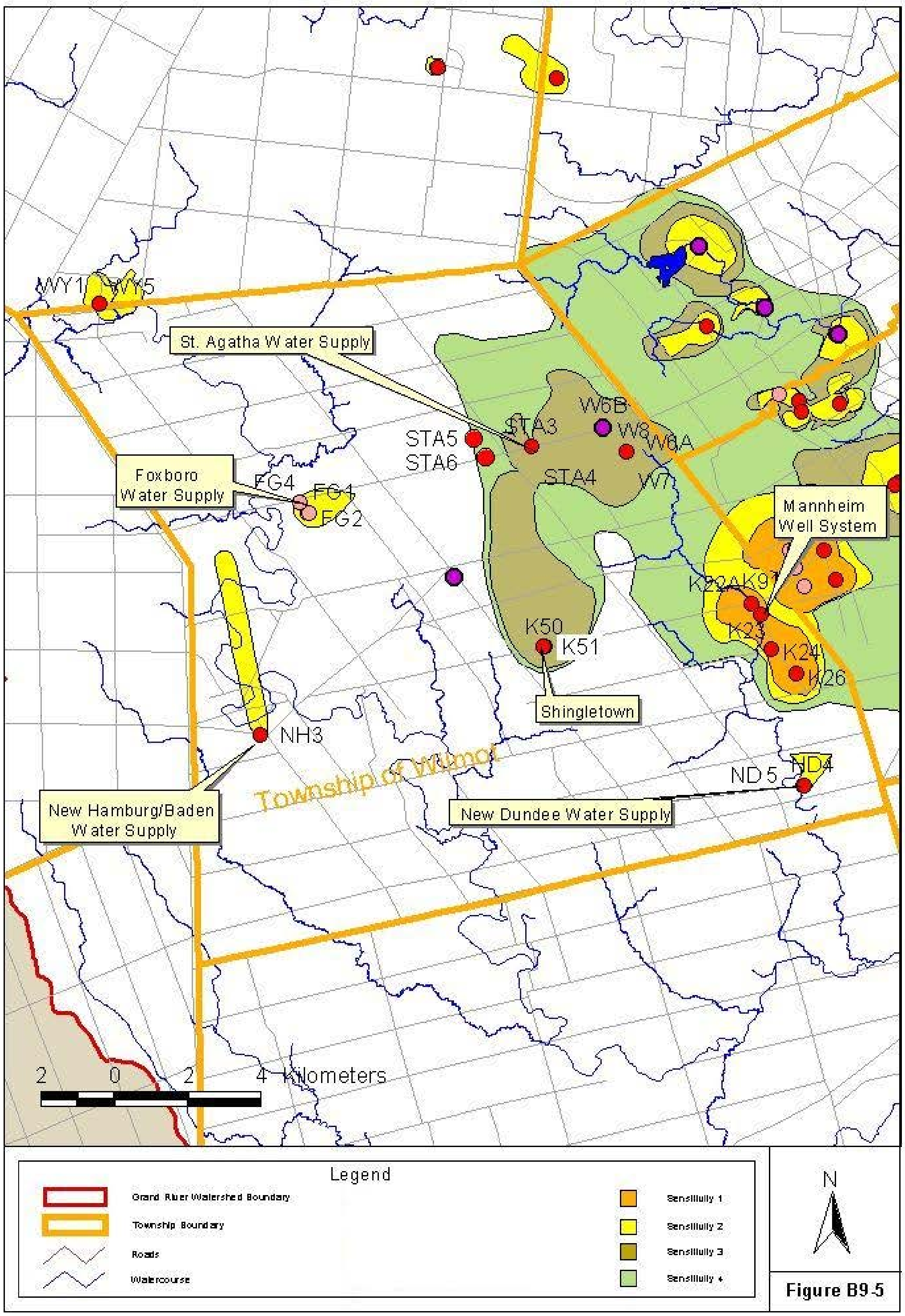
Map 6.30: City of Cambridge Wellhead Protection Areas



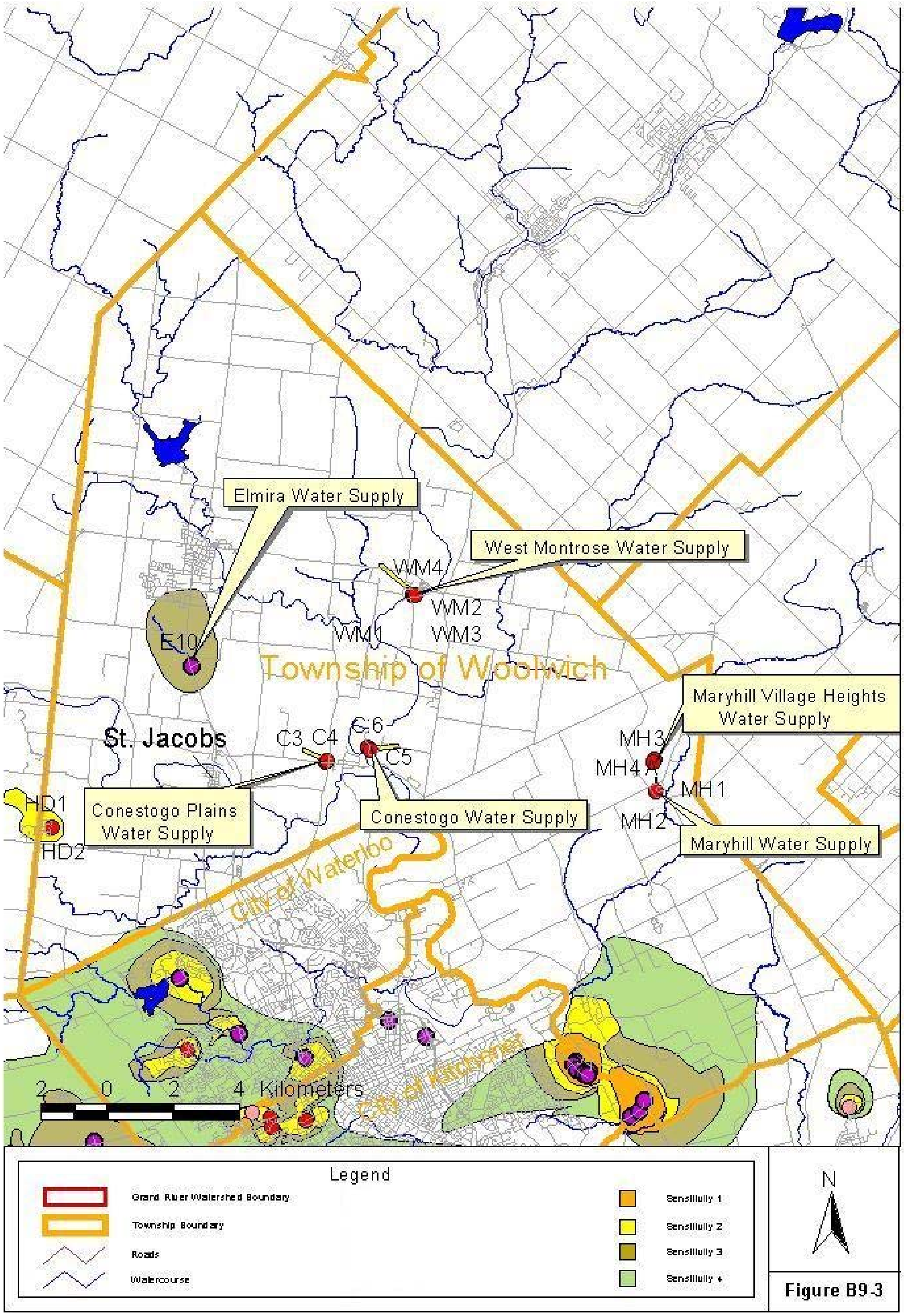
Map 6.31: Cities of Kitchener & Waterloo Wellhead Protection Areas



Map 6.32: Township of Wilmot Wellhead Protection Areas



Map 6.33: Township of Woolwich Wellhead Protection Areas



Municipal Water Quality

Water quality results in 2006 for the Region of Waterloo IUS can be accessed through the following link:

http://www.region.waterloo.on.ca/web/region.nsf/97dfc347666efede85256e590071a3d4/c6b493f902cd2d718525727c005994b9!OpenDocument

Description of Capture Zones

Twenty-six municipal pumping wells systems are located within the IUS system.

Vulnerable Areas within the 25-year Capture Zone

Aquifer vulnerability mapping for the Region was completed by the GRCA as part the 2001 Municipal Groundwater Studies.

Threats within the 25-year Capture Zone

The Region has developed a Threats Inventory Database (TID) which is a collection of information on land-use activities that have potential to affect the quality of surface and groundwater in the Region (RMOW, 2006). The TID includes information on past and present industries, landfills, chemical and fuel storage sites, and other urban land use activities throughout the Region of Waterloo, all ranked according to the level of potential threat each poses to the surface and groundwater. A threat is defined as a past, present or future (proposed) activity or condition that is impacting or has the potential to impact a drinking water source.

Maps showing the land use within the 10-year TOT of all municipal groundwater drinking water systems are presented below. The land uses are presented thematically based on Municipal Property Assessment Corporation (MPAC) property assessment codes.

City of Cambridge

The City of Cambridge is served primarily by a series of 27 wells in the Paris-Galt moraine located mainly within highly urbanized areas as shown in **Map 6.24**.

In northwest Cambridge, the Fountain Street Well, located in the Cambridge Business Park, is adjacent to a variety of industrial and commercial enterprises. In northeast Cambridge, Hespeler Well H3 is located in the old Hespeler industrial district amid residential and commercial land use activities. The Pinebush Road and Rahmans wellfields (including Galt Wells G5 and G6) are situated the central portion of the City adjacent to the 401 in the Lovell Business Park. These lands contain everything from heavy manufacturing to small strip mall commercial outlets. The Dunbar Road well and capture zone in central Cambridge includes the site of known historical TCE contamination. This site is currently being closely monitored to determine the extent of the contaminant plume and to establish remediation strategies. Two wells in the Shades Mill wellfield on the east side of Cambridge have been classified as GUIDI wells and as a result the water is treated to address possible impacts from surface source water. The other two wells in the Shades Mill wellfield are located within the Eastern Industrial Park along side the CNR Mainline. This industrial park includes heavy industries, a waste transfer station and is adjacent to the old Cambridge Landfill site. In the south end of Cambridge, the Middleton Street wellfield capture zone sits in the heart of old Galt adjacent to brownfields and a site known for historical contamination of the wells. The capture zone is also the site of the Galt WWTP. The remaining wells throughout Cambridge are situated in predominantly residential neighborhoods within capture zones that could be categorized as having medium, low or no identified potential threats.

City of Kitchener

The City of Kitchener is served primarily by a combination of 24 groundwater wells, predominantly within the Waterloo moraine, and the production from the Manheim recharge facility. About half of the Kitchener production wells are located within highly urbanized areas as shown in **Map 6.35:** City of Kitchener Land Use in Wellhead Protection Areas.

In north Kitchener, the Strange Street Wellfield is located in the vicinity of heavy industry, commercial/industrial strip malls, gas stations, and goods movement along the CNR mainline. In addition, one of the wells is located on the grounds of a golf course. The Greenborook Wellfield, in central Kitchener, has been out of service since the detection of elevated dioxane levels in the summer of 2004. The wellfield is located in the vicinity of historic industrial and waste disposal sites. The RMOW is upgrading the water treatment facilities with UV disinfection, hydrogen peroxide injection and carbon activated filters to bring the water supply back on line. The Parkway Wellfield, in south Kitchener, is situated amid a wide variety of commercial and industrial land uses. The Strasburg Wellfield just to the south of the Parkway Wellfield is located in a residential area just on the fringe of the Huron Business Park. The Woolner wells on the east side of Kitchener have been classified as GUIDI wells. As a result the water is treated to address possible impacts from Grand River source water. The wells are also in a catchment that includes potential threats from the Waterloo Regional Airport and adjacent aggregate operations. The Manheim Wellfield on the west side of Kitchener is in the vicinity of residential and agricultural land uses and has the possible influence of road maintenance (salting) operations on Highway #7&8 just to the north of the Group 1 & 3 wells.

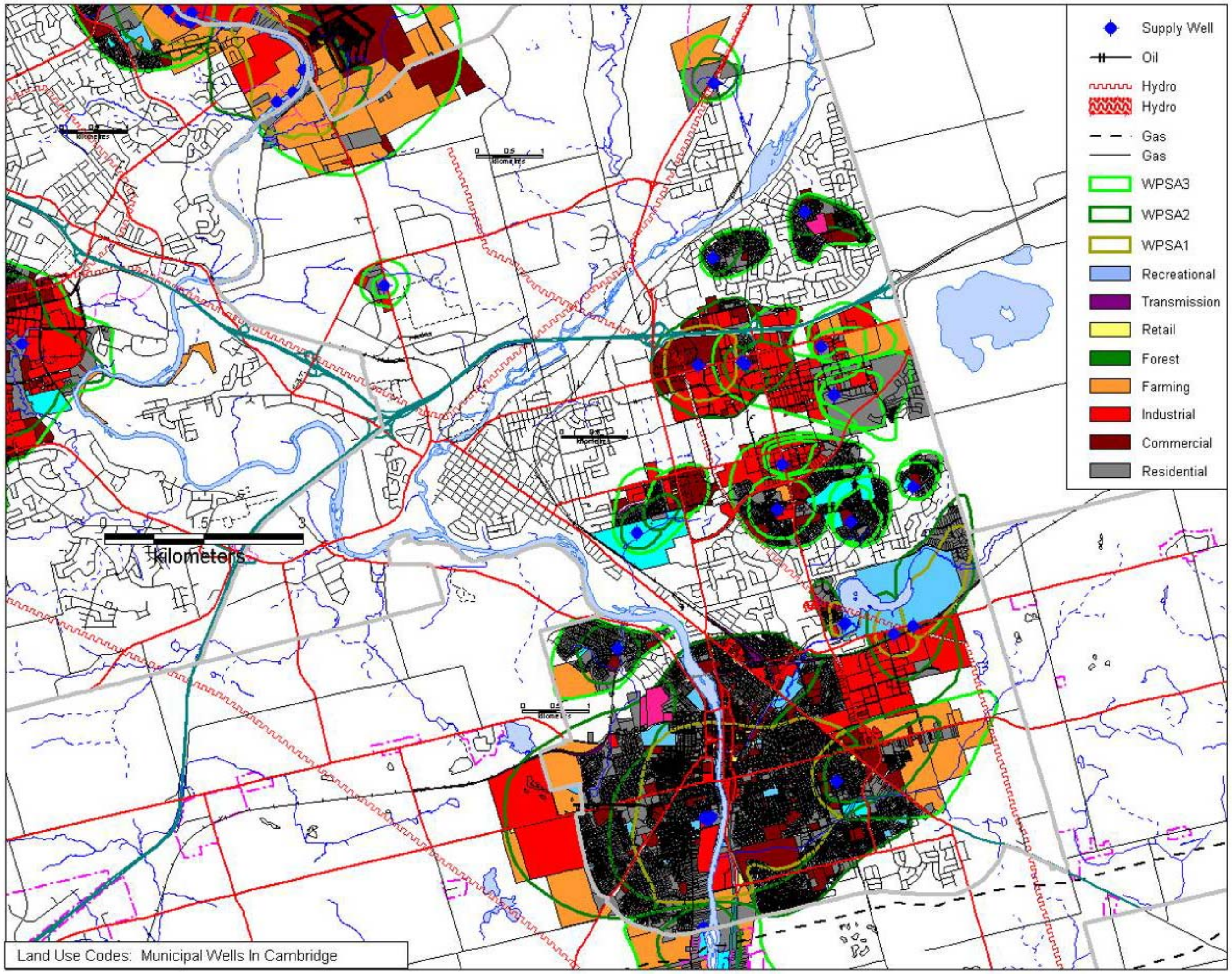
City of Waterloo

The City of Waterloo is served by a combination of 5 Waterloo and 4 Wilmot groundwater wells drawing from the Waterloo moraine along with water production from the Manheim recharge facility as shown in **Map 6.36**. The central Waterloo land uses include a number of known historically contaminated sites, existing small industries, and commercial establishments. Waterloo Well W10 on the west side of the city is classified as a GUDI in a predominantly residential area.

Township of Wilmot

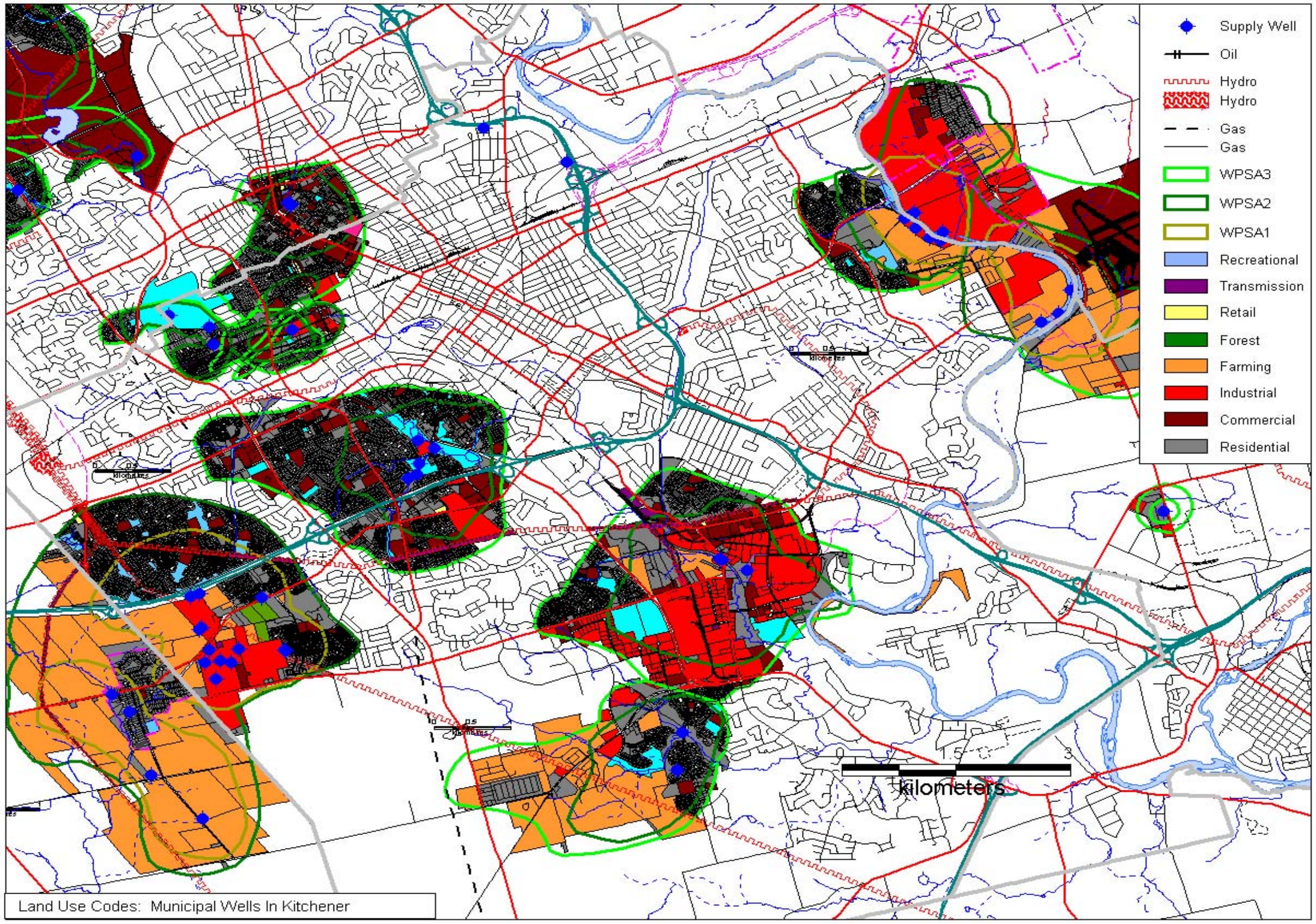
In the Township of Wilmot, 10 wells fed by the Waterloo moraine contribute to water supply in the IUS. The wellfields reside within rural land uses in the Township as shown in **Map 6.37**. The only know threat in the vicinity of the capture zones is the Erb Street landfill just to the east of the Erb Street Wellfield. Two of the Manheim Group 2 wells on the east side of Wilmot Township have been classified as GUDI wells and as a result the water is treated to address possible impacts from surface source water.

Map 6.34: City of Cambridge Land Use in Wellhead Protection Areas



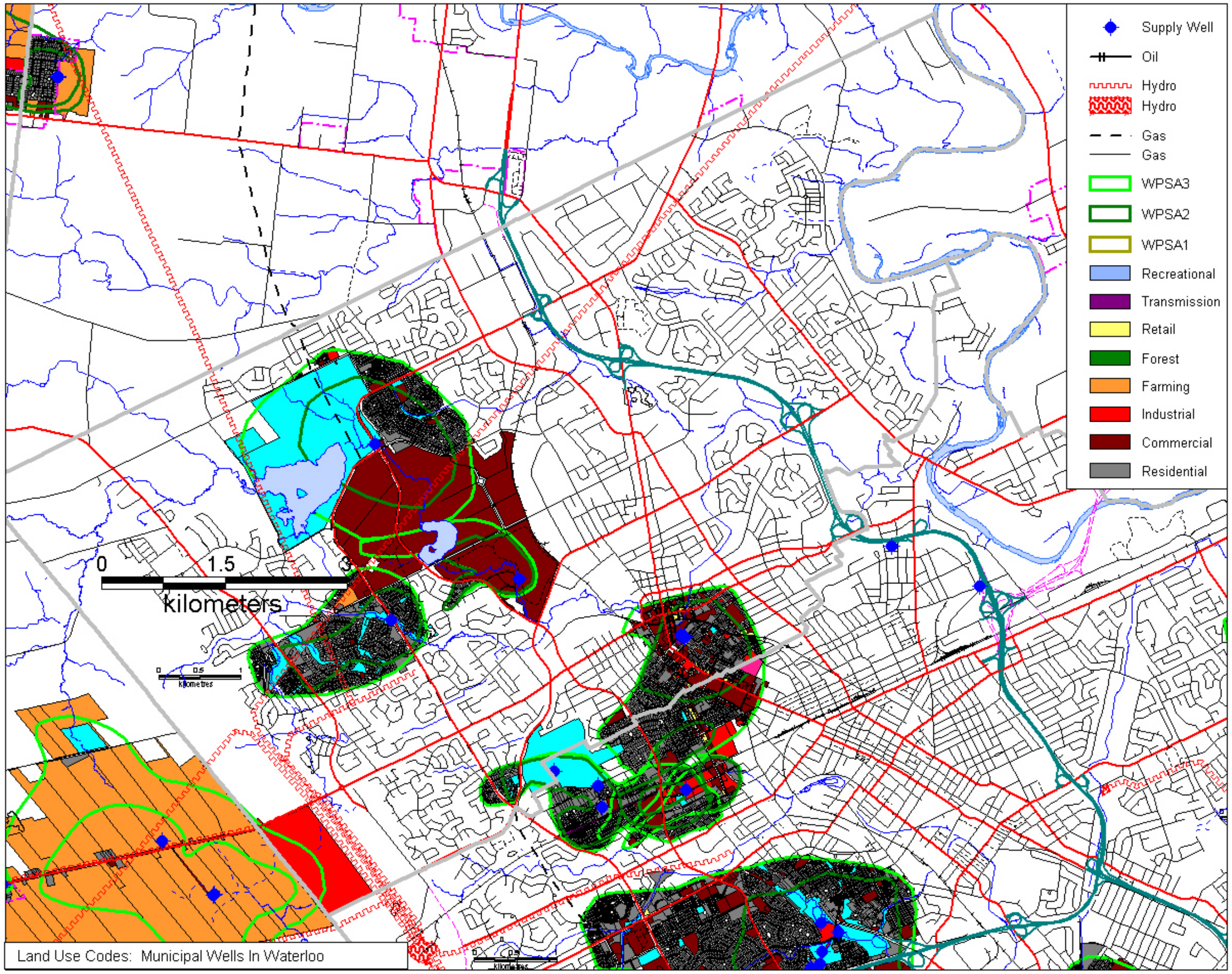
Source: MPAC, 2006

Map 6.35: City of Kitchener Land Use in Wellhead Protection Areas



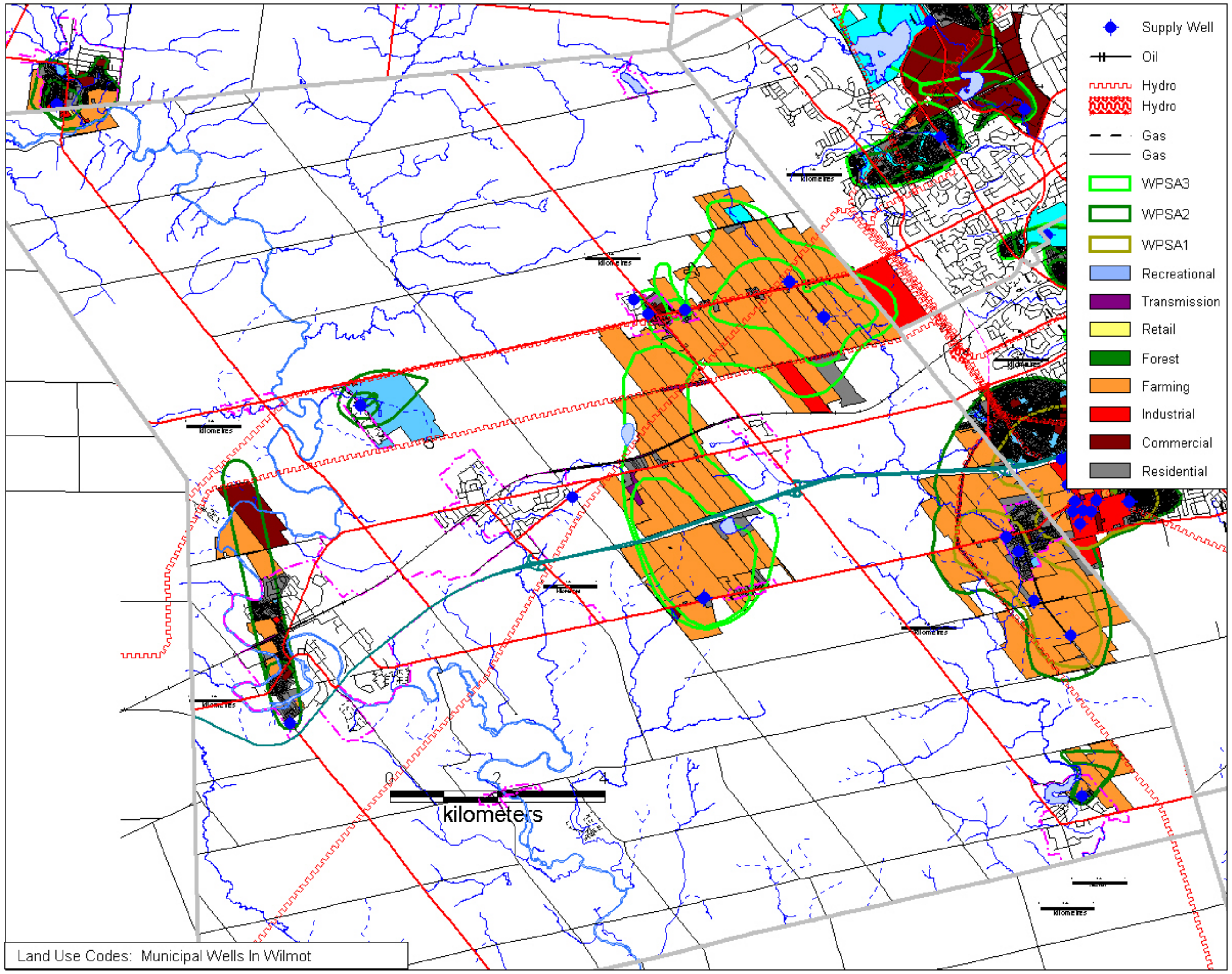
Source: MPAC, 2006

Map 6.36: City of Waterloo Land Use in Wellhead Protection Areas



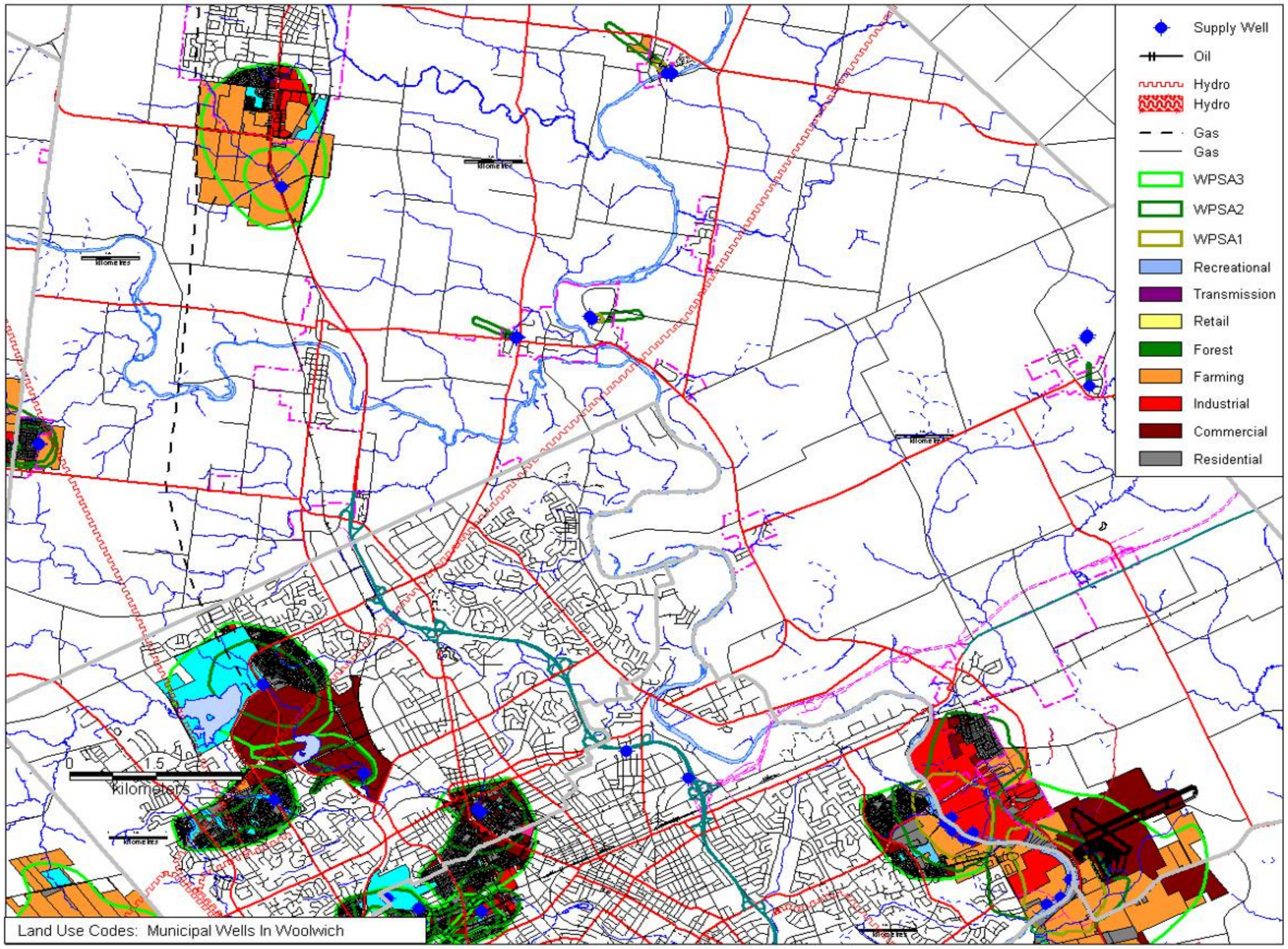
Source: MPAC, 2006

Map 6.37: Township of Wilmot Land Use in Wellhead Protection Areas



Source: MPAC, 2006

Map 6.38: Township of Woolwich Land Use in Wellhead Protection Areas



Source: MPAC, 2006

<u>*Township of Woolwich*</u>

The IUS is also connected to the communities of St. Jacob's and Elmira. The supply to these communities is augmented by Well E10 just south of Elmira as shown in **Map 6.38**. Elmira had an historical NDMA contamination problem with their groundwater supply originating in the northeast quadrant of the town that forced the closure of wells in 1990. The capture zone for Well E10 is surrounded by rural land uses but includes some industrial and residential lands in the south end of the town.

Overall the Region of Waterloo has conducted a wide range of studies to ascertain the status of its ground water quantity and quality, and continues to work with a range of partners to identify issues and eliminate specific threats to the IUS. Current issues relate to the source and quantity of contaminants (ie. NDMA, 1,4-dioxane, chlorides, PRC's, etc.) that have forced the closure and upgrading of some wells and the need to maintain close surveillance of all other water sources. However, while much has been identified already, some questions remain unanswered regarding threats at certain existing and historic land uses. The Region will continue to work to collect data at the level of detail necessary to ensure protection of its groundwater supply.

Summary

The Region of Waterloo's IUS is predominantly groundwater dependant. Water supplies are augmented with Grand River recharge at the Manheim Water Treatment Plant. The Region has identified the need to expand its long term water supply due to provincial growth projections. Vulnerable groundwater areas have been identified for all municipal drinking water sources in the Region, and an inventory of threats to these sources has been identified. The majorities of threats are related to present or historic urban land use activities such as industry and commercial/retail, as well as higher residential densities, winter maintenance practices, and historic contamination. The Region has implemented numerous programs to protect groundwater quantity and quality. The Region has also conducted a wide range of groundwater studies to quantify existing supplies, develop new supplies, and has implemented a region-wide groundwater monitoring program.

<u>*Township of North Dumfries*</u>

System Description

The Region of Waterloo operates three municipal water supply systems within the Township of North Dumfries in the communities of Ayr, Branchton, and Roseville. The Township's water supply originates from a combination of groundwater and a treated source from the Cambridge distribution system – water from Cambridge is re-chlorinated and distributed at the Lloyd Brown subdivision. The municipal water supply consists of 7 raw water well sources, 3 water filtration plants, as described in **Table 6.13**, and a re-chlorination facility (Lloyd Brown).

Table 6.13 Summary table of the Region's wells and treatment facilities in North Dumfries

System	Description	Disinfection
Ayr (Pop. 4,055)	A1 – 250 mm diameter, 51.5 m deep drilled groundwater production well discharging to WTP/Reservoir then to distribution	Sodium hypochlorite
	A2 – 250 mm diameter, 50.0 m deep drilled groundwater production well discharging to WTP/Reservoir then to distribution	
	A3 – 300 mm diameter, 51.5 m deep drilled groundwater production well discharging to WTP/Reservoir then to distribution	
Branchton Meadows (Pop. 122)	BM1 – 200 mm diameter, 29.3 m deep drilled groundwater production well discharging to WTP/Reservoir then to distribution	Sodium hypochlorite and ammonium sulphate
	BM1 – 250 mm diameter, 34.1 m deep drilled groundwater production well discharging to WTP/Reservoir then to distribution	
Roseville (Pop. 290)	R5 – 150 mm diameter, 51.8 m deep drilled groundwater production well discharging to WTP/Reservoir then to distribution	Sodium hypochlorite
	R6 – 150 mm diameter, 51.5 m deep drilled groundwater production well discharging to WTP/Reservoir then to distribution	

Groundwater Quality

Water quality results in 2006 for the raw water supply wells for Ayr, Branchton Meadows or Roseville can be accessed through the following link:

http://www.region.waterloo.on.ca/web/region.nsf/97dfc347666efede85256e590071a3d4/c6b493f902cd2d718525727c005994b9!OpenDocument

Description of Capture Zones

The Region has modeled groundwater flow and delineated WHPAs for each of the three water supply systems in the Township of North Dumfries. The Region designated all WHPAs within the township as having a Sensitivity 2. This approach was taken for all groundwater systems in the rural townships that do not have backup wells which utilize groundwater from a different source as the main wells.

Ayr

The Ayr well field obtains its water from a sand and gravel aquifer that is situated approximately 20 m to 50 m below ground surface. The laterally extensive aquifer which supplies the Village of Ayr is confined or partially confined throughout the subwatershed (WESA, 2004). The aquifer, which is between 5 m and 25 m thick, is generally thickest towards the northwest near the Village of Roseville, and thins out to the east near the Grand River (WESA, 2004).

Capture zones for the Ayr wells were delineated based on 2D groundwater flow modeling (FLOWPATH) and used pumping rates for 1993. The capture zones as presented in **Map 6.39** are long and narrow since this modeling approach does not accurately model the vertical component of flow to the wells and because the wells pump at relatively low volumes. The capture zones extend in a northeasterly direction reflecting the groundwater flow direction in the supply aquifer. The 2-year capture zone encompasses a total of 17 hectares and the 10-year capture zone covers a total of 77 hectares. The WHPAs resulting from the modelled capture zones, shown on **Map 6.39**, were rated as a Sensitivity Area 2 by the Region of Waterloo.

Branchton Meadows

The Branchton Meadows well field extracts water from the upper part of the Guelph Amabel Formation (RMOW, 1999). The bedrock aquifer is locally overlain by 25 m of sandy silt till of the Wentworth Till and produces an aquifer under confined to semi-confined conditions near the wells.

Capture zones were modelled for the Branchton Meadows wells as part of the Cambridge 3D MODFLOW model and used 2016 projected pumping rates (Duke Engineering, 1998). The capture zones are regularly shaped, and small as a result of the low pumping rate needed for this small system. The 2-year capture zone encompasses a total of 2 hectares and the 10-year capture zone covers a total of 3 hectares. The WHPAs resulting from the modelled capture zones, shown on **Map 6.39**, were rated as a Sensitivity Area 2 by the Region of Waterloo.

Roseville

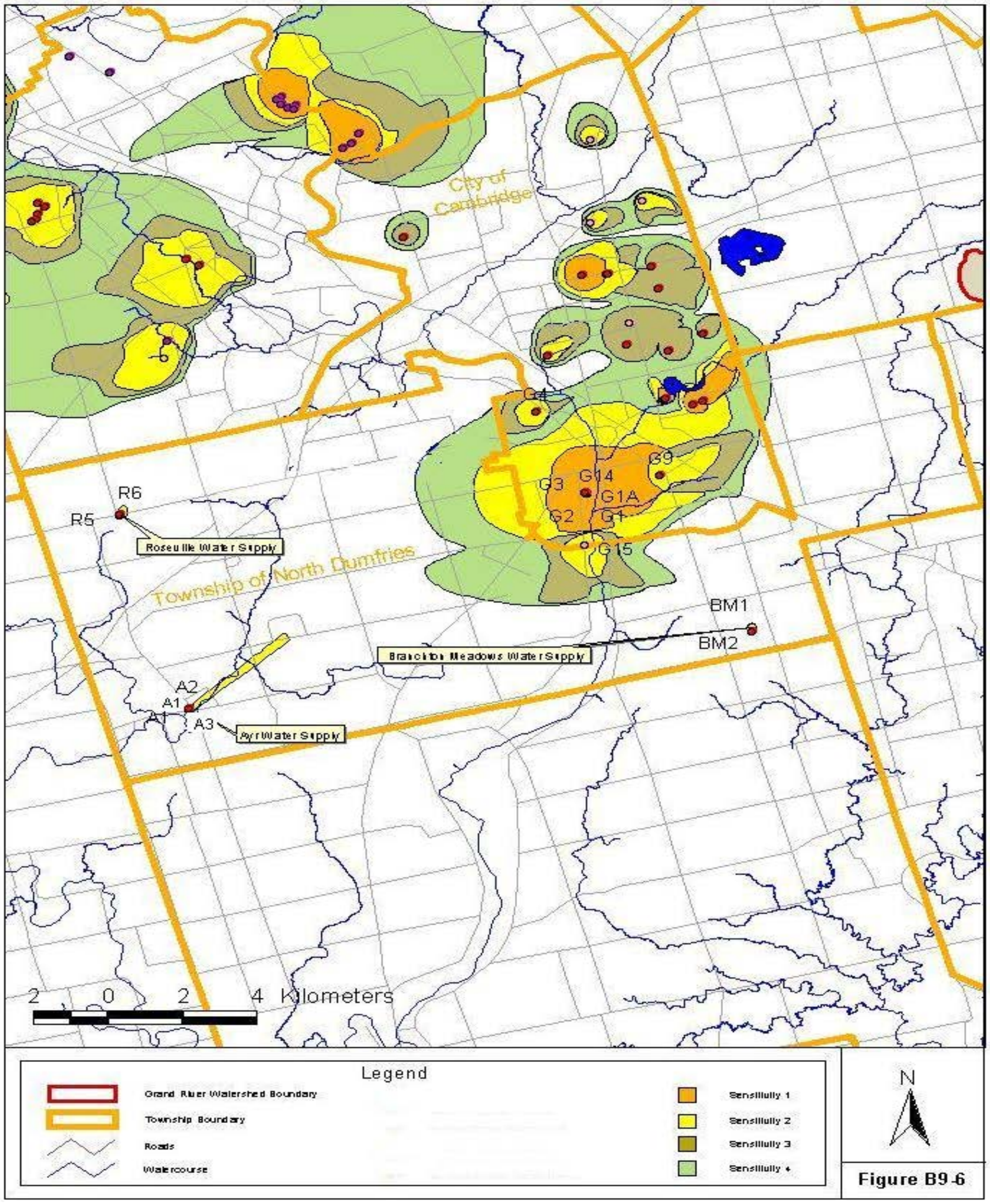
The Roseville well field which extract water from a locally confined sand and gravel aquifer located 47 m to 53 m below ground surface (RMOW, 1999). The aquifer is overlain by 15 to 20 m of clay till possibly of the Maryhill till which produces an aquifer under confined conditions near the wells.

Capture zones for the Roseville wells were modelled as a part of the Waterloo Moraine model and used 2016 projected pumping rates (Waterloo Hydrogeologic Inc., 2000). The capture zones, which extend to the northwest, are relatively small in size, reflecting the low pumping rates need for this small system. The 2-year capture zone encompasses a total of 2 hectares and the 10-year capture zone covers a total of 5 hectares. The WHPA resulting from the modeled capture zones was assigned a Sensitivity Area 2, as illustrated on **Map 6.39**, by the Region of Waterloo.

Threats within the Capture Zones

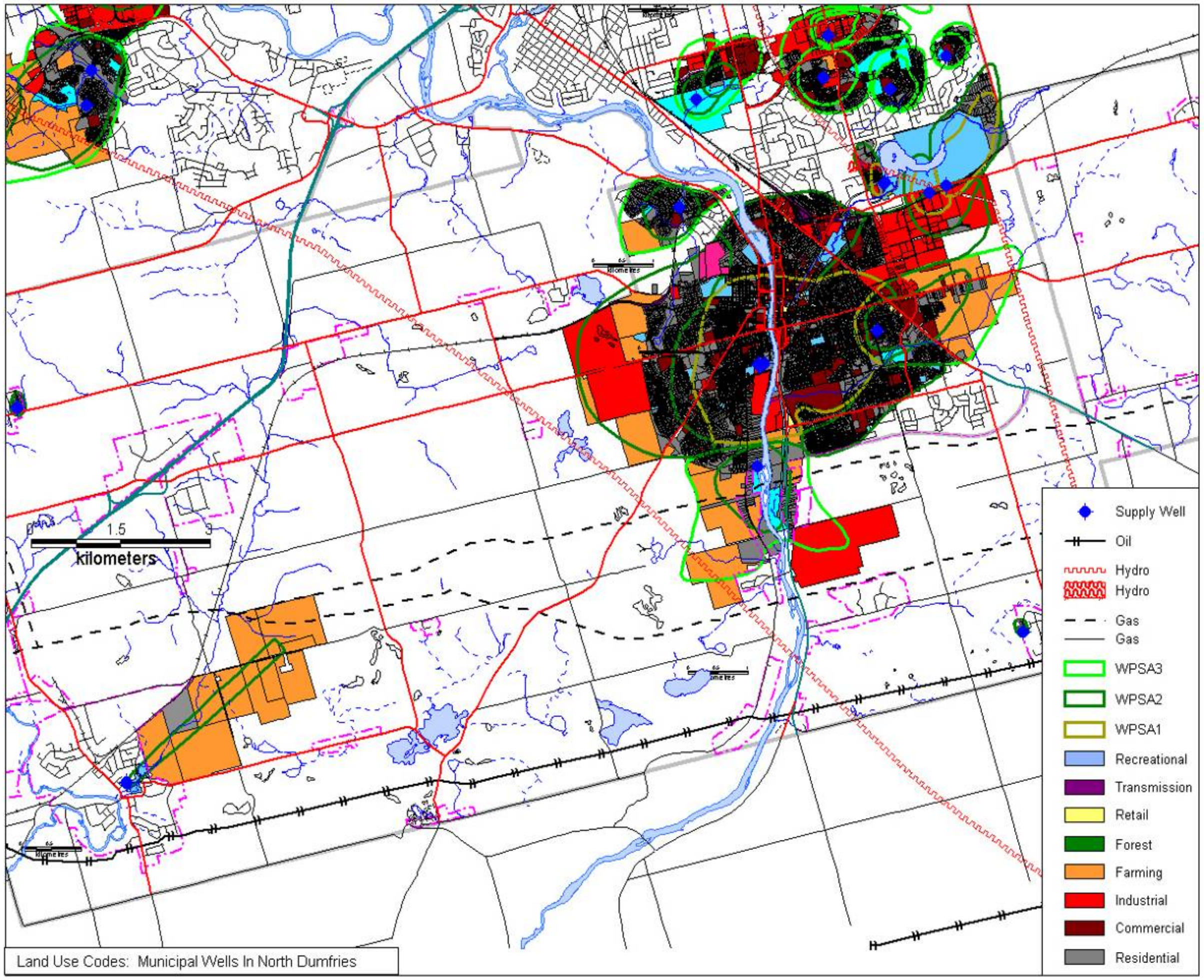
Threats are fairly limited throughout the North Dumfries capture zones, as noted in the Region's Urban Threats Inventory Database (**Map 6.40**). The Branchton and Roseville wells are situated within small residential settlements surrounded by rural agricultural land uses. The capture zone for Ayr follows the Cedar Creek valley east of the village and is surrounded by a number of aggregate pits and agricultural land uses. Several known and high potential threats exist in the Village of Ayr including fuel storage and an industrial park just to the north of the WHPA. An aggregate pit is located within the 10-year time of travel WHPA. Commercial fertilizer is estimated to be applied on approximately 82% of the 10-year WHPA based on a Consolidated Census Subdivision basis as per the 2001 Census of Agriculture and manure is estimated to be applied to approximately 27% of the 10-year WHPA based on a consolidated Census Subdivision basis as per the 2001 Census of Agriculture.

Map 6.39: Township of North Dumfries Wellhead Protection Areas



Source: MPAC, 2006

Map 6.40: Township of North Dumfries Land Use in Wellhead Protection Areas



Source: MPAC, 2006

Summary

The Township of North Dumfries is predominantly groundwater dependant. The primary threat to groundwater relates to fuel storage, industrial sites and aggregate pits adjacent to the Ayr well capture zone. The Region has identified the need to expand its long term water supply due to growth projections and potential loss of existing supplies to contamination or climate change impacts.

<u>*Township of Wellesley*</u>

System Description

The Region of Waterloo operates three municipal water supply systems within the Township of Wellesley in the communities of Linwood, St. Clements and Wellesley. The municipal water supply consists of 6 raw groundwater well sources and 3 water filtration plants as described in **Table 6.14**.

Table 6.14 Summary table of the Region's Wellesley wells and treatment facilities

Wellfield Name	Description	Disinfection
Linwood (Pop. 801)	Well L1A – 200 mm diameter, 79.5 m deep drilled groundwater production well discharging to WTP then to distribution system	Sodium hypochlorite
	Well L2 – 200 mm diameter, 78.6 m deep drilled groundwater production well discharging to WTP then to distribution system	
St. Clements (Pop. 1,394)	Well SC2 – 200 mm diameter, 20.1 m deep drilled groundwater production well discharging to WTP then to distribution system	Sodium hypochlorite
	Well SC3 – 250 mm diameter, 18.9 m deep drilled groundwater production well discharging to WTP then to distribution system	
Wellesley (Pop. 2,299)	Well WY1 – 200 mm diameter, 49.4 m deep drilled groundwater production well discharging to WTP/Reservoir then to distribution system	Sodium hypochlorite
	Well WY5 – 200 mm diameter, 52.4 m deep drilled groundwater production well discharging to WTP/Reservoir then to distribution system	

Municipal Groundwater Quality

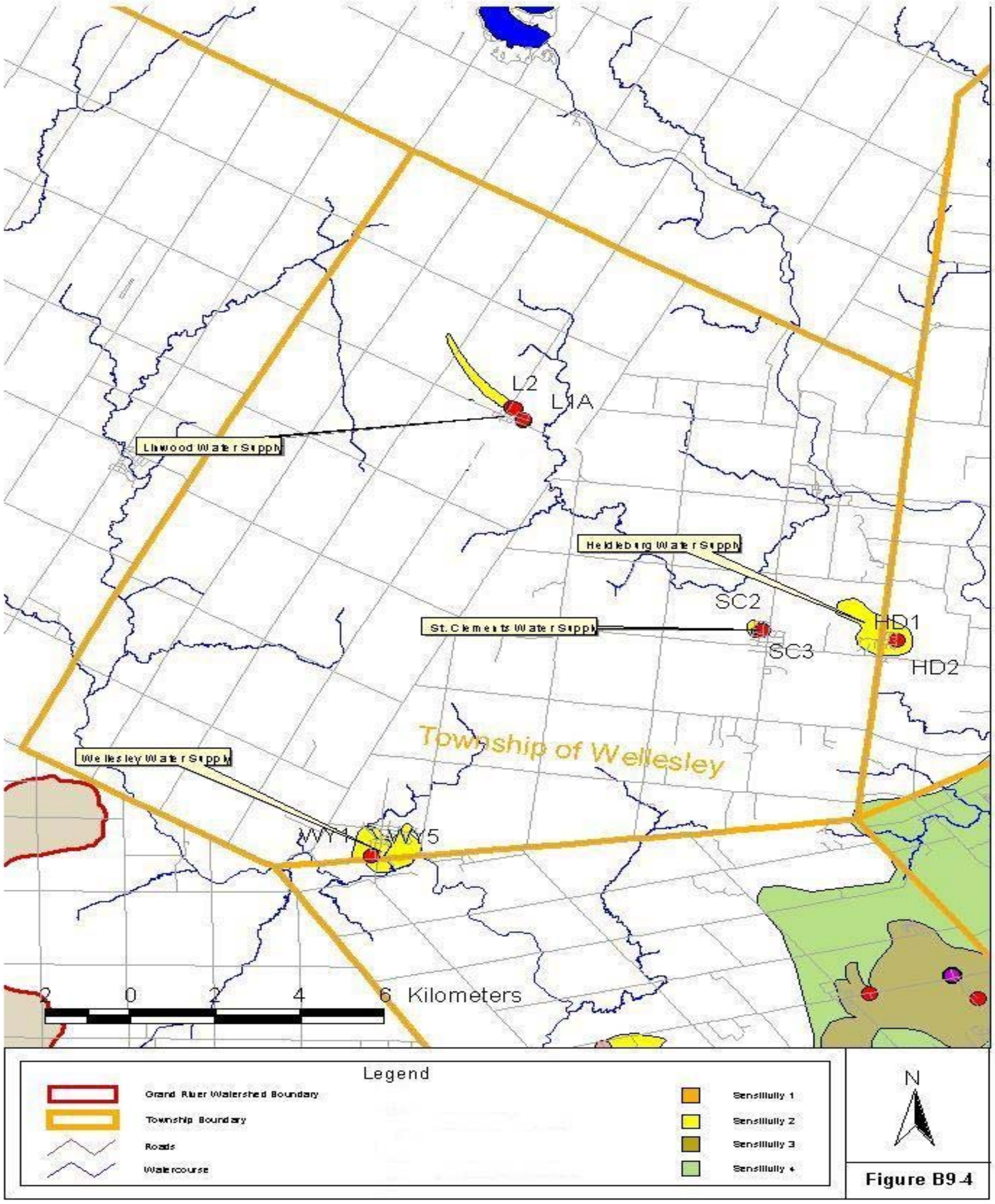
Water quality results in 2006 for the raw water supply wells for Linwood, St. Clements or Wellesley can be accessed through the following link:

<u>*http://www.region.waterloo.on.ca/web/region.nsf/97dfc347666efede85256e590071a3d4/c6b493f902cd2d718525727c005994b9!OpenDocument*</u>

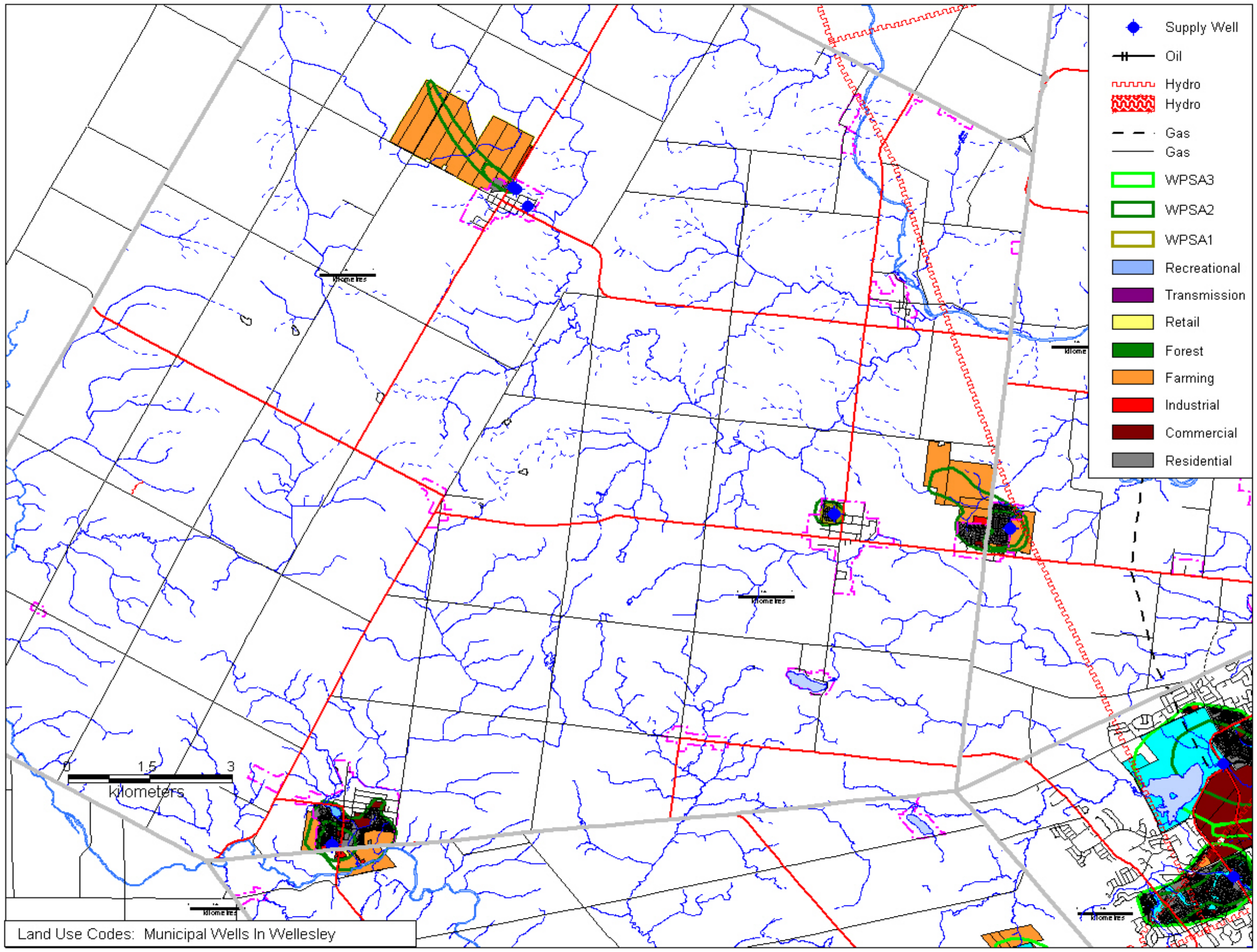
Description of Capture Zones

WHPAs have been developed for the Linwood, St. Clements and Wellesley well fields within the Township. The Region designated all WHPAs within the township as having a Sensitivity 2. This approach was taken for all groundwater systems in the rural townships that do not have backup wells which utilize groundwater from a different source as the main wells. These WHPAs are shown on **Map 6.43**.

Map 6.41: Township of Wellesley Wellhead Protection Areas



Map 6.42: Township of Wellesley Land Use in Wellhead Protection Areas



Source: MPAC, 2006

<u>*Linwood*</u>

The Linwood wells draw water from the Salina Formation, the uppermost bedrock formation in the area (RMOW, 2001). The WHPA, which extends to the northwest, has been classified as a Sensitivity Zone 2.

<u>*St. Clements*</u>

Two wells, SC2 and SC3, completed in overburden Mannheim Aquifer supply water to St. Clements. Well SC2 is screened 16 to 20 m below ground surface and Well SC3 is screened 15 to 18 m below ground surface (RMOW, 2001). The aquifer these wells pump from behaves in an unconfined nature, suggesting that at this location the aquifer is not confined (Waterloo Hydrogeologic, 2000). The WHPA is fairly small and localized, extending to the west of St. Clements. The 2-year capture zone has been designated as a Sensitivity Zone 1, and the 10-year capture zone as a Sensitivity Zone 2. WHPAs identified as a Sensitivity Zone 1 have the highest risk of being impacted by contaminant spills. These areas are the closest to the well and the subsurface geologic materials allow rapid movement of water (sands and gravel or fractured rock). In these areas it is important that businesses be extra cautious when handling hazardous chemicals and waste; and farmers should limit application of nutrients and manure.

<u>*Wellesley*</u>

The Wellesley wells obtain their water from a sand and gravel aquifer that is in direct contact with the underlying Salina Formation (RMOW, 2001). The aquifer is confined by 30 to 50 m of dense till cover (Waterloo Hydrogeologic, 2000). The WHPA extends outwards laterally in all directions and has been classified as a Sensitivity Zone 2.

Threats within the 25-year Capture Zone

Threats are fairly limited throughout the Wellesley capture zones (**Map 6.42**). The Linwood and St. Clements wells are situated within small residential settlements surrounded by rural agricultural land uses. The Linwood wells are adjacent to a rail siding and some small industrial uses. The capture zone for Wellesley underlies the majority of the community's residential and commercial land use activities. The capture zone is also adjacent to the Wellesley wastewater treatment plant.

Summary

The Township of Wellesley is predominantly groundwater dependant. The primary threat to groundwater commercial land use activities in the Wellesley well capture zone.

<u>*Township of Wilmot*</u>

System Description and Hydrogeologic Setting

The Region of Waterloo operates seven municipal water supply systems within the Township of Wilmot in the communities of Foxboro Green, New Dundee, New Hamburg, St. Agatha and Wilmot Centre. The municipal water supply consists of 8 raw groundwater well sources and 1 water filtration plant as described in **Table 6.15**.

Table 6.15: Summary table of the Region's Wilmot wells and treatment facilities

Wellfield Name	Description	Treatment
Erb Street	See **Table 6.12**	
Foxboro (Pop. 398)	Well FG1 – 200 mm diameter, 67.1 m deep drilled groundwater production well discharging to WTP then to distribution system	Sodium hypochlorite
	Well FG2 – 125 mm diameter, 51.2 m deep drilled groundwater production well discharging to WTP then to distribution system	
	Well FG4 – a 150 mm diameter, 55.5 m deep drilled groundwater production well discharging to WTP then to distribution system	
Manheim (Group 2 – Mannheim West)	See **Table 6.12**	
New Dundee (Pop. 1,132)	Well ND4 – 200 mm diameter, 17.1 m deep drilled groundwater production well discharging to reservoir then to distribution system	Sodium hypochlorite
	Well ND5 – 200 mm diameter, 15.5 m deep drilled groundwater production well discharging to reservoir then to distribution system	
Baden-New Hamburg (Pop. 9,370)	Well NH3 – 300 mm diameter, 76.0 m deep drilled groundwater production well discharging to distribution system	Sodium hypochlorite and ammonium sulphate
St. Agatha (Pop. 83)	Well SA3 – 150/200 mm diameter, 51.8 m deep drilled groundwater production well discharging to distribution system	Sodium hypochlorite
	Well SA4 – 200 mm diameter, 52.1 m deep drilled groundwater production well discharging to distribution system	
Wilmot Centre	See **Table 6.12**	

Municipal Water Quality

Water quality results in 2006 for the raw water supply wells for Wilmot Township can be accessed through the following link:

http://www.region.waterloo.on.ca/web/region.nsf/97dfc347666efede85256e590071a3d4/c6b493f902cd2d718525727c005994b9!OpenDocument

Description of Capture Zones

WHPAs have been developed for the well fields within Wilmot Township. The Region designated all WHPAs within the township as having a Sensitivity 2. This approach was taken for all groundwater systems in the rural townships that do not have backup wells which utilize groundwater from a different source as the main wells. These WHPAs are shown on **Map 6.33**.

Threats within the 25-year Capture Zone

Threats are fairly limited throughout the Wilmot capture zones outside of the IUS (**Map 6.37**). The Foxboro wells are situated within small residential settlements adjacent to recreational land uses. The New Dundee and St. Agatha are adjacent to predominantly farm uses. The capture zone for New Hamburg underlies the majority of the community's residential and commercial land use activities. The capture zone is also adjacent to some farm uses.

Summary

The Township of Wilmot is predominantly groundwater dependant. The primary threat to groundwater relates to commercial activities in the New Hamburg well capture zone.

Township of Woolwich

System Description and Hydrogeologic Setting

The Region of Waterloo operates seven municipal water supply and distribution systems within the Township of Woolwich in the communities of Conestogo, Elmira, Heidelberg, Maryhill and West Montrose. The municipal water supply consists of 14 active raw groundwater well sources and 3 water filtration plants as described in **Table 6.16**. The well for Elmira forms part of the IUS as described previously. Water is treated with sodium hypochlorite, sodium silicate, ammonium sulphate and filtration.

Table 6.16 Summary table of the Region's Woolwich wells and treatment facilities

Wellfield Name	Description	Treatment
Conestoga Golf (Pop. 411)	Well C5 Raw – 150 mm diameter, 17.7 m deep drilled groundwater production well discharging to distribution system	Sodium hypochlorite
	Well C6 Raw – 200 mm diameter, 18.0 m deep drilled groundwater production well discharging to distribution system	
Conestoga Plains (Pop. 367)	Well C3 Raw – 210 mm diameter, 32.3 m deep drilled groundwater production well discharging to reservoir then to distribution system	Sodium hypochlorite
	Well C4 Raw – 210 mm diameter, 32.0 m deep drilled groundwater production well discharging to reservoir then to distribution system	
Elmira	See **Table 6.12**	
Heidelberg (Pop. 1,059)	Well HD1 – 150/200 mm diameter, 60.3 m deep drilled groundwater production well discharging to distribution system	Sodium hypochlorite
	Well HD2 – 150/200 mm diameter, 58.5 m deep drilled groundwater production well discharging to distribution system	
Maryhill (Pop. 160)	Well MH1 – 168 mm diameter, 45.1 m deep drilled groundwater production well discharging to distribution system	Sodium hypochlorite and ammonium sulphate

Table 6.16 Summary table of the Region's Woolwich wells and treatment facilities

Wellfield Name	Description	Treatment
Maryhill Village Heights (Pop. 134)	Well MH2 – 200 mm diameter, 19.5 m deep drilled groundwater production well discharging to distribution system	Sodium hypochlorite
	Well M0H3 – 200 mm diameter, 29.5 m deep drilled groundwater production well discharging to distribution system	
	Well M0H4A – 200 mm diameter, 28.7 m deep drilled groundwater production well discharging to distribution system	
West Montrose (Pop. 182)	Wells WM1,2,3,4 Raw GUDI – 120 mm diameter, 4 m deep horizontal induction/infiltration wells discharging to WTP/reservoir then to distribution system	Sodium hypochlorite and ammonium sulphate

Municipal Water Quality

Water quality results in 2006 for the raw water supply wells for Woolwich Township can be accessed through the following link:

http://www.region.waterloo.on.ca/web/region.nsf/97dfc347666efede85256e590071a3d4/c6b493f902cd2d718525727c005994b9!OpenDocument

Description of Capture Zones

WHPAs have been developed for the well fields within Woolwich Township. The Region designated all WHPAs within the township as having a Sensitivity 2. This approach was taken for all groundwater systems in the rural townships that do not have backup wells which utilize groundwater from a different source as the main wells. These WHPAs are shown on **Map 6.33.**

Threats within the 25-year Capture Zone

With the exception of Elmira, threats to municipal water supply systems are fairly limited throughout the Woolwich capture zones. The Conestoga, Maryhill and West Montrose systems are situated within small residential settlements surrounded by rural agricultural land uses (**Map 6.38**). The capture zones for the Maryhill MH1&2 wells and the Conestogo Plains C3&4 wells are adjacent to properties identified as high potential threats. The West Montrose horizontal induction/infiltration wells have been classified as GUDI wells. As a result the water is treated to address possible impacts from Grand River source water. The capture zone for Heidelberg underlies the majority of the community including several known and high potential threats including the RMOW Heidelberg municipal maintenance facility. The capture zone is also adjacent to the Heidelberg wastewater treatment plant.

Summary

The Township of Woolwich is predominantly groundwater dependant. The primary threat to groundwater (outside of Elmira) relates to fuel storage, salt storage, farm supplies, and metal fabricating materials in several of the well capture zones.

6.3.1.7 County of Oxford

The County of Oxford Phase II Groundwater Protection Study (Golder Associates, 2001) completed a number of tasks including WHPA delineation, vulnerability mapping and the compilation of a regional threats inventory. Since the completion of the Oxford County study, several additional reports have been completed which build upon Golder Associates (2001) original work. These reports include the Additional Aquifer Vulnerability Mapping, Oxford County (Golder Associates, 2003) and the County of Oxford Vulnerability (SWAT) Pilot Study (Golder Associates, 2005).

MODFLOW was used to develop well field-scale groundwater models to delineate 2-, 5-, 10-, and 25-year capture zones for each of the County's municipal well fields. The pumping rates used were dependent on the municipality as to whether current average flows or projected flows were used to model the capture zones. The uncertainty in the capture zone delineation was addressed though the use of 2 correction factors; an expansion of the capture zone by 5 degrees from the centerline and an increase of 20% from the centerline of the capture zone.

In the County of Oxford's Phase II Groundwater Protection Study, a vulnerability assessment was completed for each of the 4 aquifer units in the study area. For each major aquifer, a numerical score related to the hydraulic conductivity of the material in the stratum overlying the aquifer was multiplied by the thickness of the stratum to which it was assigned. The resulting products for each of the strata overlying the aquifer were summed to give the vulnerability score for that well location. Following the calculation of the vulnerability scores, the scores were classed according to high (< 30), moderate (30 – 80) and low vulnerability (> 80). These results were then interpolated across the study area to create 4 vulnerability maps for the shallow overburden aquifer, intermediate overburden aquifer, deep overburden aquifer and bedrock aquifer.

From these 4 maps, a composite groundwater vulnerability map was generated by mapping the first aquifer encountered at each well location. For much of the County, this was the shallow aquifer. In areas where the shallow aquifer was not present, the vulnerability for the next aquifer encountered was mapped. If no overburden aquifers were present, the vulnerability rating for the composite map was derived from the bedrock aquifer.

Additionally a potential contaminant sources inventory was compiled on a regional basis using existing databases. The County also completed a detailed inspection and land use inventory within municipal well capture zones which involved field inspections and the identification of various land uses and potential sources of contaminations associated with the various land uses. Each land use was mapped according to its risk rating adapted from the USEPA and was provided to the County for internal use. Intensive livestock operations were also mapped County-wide using existing Nutrient Management Plans.

Since the completion of the Phase II Groundwater Protection Study, a second vulnerability map has been generated (Golder Associates, 2003) using the MOE's ISI methodology (refer to Land Use Policy Branch, 2001). The approach used the 'first significant aquifer' only and the resulting map was less conservative than the mapping completed as a part of the Phase II Groundwater Protection Study.

In 2005, the County of Oxford completed a pilot surface to well advection time (SWAT) analysis for the Ingersoll, Woodstock, Tillsonburg and Norwich wellfields (Golder Associates, 2005). The conclusions of this study found the SWAT calculations provided a reasonable means of quantifying the relative vulnerability of the supply aquifers. In July of 2006 staff from the GRCA met with County of Oxford staff to discuss high level threats to the municipal groundwater supply as summarized in **Table 6.17**. As a component of Source Protection Planning, the County of Oxford is currently undertaking a project to update the threats inventory within all County WHPAs and, to a lesser extent, within identified highly vulnerable areas. This project is expected to take 12 months to complete.

Township of Blandford-Blenheim

Within the Township of Blandford-Blenheim, four groundwater-dependent communities, Bright, Drumbo, Plattsville and Princeton (which currently receives groundwater delivered in tanker trucks from Woodstock) are located within the Grand River watershed.

Bright

System Description

The Bright Well Supply consists of two groundwater wells and a pumphouse with a 76 m3 reservoir for storage. Upgrades including an additional pumphouse for chemical treatment were installed in 2005.

Water treatment for the Bright system consists of the addition of sodium hypochlorite and sodium silicate to the raw groundwater prior to distribution (Bright MOE Drinking Water Systems Regulation O. Reg. 170/03, Annual Report, 2005).

Municipal Groundwater Quality

According to the Bright Drinking Water Systems Regulations Annual Report for 2005, no groundwater quality exceedances were reported over the course of 2005.

Table 6.17: High Level Threats in the County of Oxford

	Groundwater
Direct Introduction	
Water treatment plant wastewater discharge	none
Sewage treatment plant effluent	Drumbo discharges to a dry ditch that outlets to the Nith River Plattsville has a seasonal outlet to the Nith River
Sewage treatment plant by-passes	Any by-pass is managed in accordance with MOE requirements
Industrial effluents	Sandpaper plant in Plattsville
Landscape Activities	
Road salt application	County salt storage facility in Drumbo is outside of WHPAs County applies salt/sand to County roadways as required
De-icing activities	none
Snow storage	none
Cemeteries	No cemeteries likely within the WHPAs
Stormwater management systems	None within WHPAs

Table 6.17: High Level Threats in the County of Oxford

	Groundwater
Landfills	Abandoned landfill sites identified in County Official Plan No active landfills located in GRCA WHPAs
Organic soil-conditioning	None within GRCA WHPAs
Septage application	Private haulers mostly delivering septage to WWTP's
Hazardous waste disposal	Rotating HHW programs for residential collection
Liquid industrial waste	none
Mine tailings	none
Biosolids application	Application within 2-yr TOT of a municipal well is not allowed
Manure application Fertilizer application Pesticide / herbicide application	Agricultural applications are used widely in the County Nutrient Management Act dictates manure control for some Livestock operations Crop activities predominate in the southern sand plains Livestock operations typically in north end of the County
Historical activities – contaminated Lands	Official Plan identifies some historical activities in all three large urban centres Little within GRCA WHPAs
Storage of Potential Contaminants	
Fuels / hydrocarbons	Truck stop at 401 and Cty. Rd. #3
DNAPL's (dense non-aqueous phase liquids) Organic solvents Pesticides (of concern to drinking water) Fertilizers Manure	Source Protection Study will focus on property level threats

Description of Capture Zones

Within the community of Bright, capture zones were completed for the Hewitt and Piggott wells. Capture zones for these wells, modelled as a part of the Phase II County of Oxford Groundwater Protection Study, are shown on **Map 6.43**. Two-, 5-, 10-, and 25-year capture zones were modelled using current, average pumping rates (Golder Associates, 2001). Wells BW1 and BW2 (Baird Wells), also shown on Map 66, were removed from service as of 2001, and therefore do not have capture zones. The capture zones for the Hewitt and Piggott wells extend northwards, with a slight curve to the north-west. The Piggott well has a much longer 25-year capture zone than the Hewitt well, extending about 3 km from the well. The Hewitt well was abandoned in 2002. A replacement well was constructed in 2004/05 in the vicinity of the Piggott well.

Vulnerable Areas within the 25-year Capture Zone

The primary municipal supply aquifer for Bright was identified as the Intermediate Aquifer by Golder Associates (2001). The vulnerability of the Intermediate Aquifer across the County of Oxford is shown on **Map 6.44**. In the vicinity of Bright, the vulnerability of the Intermediate Aquifer has been mapped as mainly low to medium susceptibility to contamination.

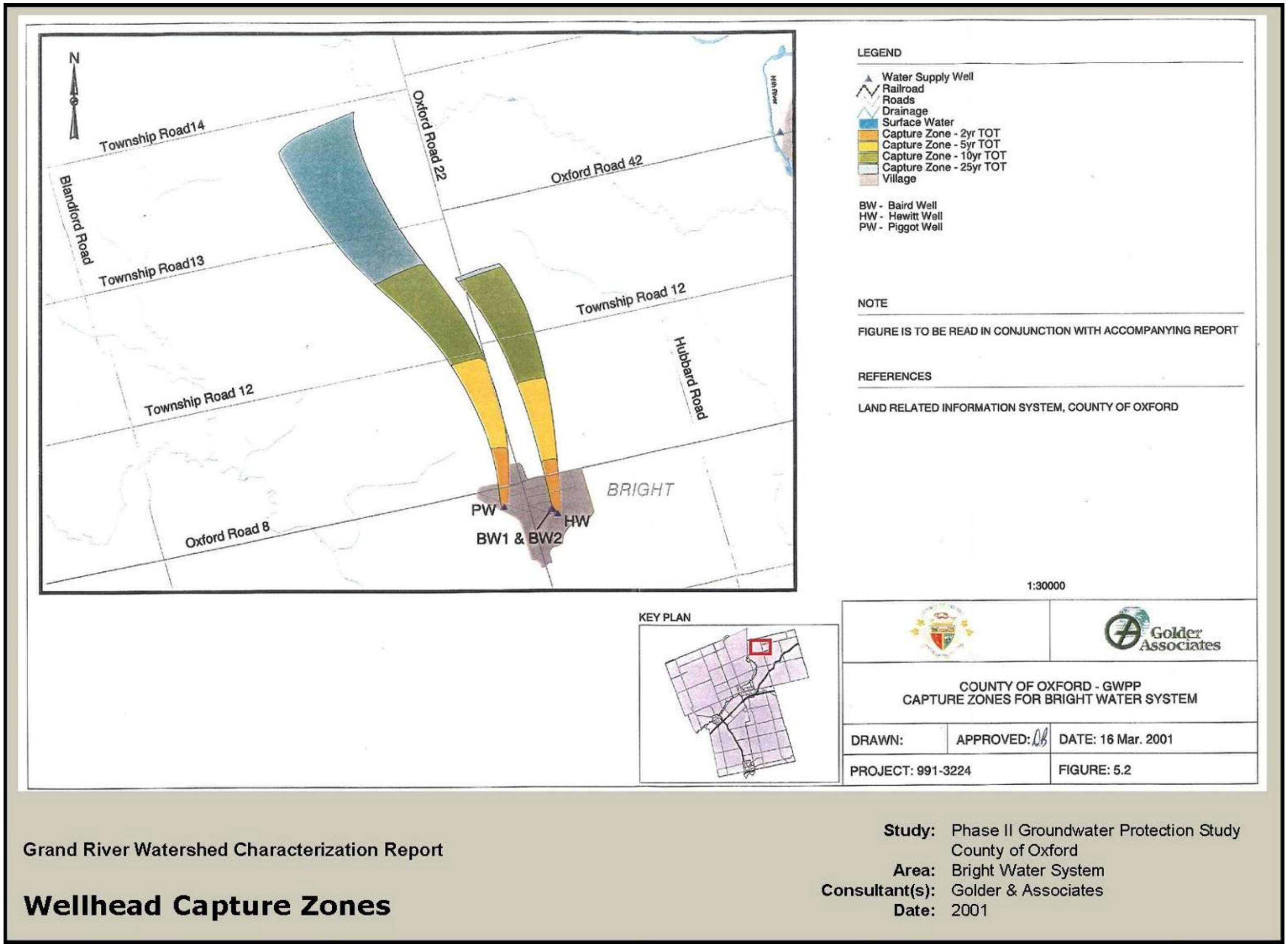
Threats within the 25-year Capture Zone

Threats that were mapped on a County-wide basis are shown on **Map 6.45** (Golder Associates, 2001). Within Bright's capture zone, a petroleum well, an intensive livestock operation and a UST were identified. The County of Oxford is currently managing a study to inventory threats within Bright's 25-year capture zone.

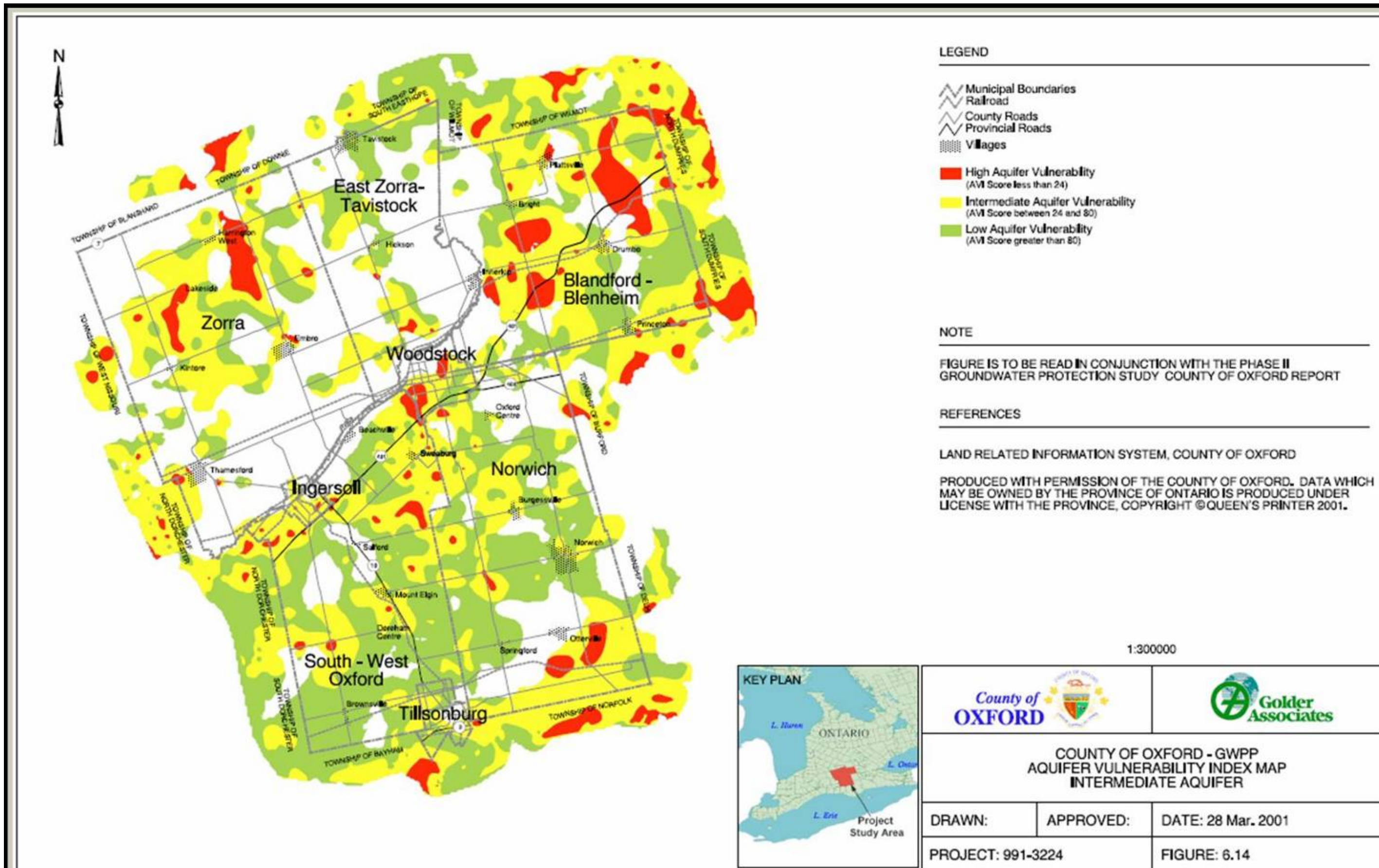
Summary

The Village of Bright is groundwater dependant. Threats range from rural land use activities (petroleum wells, septic systems, and livestock) and underground storage in the village. The vulnerability of the source in the Intermediate Aquifer has been mapped as low to medium susceptibility to contamination. The village wells are reaching capacity limits and the County has considered the need for expanding its water supplies, but has not yet completed a long term water supply strategy. The County of Oxford is considered a leader in well head protection and has conducted a number of provincial pilot studies. They have completed a variety of groundwater studies to map well head protection areas, identify regional threats to existing water supplies develop strategies for well head protection.

Map 6.43: Wellhead Capture Zones in Bright, Oxford County



Map 6.44: Intermediate Aquifer Vulnerability in the County of Oxford

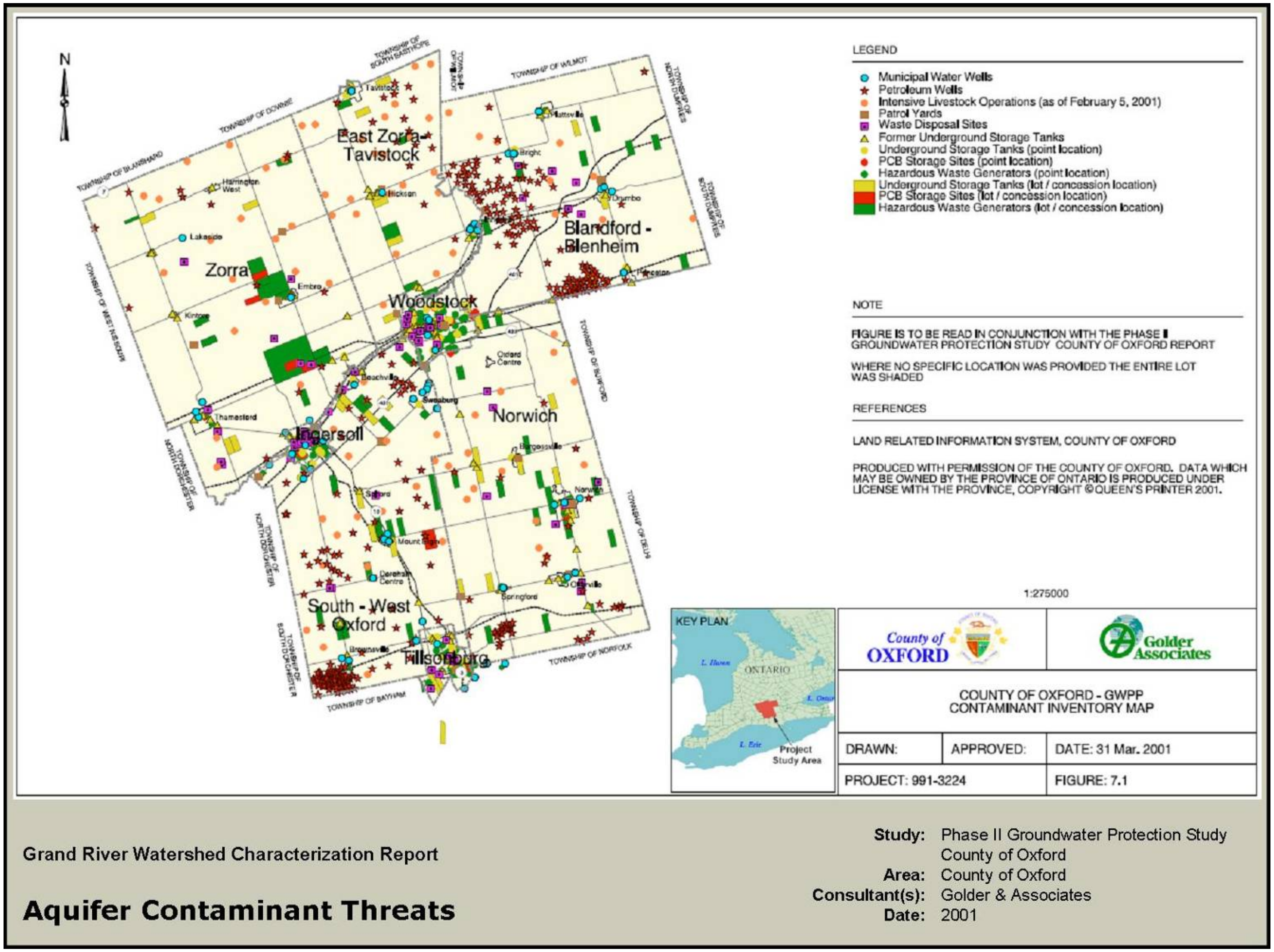


Grand River Watershed Characterization Report

Aquifer Vulnerability – Intermediate Aquifer

Study: Phase II Groundwater Protection Study County of Oxford
Area: County of Oxford
Consultant(s): Golder & Associates
Date: 2001

Map 6.45: Aquifer Contaminant Threats in the County of Oxford



Drumbo

System Description and Hydrogeologic Setting

The community of Drumbo is supplied by groundwater from two wells which tap a deep, semi-confined, overburden aquifer. The system consists of the wells, pumphouse and 450 m3 reservoir for storage. The water system services an estimated population of 510 people (Drumbo MOE Drinking Water Systems Regulation O. Reg. 170/03, Annual Report, 2004). Glaciofluvial ice contact deposits are the principal surficial Quaternary geology formations surrounding the community of Drumbo. Treatment for the Drumbo water supply system consists of the addition of sodium hypochlorite to the raw water (Drumbo MOE Drinking Water Systems Regulation O. Reg. 170/03, Annual Report, 2005).

Municipal Groundwater Quality

According to the Drumbo Drinking Water Systems Regulations Annual Report for 2005, no groundwater quality exceedances were reported over the course of 2005.

Description of Capture Zones

Capture zones for Drumbo's municipal wells are shown on **Map 6.46**. At the time the capture zones were modelled, 3 wells serviced the community. There are three municipal wells in Drumbo. Well 1 has never been connected to the system but is planned for connection in 2007/08. Well 2 was taken offline in order to be rehabilitated. The rehabilitation is complete and the well is back online. The capture zones shown on **Map 6.46** extend in a northwesterly direction, north of the village, through residential and agricultural properties and across Highway 401. The projected population growth for Drumbo and increase in water use demand at the time the capture zones shown in **Map 6.46** were modelled was 30%. Therefore, the pumping rate for the Drumbo supply wells used to forecast the time-related capture zones was increased by 30% compared to rates estimated for 1999 (i.e. 197 m^3/day).

Vulnerable Areas within the 25-year Capture Zone

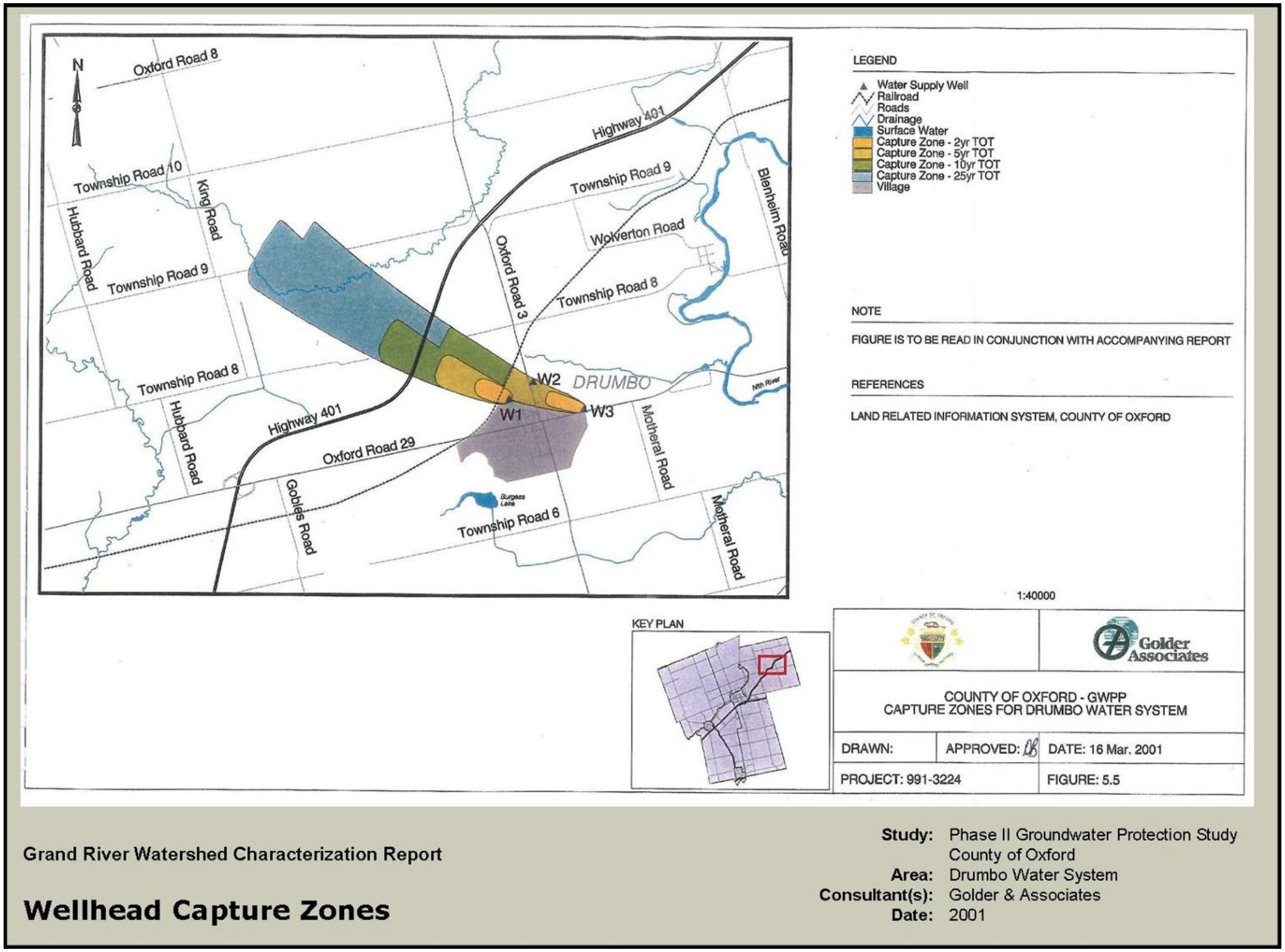
County-wide vulnerability mapping for the Deep Aquifer is shown on **Map 6.47**. In the vicinity of Drumbo, this aquifer has been mapped as having a low vulnerability to contamination from surficial sources.

Threats within the 25-year Capture Zone

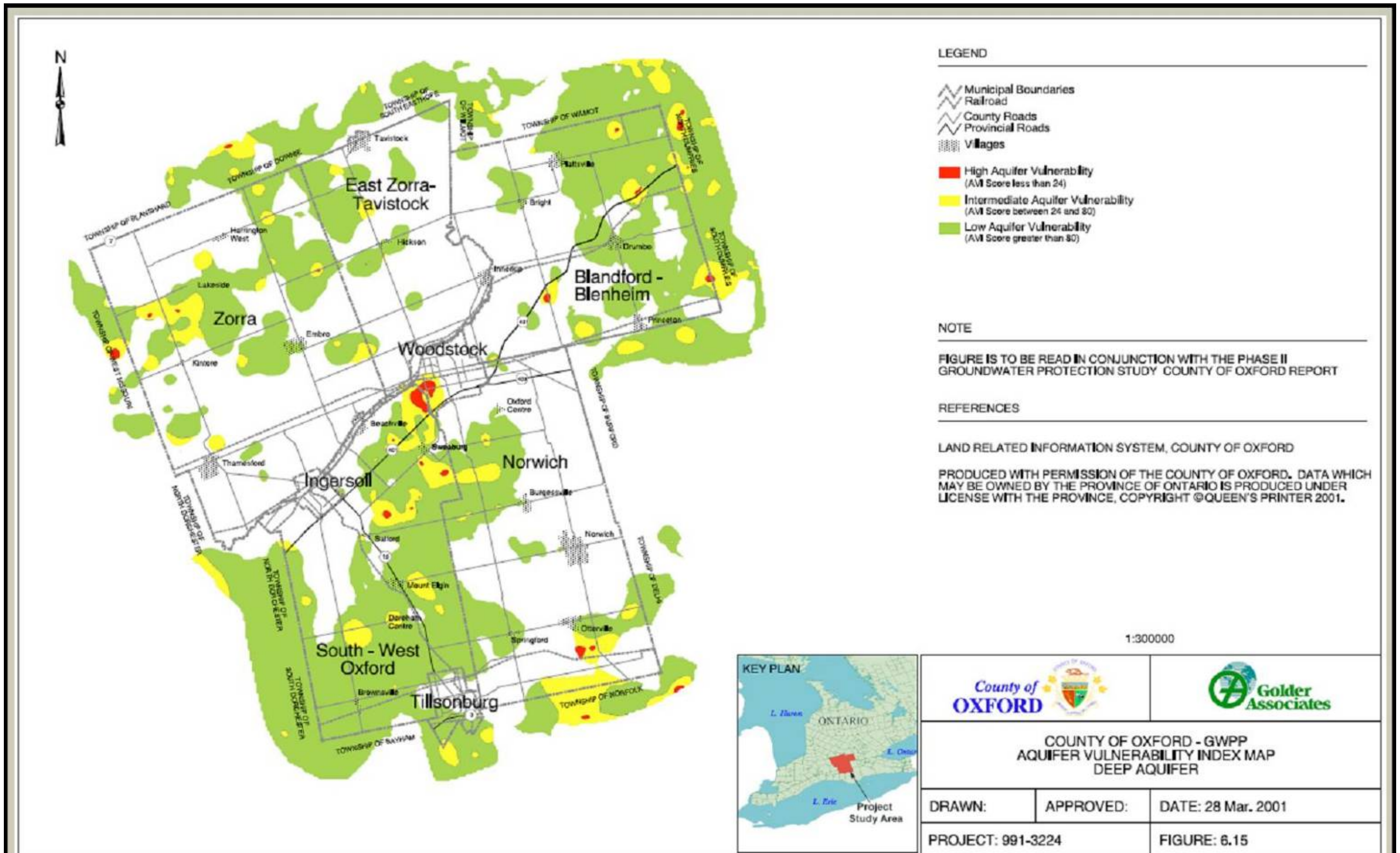
Golder Associates (2001) inventoried potential contaminant sources within Drumbo's 25-year capture zones (**Map 6.46**) and found a patrol yard located immediately north of the ten year capture zone for Well 2. The yard contained two identified USTs, covered sand and salt storage, a parked fuel transport truck, ASTs and a shed used for chemical storage.

The County of Oxford is currently managing a study to inventory threats within Drumbo's 25-year capture zones.

Map 6.46: Wellhead Capture Zones in Drumbo, County of Oxford



Map 6.47: Deep Aquifer Vulnerability in the County of Oxford



Grand River Watershed Characterization Report

Aquifer Vulnerability – Deep Aquifer

Study: Phase II Groundwater Protection Study County of Oxford
Area: County of Oxford
Consultant(s): Golder & Associates
Date: 2001

Summary

The Village of Drumbo is groundwater dependant. Threats range from developed activities (UST's, patrol yard, waste disposal site) to rural land use activities (septic systems, livestock operations). The vulnerability of the source in the Intermediate Aquifer has been mapped as low susceptibility to contamination. The in-service wells are approaching capacity limits and the County is planning to bring the existing unconnected well online in 2007/08. The County is also planning to connect a pipeline from Drumbo to Princeton in 2010 to eliminate the need for the trucked in water that was required when the Princeton wells were abandoned due to bacteria problems in 2003. The County of Oxford is considered a leader in well head protection and has conducted a number of provincial pilot studies. They have completed a variety of groundwater studies to map well head protection areas, identify regional threats to existing water supplies develop strategies for well head protection.

<u>Plattsville</u>

System Description and Hydrogeologic Setting

Within the community of Plattsville, 2 wells service an estimated population of 1,146 people (Plattsville MOE Drinking Water Systems Regulation O. Reg. 170/03, Annual Report, 2004). The water system consists of the two wells, a pump house and a 1,590 m^3 water standpipe. The standpipe will be replaced with a 2050 m^3 water storage tower in 2007.

These 2 wells, completed at depths ranging from 12 to 15 m below ground surface, tap an unconfined, shallow overburden aquifer (Golder Associates, 2001). The area surrounding the community of Plattsville is underlain by extensive glaciofluvial outwash sand and gravel deposits that generally follow the floodplain of the Nith River. Within the Plattsville area, the shallow overburden aquifer that is tapped by the municipal wells is underlain by 20 to 30 m of silt and clay sediments which are underlain by bedrock (Golder Associates, 2001).

Municipal Groundwater Quality

Groundwater quality exceedances as reported in the Plattsville Drinking Water Systems Regulations Annual Report for 2005 are summarized in **Table 6.18**, exclusive of operational issues that do not relate to source protection.

Table 6.18: Groundwater Quality Exceedances in the Plattsville Drinking Water Systems (2005)

Incident Date	Parameter	Result	Corrective Action	Corrective Action Date
Feb 9/05	Total Coliform	> 0 1 Colonies/ 100 ml	Report, resample	Feb 10/05
July 7/05	Background bacteria >200 colonies/100 ml	1200 Colonies/ 100 ml	Report, resample	July 8/05
July 28/05	Background bacteria >200 colonies/100 ml	550 Colonies/ 100 ml	Report, resample	July 28/05

Description of WHPAs

The capture zone delineated for Plattsville Wells 1 and 2 is illustrated on **Map 6.48**. The capture zone extends to the northeast into the western developed area of the village. The projected population growth in the Plattsville area is 20%. Therefore, the pumping rate for the Plattsville water supply wells used to forecast the time-related capture zones shown on **Map 6.48** was increased by 20% compared to the 1999 rate (Golder Associates, 2001).

Vulnerable Areas within the 25-year Capture Zone

County-wide vulnerability mapping for the Shallow Overburden Aquifer is shown on **Map 6.49**. In the vicinity of Plattsville, this aquifer has been mapped as having a high vulnerability to contamination from surficial sources.

Threats within the 25-year Capture Zone

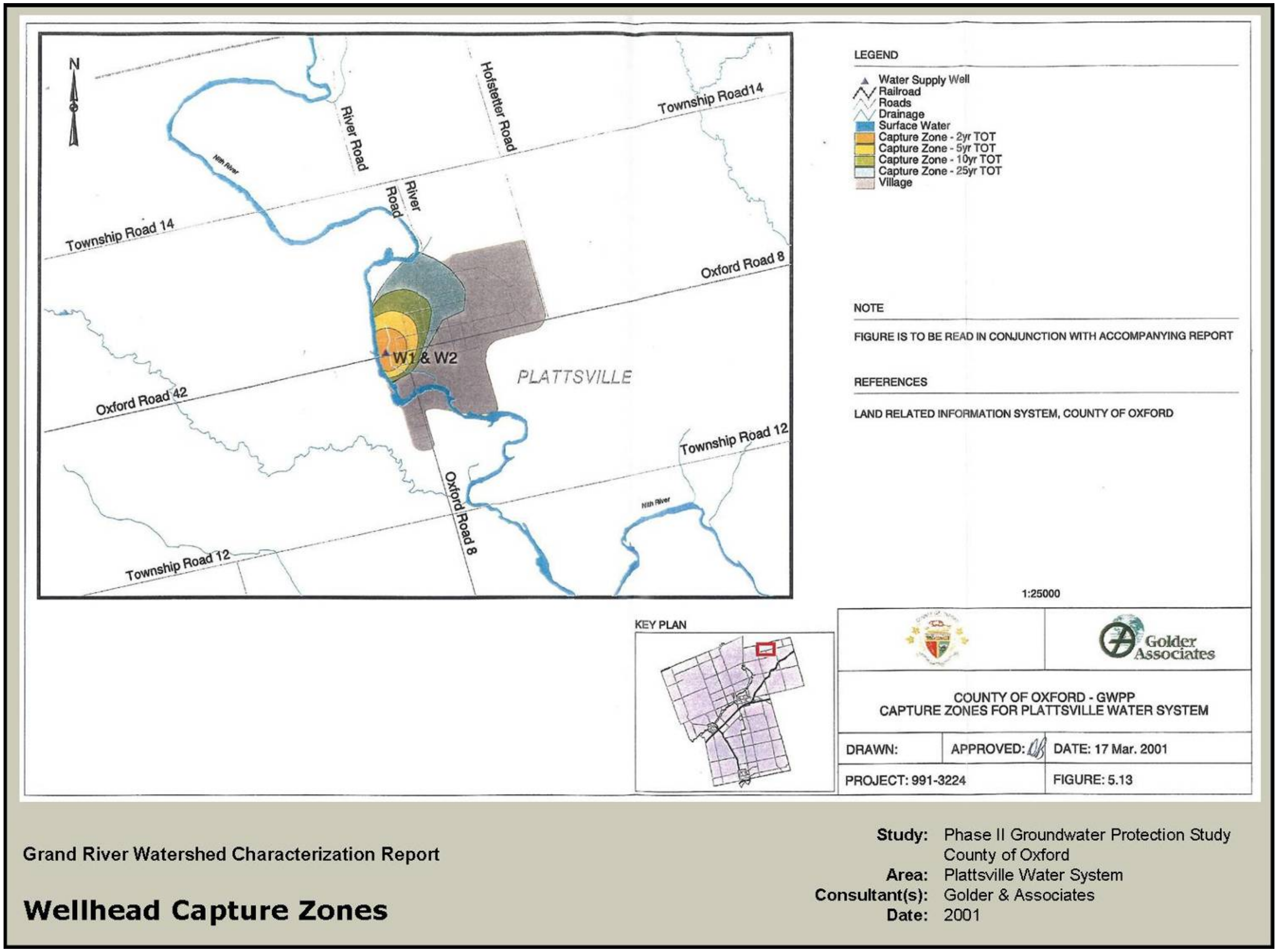
Land uses, as compiled by Golder Associates (2001) within the capture zone include a feed mill, automotive service station, a manufacturing facility, commercial, residential and agricultural properties (**Map 6.45**). A fuel storage shed was identified adjacent to the well pumphouse.

The County of Oxford is currently managing a study to inventory threats within Plattsville's 25-year capture zones.

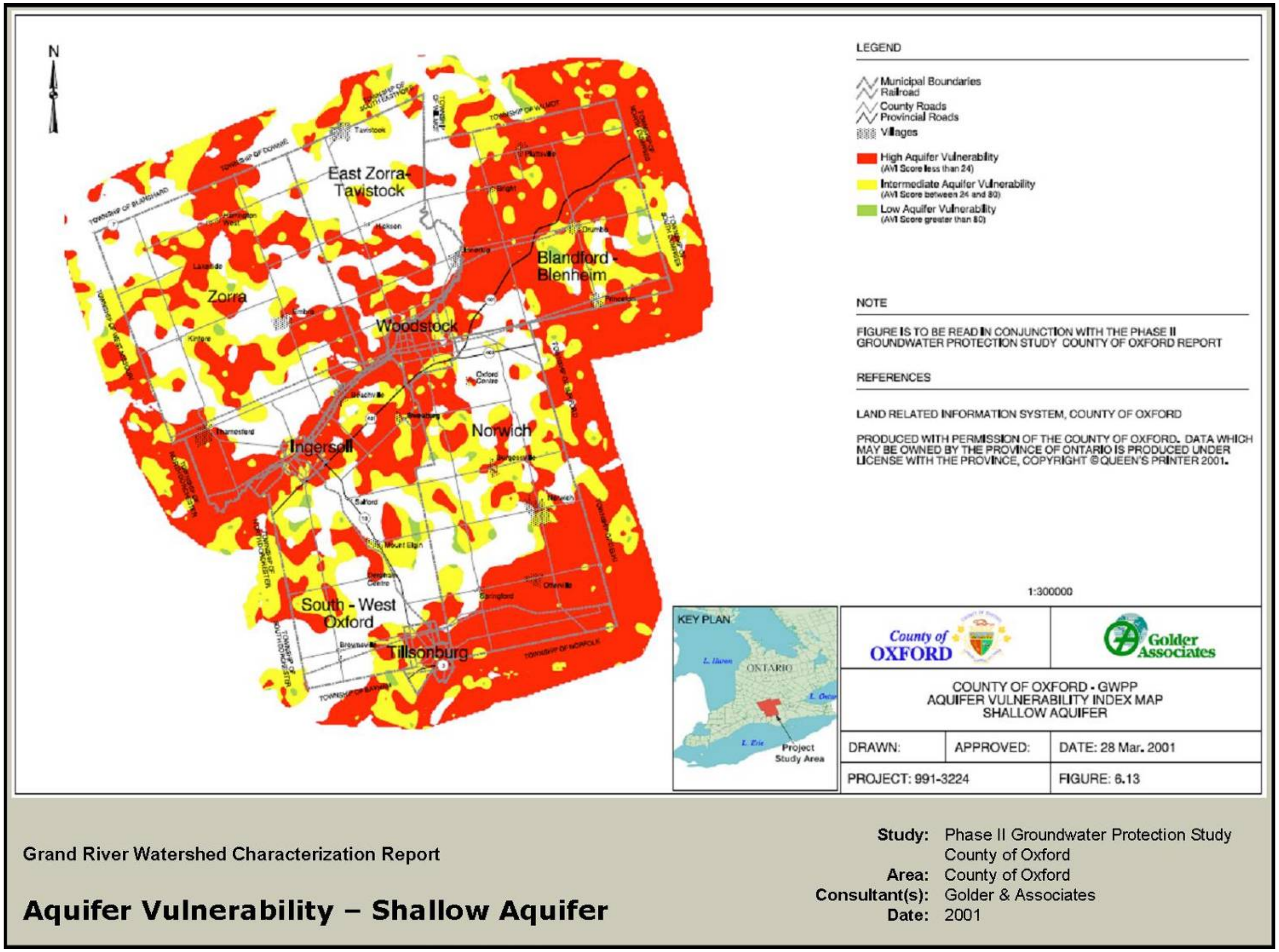
Summary

The Village of Plattsville is groundwater dependant. Threats range from historic activities (UST's, waste disposal site) to rural land use activities (septic systems, agriculture). In the vicinity of Plattsville the vulnerability of the supply aquifer has been rated as highly vulnerable to contamination from surficial sources. In 1999 the County completed a Class EA water and wastewater supply study that determined there is sufficient capacity in the existing water system for the 20 year planning horizon. The County of Oxford is considered a leader in well head protection and has conducted a number of provincial pilot studies. They have completed a variety of groundwater studies to map well head protection areas, identify regional threats to existing water supplies develop strategies for well head protection.

Map 6.48: Wellhead Capture Zones in Plattsville, County of Oxford



Map 6.49: Shallow Aquifer Vulnerability in the County of Oxford



6.3.1.8 County of Brant

Within the County of Brant, four groundwater-based communities, Paris, St. George, Mount Pleasant and the Brant Airport, are located within the Grand River watershed.

Town of Paris

System Description

The community of Paris is supplied by two well fields: Gilbert and Telfer. As of 1998, the Paris groundwater supply system serviced an estimated population of 8,500 people (Bellamy and Boyd, 2005). Within the Paris area, there are three general hydrogeologic units: an upper, unconfined aquifer, an intermediate unit that has been characterized as an aquitard (primarily glacial till consisting of Catfish Creek and Port Stanley Till units) with some aquifer units within it, and a lower bedrock aquifer. These two aquifer units form the two groundwater supply sources for Paris (Lotowater, 2004).

The Gilbert well field consists of 4 wells; 2 wells are completed in a shallow, unconfined overburden aquifer at depths of approximately 13 m and 2 wells are completed in the bedrock (Salina Formation) at depths of approximately 33 and 36 m. The wells pump into a 2-cell reservoir system, and from the reservoir, water is pumped into the Paris distribution system.

Three wells comprise the Telfer well field, P31, P32 and P36. Well P31, which is a bedrock well, is located inside the Telfer pumphouse. P32, also a bedrock well, is located outside the pumphouse and P36, an overburden well, is located approximately 300 m north of the pumphouse (Paris Drinking Water Systems Regulation O. Reg. 170/03, Annual Report, 2004). As of December 2005, Well P36, which has a Permit to Take Water, had not yet been equipped with a pump and connected to the distribution system.

Raw water at both the Gilbert and Telfer well fields is treated with a 12% sodium hypochlorite solution and a 25% hydrofluorosilicic acid solution (Paris Drinking Water Systems Regulation O. Reg. 170/03, Annual Report, 2005).

Municipal Groundwater Quality

In 2005, one sampling event at the Gilbert wellfield resulted in a total coliform count of 1 CFU. The water was resampled as a corrective action. There were no exceedances reported for the Telfer wellfield in 2005 according to the Paris Drinking Water Systems 2005 Annual Report.

Water quality data for the Gilbert wellfield has shown nitrate concentrations in the upper aquifer wells to range from approximately 9 to 11 mg/L. Chloride concentrations are approximately 60 mg/L and there have been no detections of volatile organic compounds or pesticides in the raw water (Lotowater, 2004).

At the Telfer wellfield, water quality monitoring described in Lotowater (2004) indicates that nitrate concentrations at Well P31 were between 10 and 12 mg/L and at Well P32, nitrate concentrations were from 7 to 8 mg/L. Both wells are completed in bedrock. Chloride concentrations were reported to range from 15 to 45 mg/L.

Description of Capture Zones

As shown on **Map 6.50**, capture zones for the Gilbert and Telfer wellfields extend in a northwesterly direction. The Grand River has been interpreted to be a regional hydraulic boundary for both municipal supply aquifers.

Vulnerable Areas within the 25-year Capture Zone

The 2 wells in the Gilbert wellfield (Paris) that are completed within the upper overburden aquifer have a relatively high vulnerability to surface or near surface contaminants due to the absence of an overlying aquiftard. The Gilbert wells which are completed in the bedrock aquifer are much less susceptible to contamination as a result of the presence of an overlying aquitard.

The wells at the Telfer site have been reported to be moderately vulnerable to surface sources of contamination (Lotowater, 2004). The presence of an intermediate aquitard overlying the municipal wells has a slightly higher sand content in the vicinity of the Telfer wells, which may allow for the downward migration of surficially-sourced contaminants into the underlying supply aquifer.

Vulnerability of the first significant aquifer, as shown on **Map 6.51**, has been ranked as highly susceptible to surficial sources of contamination in the Paris area.

Threats within the 25-year Capture Zone

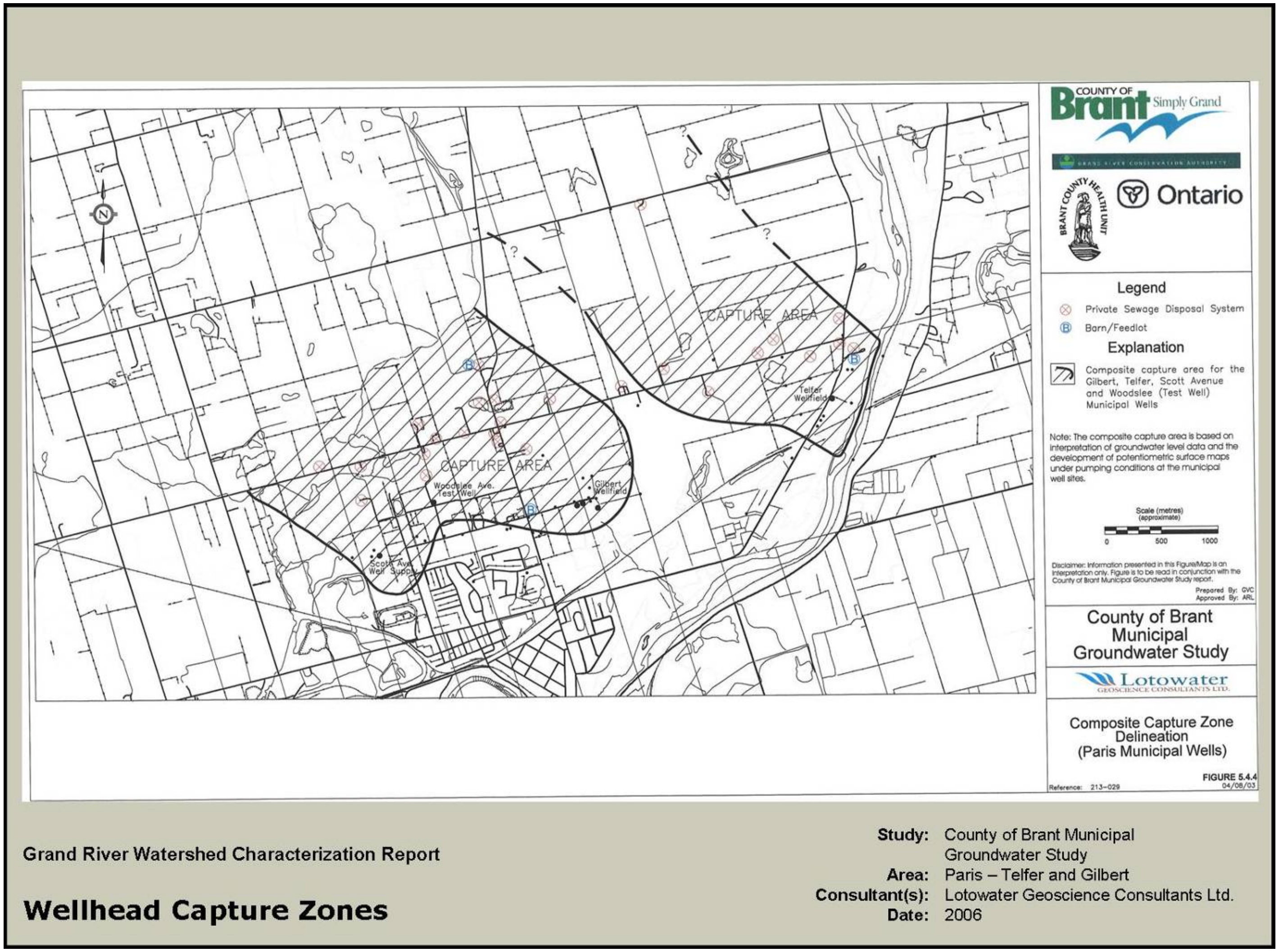
Potential contaminant sources within the 25-year capture zones were inventoried and mapped as a part of the County's municipal groundwater study (Lotowater, 2004).

Within the Gilbert wellfield's 25-year capture zone, there are 2 livestock operations (one active, one inactive), septic systems serving approximately 11 locations, potential spills or leaks in the eastern portion of the industrial lands located between Scott Avenue and Woodslee Avenue, potential spills in Grand River Street North and the application of de-icing chemicals on Grand River Street North. Surface water from Charlie Creek may also be leaking into the upper aquifer.

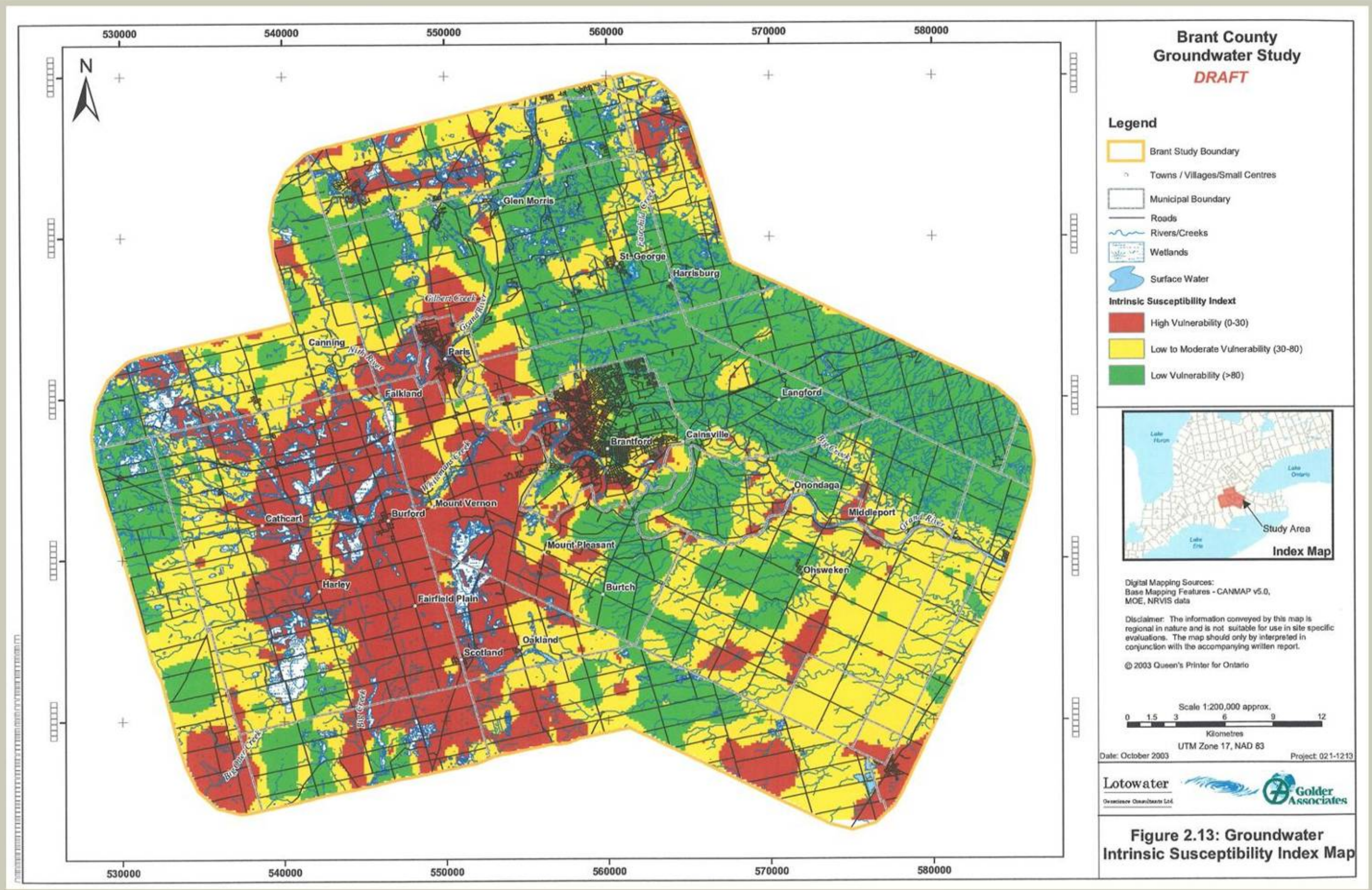
Potential contaminant sources within the Telfer wellfield's 25-year capture zone include one livestock operation located approximately 500 m of the municipal wells and septic systems which serve approximately 9 locations within the capture zone. **Map 6.50** (Lotowater, 2006) illustrates a number of the potential threats within the Gilbert and Telfer wellfields' capture zones.

Non-point sources of potential contamination in the Gilbert and Telfer capture zones include fertilizer and pesticide application on farm fields.

Map 6.50: Wellhead Capture Zones in Paris (Telfer and Gilbert), Brant County



Map 6.51: Aquifer Contaminant Vulnerability in the County of Brant



Grand River Watershed Characterization Report

Aquifer Contaminant Vulnerability

Study: County of Brant Municipal Groundwater Study
Area: County of Brant
Consultant(s): Lotowater Geoscience Consultants Ltd.
Date: 2006

In June of 2006 staff from the GRCA met with County staff to discuss high level threats to the municipal groundwater supply as summarized in **Table 6.19**.

Table 6.19: High Level Threats in the Town of Paris

	Groundwater
Direct Introduction	
Water treatment plant wastewater discharge	None
Sewage treatment plant effluent	Paris (north) and adjoining County residential septic systems
Sewage treatment plant by-passes	Several sewage pumping stations in Paris (upgrade to main P.S. is pending)
Industrial effluents	N/W Paris industrial park has food processing and cabinet manufacturing industries
Landscape Activities	
Road salt application	County has open road salt storage in Mt. Pleasant Gilbert Wells in Paris (GUDI) are at risk from chlorides
De-icing activities	County considering pre-wetting systems
Snow storage	None
Cemeteries	None
Stormwater management systems	Some infiltration and some wet ponds in Paris
Landfills	Paris landfill is closed Former CN landfill (in Paris?) has some leaching problems Active Biggar's Lane landfill is in SE quadrant of the County
Organic soil-conditioning	None
Septage application	Septage goes to Brantford WWTP
Hazardous waste disposal	HHW days held once/year
Liquid industrial waste	None
Mine tailings	None
Biosolids application	None
Manure application Fertilizer application Pesticide / herbicide application	No manure application within 300m of (GUDI) Gilbert wells County does not apply pesticides/herbicides on own property No programs for urban pesticide/herbicide reductions
Historical activities – contaminated lands	Mostly old gas stations
Storage of Potential Contaminants	
Fuels / hydrocarbons	None
DNAPL's (dense non-aqueous phase liquids)	One PCB site located just south of Gilbert Well
Organic solvents	None
Pesticides (of concern to drinking water)	None
Fertilizers	None
Manure	None

Summary

The Town of Paris is dependant on groundwater as its sole source of municipal water supply. The municipal supply aquifers have been identified as being moderately to highly susceptible to contamination from surficial sources. Primary threats to the municipal water supply range from natural characteristics of the water (iron and sulphates in the bedrock) to developed land use activities (septic systems, agriculture, winter control chemicals and spills). The

County of Brant has identified the need to expand its long term water supply due to growth projections and potential loss of existing supplies to contamination but has not completed a long term strategy. The County has conducted a number of groundwater studies to identify threats to existing water supplies develop strategies for wellhead area protection and is currently assessing threats and the vulnerability of the bedrock municipal supply aquifer.

Villages of St. George, Mount Pleasant and Brant Airport

System Description and Hydrogeologic Setting

Three well fields, Airport, St. George and Mount Pleasant, provide groundwater to communities within the County of Brant. The Airport location consists of 1 well, the St. George well field consists of 3 wells, and the Mount Pleasant well field consists of 2 wells.

The population serviced by the Airport groundwater supply consists of approximately 200 homes and 20 commercial/industrial units (County of Brant, Airport Well Supply, Drinking Water Systems Regulation O. Reg. 170/03). The water supply system at the Airport site consists of 1 well with a vertical turbine pump, a storage reservoir, a high lift pump station with two supply pumps, two fire pumps, one emergency supply pump, disinfection facilities consisting of two sodium hypochlorite storage tanks, two sodium hypochlorite metering pumps and a distribution system. Twelve percent sodium hypochlorite is used to disinfect the water. The Airport well is completed in an unconfined sand and gravel aquifer. At the production site, the aquifer is approximately 25 m thick and contains a significant component of coarse sand and gravel. Lotowater (2005) suggested that this aquifer is laterally continuous in the vicinity of the Airport well and can be correlated with the aquifer that exists at the Mount Pleasant well site.

The St. George well field supplies water to the former village of St. George and services approximately 1,200 people and local industries (County of Brant, Airport Well Supply, Drinking Water Systems Regulation O. Reg. 170/03). The St. George wells, which flow under non-pumping conditions, are completed in a sand and gravel aquifer. The water supply system consists of the 3 wells located in one pumping station, disinfection facilities consisting of 2 sodium hypochlorite storage tanks and 2 metering pumps, a chlorine contact chamber, an elevated water storage tank, a stand pipe and the distribution system. Twelve percent sodium hypochlorite is used to disinfect the raw water.

The Mount Pleasant groundwater supply provides water to the community of Mount Pleasant and the Tutela Heights area. The Mount Pleasant well field consists of 2 wells completed in a sand and gravel aquifer that exists under confined to semi-confined conditions in the vicinity of the well site. The water supply system consists of 2 wells located in 2 side-by-side pumping stations, an in-ground reservoir, high lift pumps, a bulk water supply station and the distribution system. Raw water is treated with a 12% sodium hypochlorite solution for disinfection.

Municipal Groundwater Quality

No water quality exceedances were reported for the Airport well in the Drinking Water Systems Regulations 2005 Annual Report.

Water quality data, as reported by Lotowater (2004), indicated that volatile organic compounds and pesticides have not been detected at the Airport well, and both chloride and nitrate concentrations are very low (21 mg/L and 4 mg/L respectively).

In the Drinking Water Systems Regulations 2005 Annual Report for the St. George system, one water quality occurrence was reported where the background bacteria count was >2000 CFU. The water was resampled as a corrective action. Drinking water quality for St. George, summarized by Lotowater (2004) found that there have been no volatile organic compounds or pesticides in the raw well water. Nitrate concentrations were measured at 5 mg/L and chloride concentrations ranged from 20 to 27 mg/L.

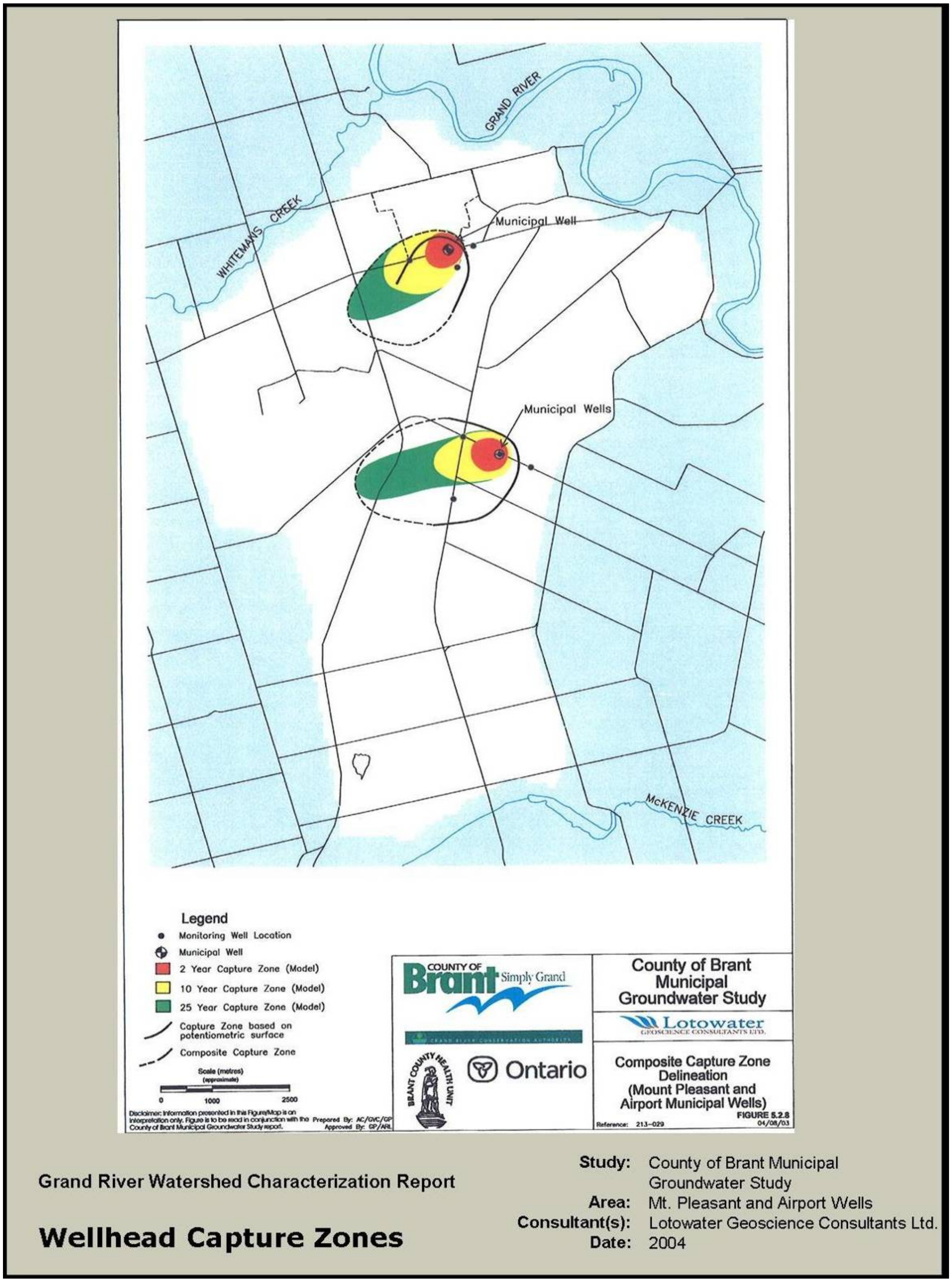
In the Drinking Water Systems Regulations 2005 Annual Report for the Mount Pleasant system, one water quality occurrence was reported where the background bacteria count was 1,600 CFU. The water was resampled as a corrective action. Lotowater (2004) reported that drinking water quality monitoring data for the Mount Pleasant system indicated the presence of volatile organic compounds/pesticides in the raw water. Nitrate concentrations were reported to be relatively low (<2 mg/L) and chloride concentrations ranged from 7 to 120 mg/L (Lotowater, 2004).

Description of Capture Zones

Capture zones for the Airport, St. George and Mount Pleasant wells were developed using a combination of field testing and MODFLOW (at a well field scale) to develop 2-, 10-, and 25-year time of travel capture zones. Pumping rates used in the model were based on the maximum permitted rates. Uncertainty in the capture zones was addressed by adjusting porosity values in the model.

The capture zone for the Airport well, as shown on **Map 6.52,** extends in a southwesterly direction. The 25-year time or travel capture zone covers a surface area of approximately 2.5 km2. The St. George capture zones, as shown on

Map 6.52: Wellhead Capture Zones in the County of Brant (Mount Pleasant and Airport Wells)



Map **6.53**, extend to the northwest and the 25-year time of travel capture zone covers an area of approximately 10 km2**.** **Map 6.50** shows the capture zones for the Mount Pleasant wells. The 25-year capture zones extend to the southwest and cover a surface area of approximately 2.5 km2.

Vulnerable Areas within the 25-year Capture Zone

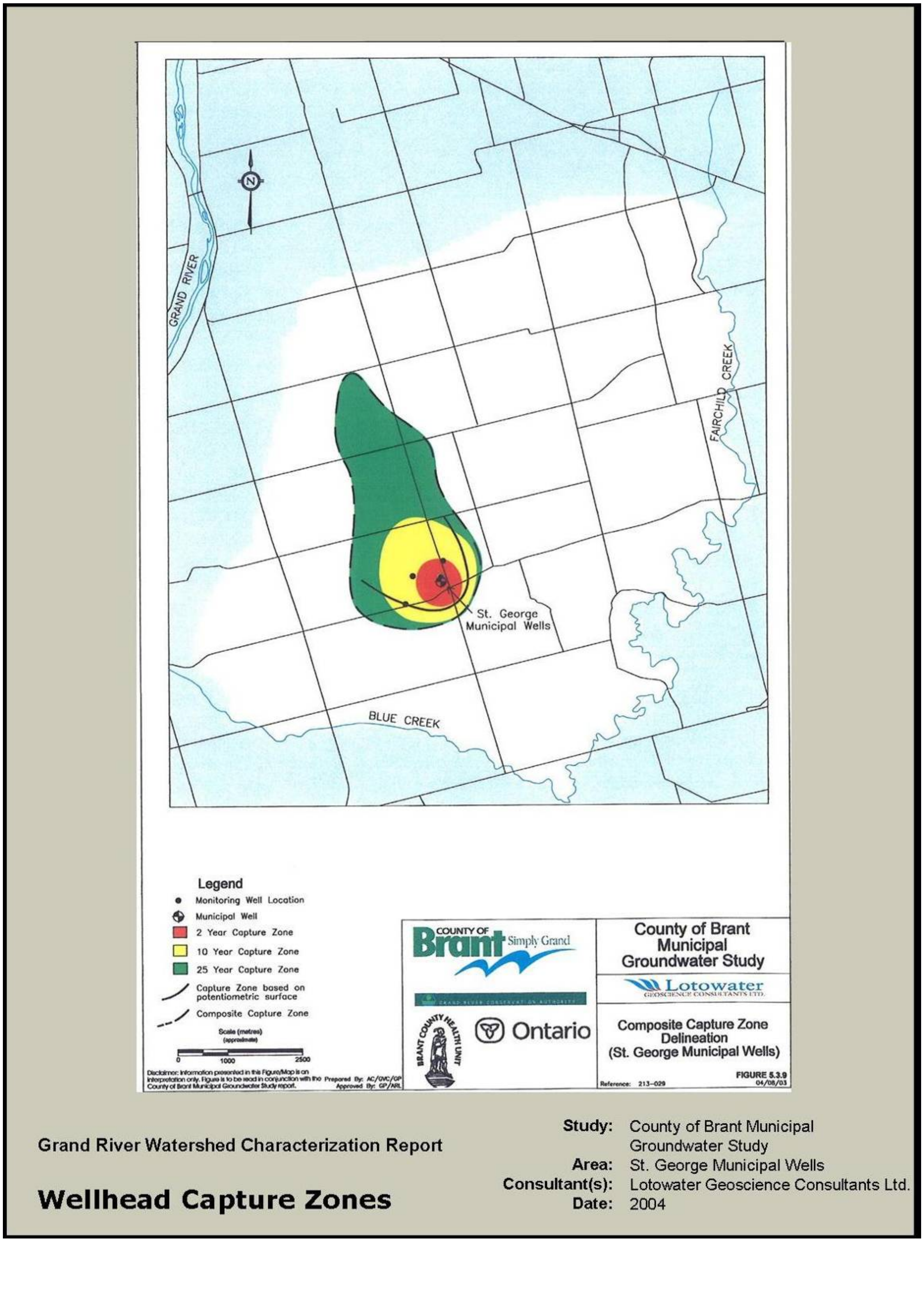
Given that the Airport well is completed in an unconfined aquifer, and is thus vulnerable to surface sources of contamination, Lotowater (2004) indicated that impacts to drinking water quality are relatively minor.

As shown on **Map 6.51**, the vulnerability of the first significant aquifer in both the St. George and Mount Pleasant areas has been mapped as low to moderate susceptibility to contamination from surficial sources.

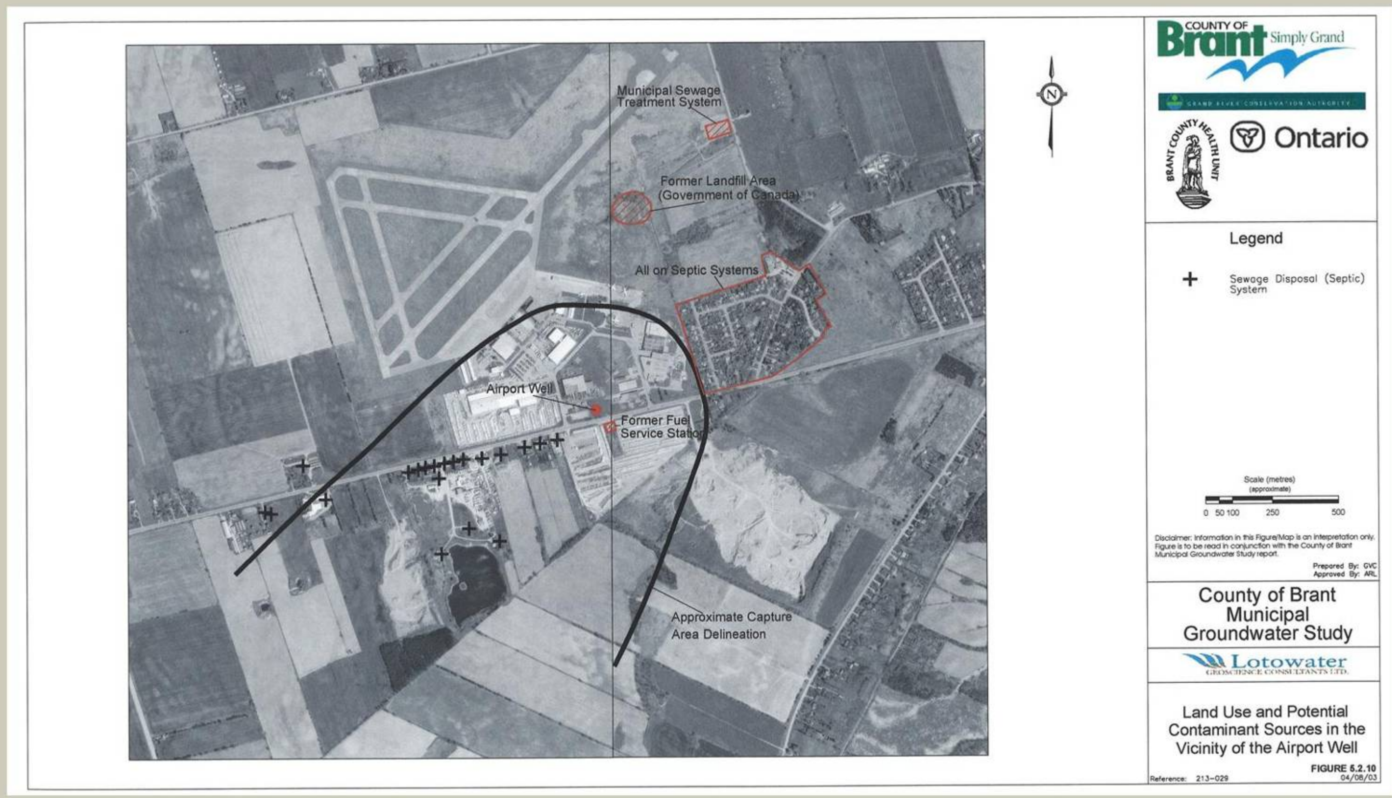
Threats within the 25-year Capture Zone

Threats within the vicinity of the Airport well were compiled by Lotowater (2004) and are shown on **Map 6.54**. These threats included a sewage treatment facility located 1.2 km northeast (downgradient) of the well, a raw sewage spill at the sewage treatment facility, a storm water collection system which discharges to a swale located approximately 650 m northeast of the well, a former landfill site located approximately 750 m north of the well, and a number of manufacturing facilities which likely use chemicals (solvents) and fuels.

Map 6.53: Wellhead Capture Zones in the County of Brant (St. George)



Map 6.54: Potential Sources of Contamination in Brant County (Airport Wells)

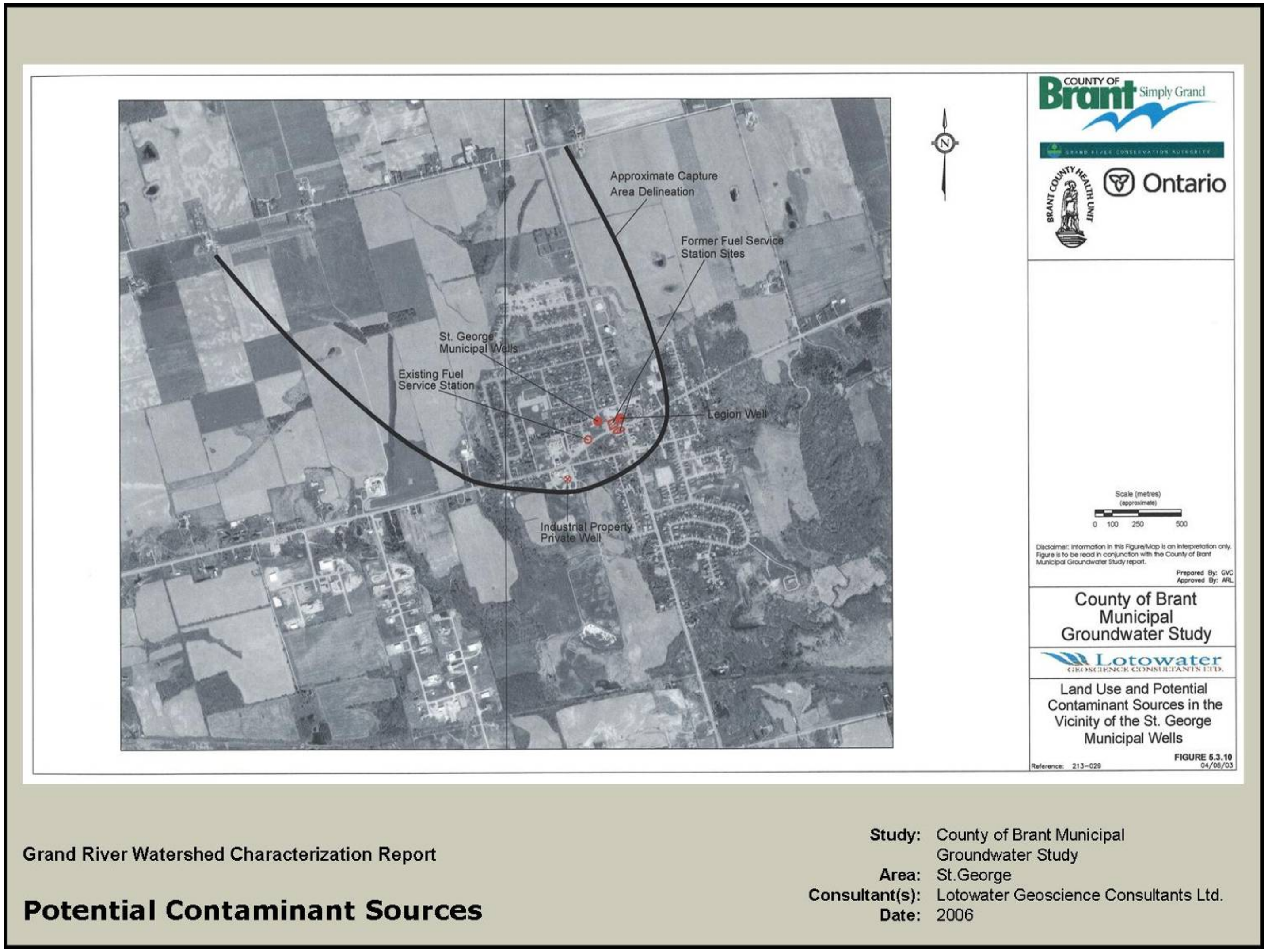


Grand River Watershed Characterization Report

Potential Contaminant Sources

Study: County of Brant Municipal Groundwater Study
Area: Airport
Consultant(s): Lotowater Geoscience Consultants Ltd.
Date: 2006

Map 6.55: Potential Sources of Contamination in St. George



Map 6.56: Potential Sources of Contamination in Mount Pleasant

Grand River Watershed Characterization Report

Potential Contaminant Sources

Study: County of Brant Municipal Groundwater Study
Area: Mt. Pleasant
Consultant(s): Lotowater Geoscience Consultants Ltd.
Date: 2006

Within the vicinity of the St. George wells, potential threats to the aquifer were compiled by Lotowater (2004). Potential threats, shown on **Map 6.55**, include a former landfill located approximately 4 km northwest of the community, petroleum hydrocarbon contamination in the subsurface at two former fuel service stations located approximately 200 m from the municipal wells, an active service station located approximately 200 m southwest of the municipal wells as well as a number of private wells located within the capture zones. There is also a possibility that biosolids have been spread on farm fields within or near the capture zones, to the north-northwest of the community.

Potential threats within Mount Pleasant's 25-year time of travel capture zone were inventoried by Lotowater (2004) and are shown on **Map 6.56**. The results of this inventory found a former landfill to exist approximately 250 to 300 m to the west of the Mount Pleasant municipal wells, however previous studies (summarized by Lotowater (2004) found that the landfill was not a major contaminant source to the municipal wells. Other potential threats to the Mount Pleasant well site include a former gas station/scrap yard, homes and farms in the vicinity of the municipal wells that use on-site sewage disposal systems, a poultry operation located approximately 500 m southeast of the well field, and a municipal works yard which stores and uses road salt, petroleum hydrocarbons and other chemicals such as solvents. Farms border the municipal well site to the southwest and northeast which apply fertilizer and manure to the fields.

Land uses within the vicinity of the Airport well include manufacturing, aggregate extraction, institutional, commercial, residential and an airport. Land use surrounding the St. George well field is primarily urban. Land use in the vicinity of the Mount Pleasant well field is primarily agricultural. In June of 2006 staff from the GRCA met with County staff to discuss high level threats to the municipal groundwater supply as summarized in **Table 6.20**.

Table 6.20: High Level Threats in the Villages of St. George and Mount Pleasant

	Groundwater
Direct Introduction	
Water treatment plant wastewater discharge	None
Sewage treatment plant effluent	Part of Cainsville, Mt. Pleasant and Airport residential are on septic systems
Sewage treatment plant by-passes	None
Industrial effluents	Metal processing and automotive manufacturing industries are situated in the vicinity of the airport Airport has buried fuel tanks Lagoon for food processing facility in St. George was closed in 2003
Landscape Activities	
Road salt application	County has open road salt storage in Mt. Pleasant
De-icing activities	Airport (?) County considering pre-wetting systems
Snow storage	None
Cemeteries	None
Stormwater management systems	Some infiltration and some wet ponds
Landfills	St. George & Mt. Pleasant landfills have closed Mt. Pleasant site is near existing wells Active Biggar's Lane landfill is in SE part of the County

Table 6.20: High Level Threats in the Villages of St. George and Mount Pleasant

	Groundwater
Organic soil-conditioning	None
Septage application	Septage goes to Brantford WWTP
Hazardous waste disposal	HHW days held once/year
Liquid industrial waste	None
Mine tailings	None
Biosolids application	Land application of Brantford and RMOW biosolids
Manure application Fertilizer application Pesticide / herbicide application	Mt. Pleasant has an issue with manure, pesticides and fertilizer (not GUDI) County property applied with pesticides/herbicides No programs for urban pesticide/herbicide reductions
Fuels / hydrocarbons	Trans Canada Pipeline on Hwy #24 north of Hwy #5
DNAPL's (dense non-aqueous phase liquids)	One PCB site located south of Mt. Pleasant Well
Historical activities – contaminated lands	Mostly old gas stations
Storage of Potential Contaminants	
Organic solvents	None
Pesticides (of concern to drinking water) Fertilizers Manure	Agricultural supply company on Hwy #24 in Oakland blends fertilizers Chickens bred in farms south of Mt. Pleasant S/W County has high manure demands (possible storage) for tobacco and ginseng farms Majority of County farms are small family operations

Summary

Within the County of Brant, three small municipal water supply systems (the airport and the Villages of St. George and Mount Pleasant) are groundwater dependant, with a source from an aquifer mapped as 'medium to high' vulnerability. Primary threats to these municipal supply aquifers range from natural characteristics (iron and sulphates in the bedrock) to developed land use activities (sewage disposal, agriculture, landfill, manufacturing, historic activities and fuel storage). The County of Brant has identified the need to expand its long term water supply due to growth projections and potential loss of existing supplies to contamination but has not completed a long term strategy. The County has conducted a number of groundwater studies to identify threats to existing water supplies develop strategies for wellhead area protection and is currently assessing threats and the vulnerability of the bedrock municipal supply aquifers.

6.3.1.9 City of Hamilton

Within the portion of the City of Hamilton situated within the boundary of the Grand River watershed, only one community, Lynden, is serviced by a municipal well system.

Village of Lynden

System Description

The Lynden well supplies municipal water to approximately 400 people. The water supply system is comprised of the single well which draws water from a confined gravel aquifer that is situated directly on the bedrock surface. The groundwater is pumped into a dual cell type reservoir in which compressed air is diffused into the first cell to reduce levels of hydrogen sulphide in the water. Sodium hypochlorite is injected into the water prior to release into the disinfection cell. A second chlorination point is available on the high lift pump discharge to boost chlorine residual levels. An on-line turbidity analyzer continuously measures the turbidity of the treated water.

Municipal Groundwater Quality

According to the Drinking Water Systems Regulations 2006 Annual Report for Lynden, there were no exceedances to the Lynden well system. Annual reports can be found on the City of Hamilton's website at:

http://www.myhamilton.ca/myhamilton/Cityandgovernment/CityDepartments/PublicWorks/Water/DrinkingWater/drinkingwaterreports.htm.

Description of Capture Zones

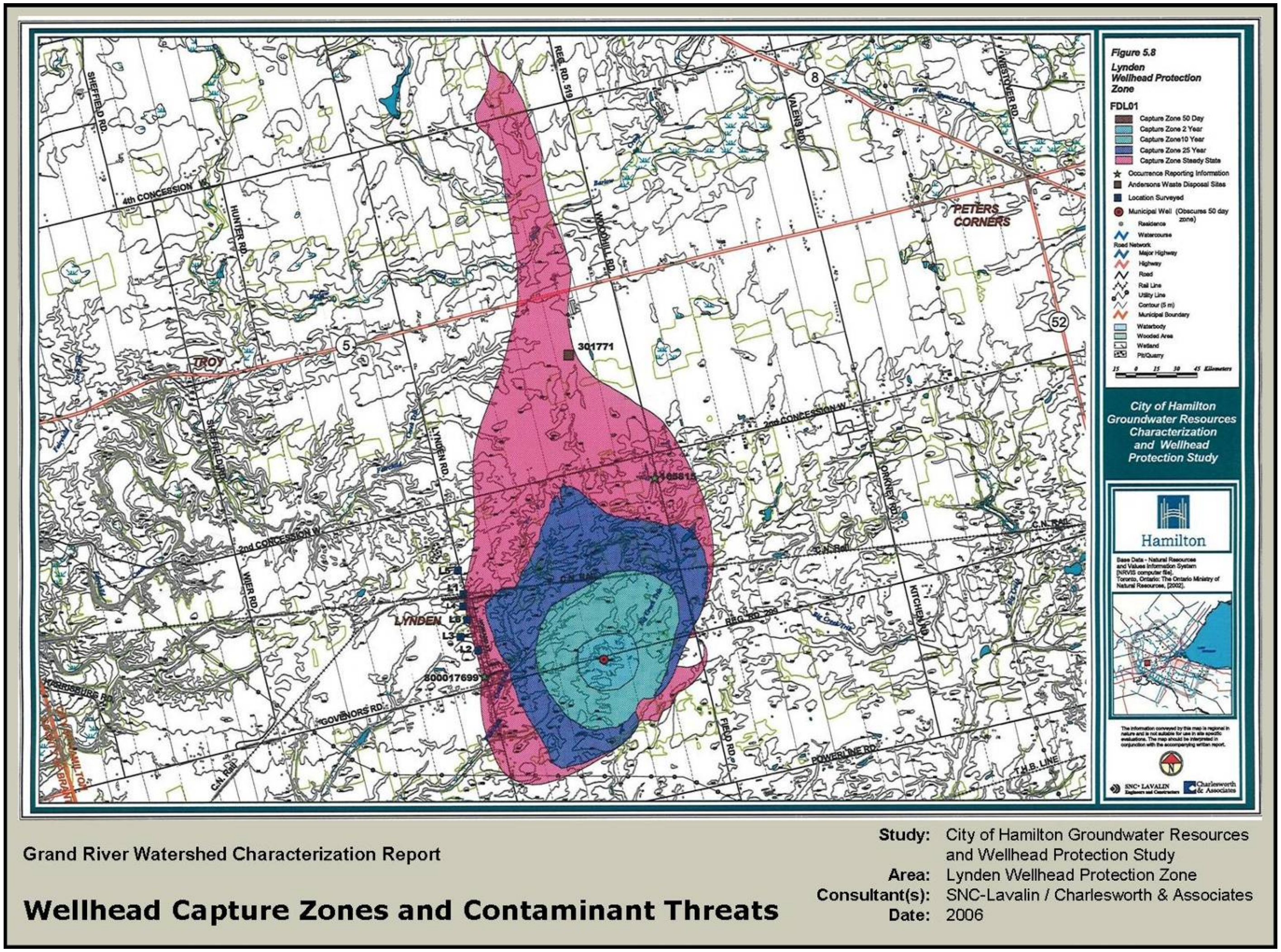
The Hamilton Groundwater Resource Characterization and Wellhead Protection Partnership Study (SNC-Lavalin et al., 2006) developed capture zones for the Lynden well, as shown on **Map 6.57**. The 50-day, 2-, 10-, 25-year and steady state capture zones were developed through a well field-scale MODFLOW groundwater model. The pumping rate used in this model was the maximum permitted rate. Uncertainty analyses were carried out by varying hydraulic conductivity, recharge rates and porosity in each aquifer/aquitard unit.

The 2-, 10-, and 25-year capture zones are roughly in a circular shape, with the 25-year capture zone extending about 2 km to the north of the Lynden well. The steady-state capture zone is very elongated, and extends about 7 km to the north.

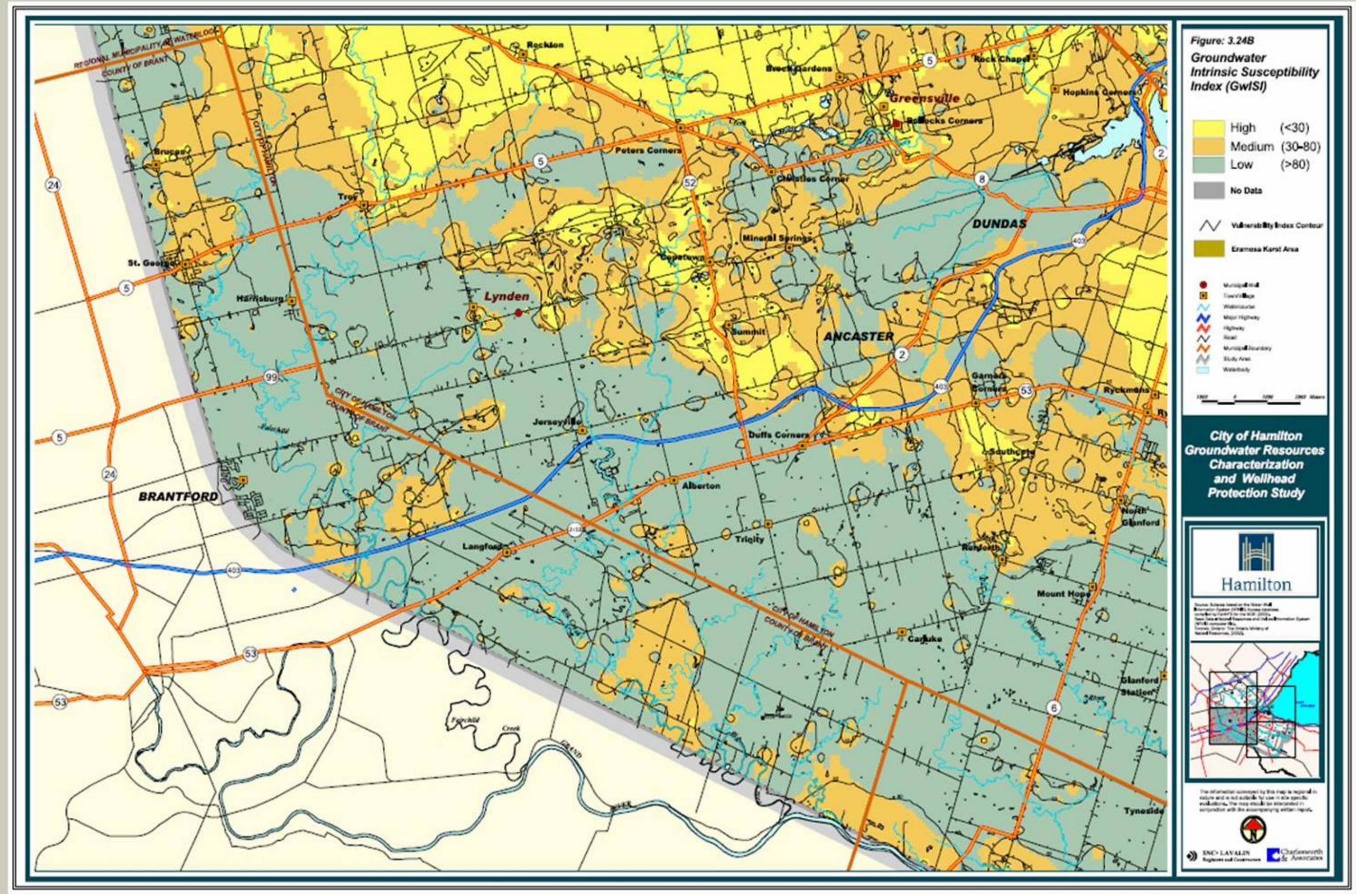
Vulnerable Areas within the 25-year Capture Zone

The City of Hamilton's Groundwater Resource Characterization and Wellhead Protection Partnership Study groundwater vulnerability assessment uses the ToT method described by the MOE Technical Terms of Reference for groundwater vulnerability assessment. This method used the derived water table surface to identify the location of the water table in each well. The first significant aquifer was then defined as the first partially saturated aquifer unit that was greater than 2 m thick. If no aquifer was detected using this method, then the first partially saturated aquifer unit greater than 1 m was identified. If this second query returned no results, it was assumed that the aquifer was located at the well screen and the depth of the top of the aquifer was set to the depth of the screen.

Map 6.57: Wellhead Capture Zones and Contaminant Threats in Lynden, Hamilton



Map 6.58: Aquifer Vulnerability in Lynden and Surrounding Area, Hamilton



Grand River Watershed Characterization Report

Aquifer Vulnerability

Study: City of Hamilton Groundwater Resources and Wellhead Protection Study
Area: Lynden and Surrounding Area
Consultant(s): SNC-Lavalin / Charlesworth & Associates
Date: 2006

In this study, an aquifer was considered confined if the water table was greater than 4 m above the top of the aquifer and unconfined if less than 4 m.

At each well, ISI values were calculated by multiplying the K-factor (a value loosely related to the exponent of the vertical hydraulic conductivity) by the thickness of the corresponding geologic material and summing the values from the ground surface to the effective depth (either the water table surface of the top of the aquifer unit). The ISI values at each well were then classified according to high susceptibility (< 30), moderate susceptibility (30 – 80), and low susceptibility (> 80) to contamination and kriged to generate a surface. Using this methodology, one map was produced for the study area representing the groundwater vulnerability of the first significant aquifer.

Within the area surrounding the Lynden municipal supply well, groundwater susceptibility to contamination has been mapped as low vulnerability as a result of the greater overburden thickness in this area. The results of the vulnerability mapping in the Lynden area are shown on **Map 6.58**.

Threats within the 25-year Capture Zone

As a part of the Hamilton Groundwater Resource Characterization and Wellhead Protection Partnership Study, a threats inventory was completed within the Lynden WHPA. The area surrounding the municipal well field is primarily agricultural. The results of the database search indicated the presence of a co-op store (an identified pesticide handler), 2 automotive sites, a fire station, a marine hardware distribution store and a dump. The dump is identified in the Anderson's Waste Disposal Database as Beverly Concession 2 Dump. However a vacant farmer's field was identified at this location as per the Groundwater Characterization Study, however a foundry is located in the vicinity of the dump site (personal observation). The mapped potential contaminant sources within the Lynden area are shown on Map 81. In September of 2006, staff from the GRCA met with City of Hamilton staff to discuss high level threats to the municipal groundwater supply as summarized in **Table 6.21**.

Table 6.21: High Level Threats in the Village of Lynden

	Groundwater
Direct Introduction	
Water treatment plant wastewater discharge	none
Sewage treatment plant effluent	Village on private septic systems
Sewage treatment plant by-passes	none
Industrial effluents	Foundry located several kilometers north of Lynden on edge of steady state capture zone
Landscape Activities	
Road salt application	City of Hamilton manages salt operations
De-icing activities	none
Snow storage	none
Cemeteries	Cemetery south of village in steady state capture zone
Stormwater management systems	none
Landfills	None within the WHPA
Organic soil-conditioning	none
Septage application	none
Hazardous waste disposal	Foundry identified as open waste disposal site

Table 6.21: High Level Threats in the Village of Lynden

	Groundwater
Liquid industrial waste	none
Mine tailings	none
Biosolids application	Biosolids applications require CofA's for individual fields
Manure application	Village well site is surrounded by agricultural activities (particularly cash crops) that require nutrient and pesticide applications
Fertilizer application	
Pesticide / herbicide application	
Historical activities – contaminated lands	Wellhead protection study identifies "occurrence reporting information" in steady state capture zone
Storage of Potential Contaminants	
Fuels / hydrocarbons	Village has a Co-op and a gas station
DNAPL's (dense non-aqueous phase liquids)	none
Organic solvents	
Pesticides (of concern to drinking water)	Co-op supplies agricultural pesticides and fertilizers
Fertilizers	
Manure	Farm specific storage (check individual nutrient management plans)

Summary

Within the portion of the City of Hamilton situated within the boundary of the Grand River watershed, only one community, Lynden, is serviced by a municipal well system. The Village of Lynden is groundwater dependant. Groundwater susceptibility to contamination has been mapped as low vulnerability as a result of the greater overburden thickness in this area. The primary threats are related to urban land use activities (industry, pesticide and fuel storage, private septic systems) as well as rural land use activities (agricultural farming practices) surrounding the well site. The City of Hamilton has completed a Comprehensive Water Servicing Master Plan (Phases 1&2) for the Lynden Rural Settlement Area and a Municipal Class EA (Phases 3&4) process to site a second source well is underway. The City has also conducted groundwater studies to identify aquifer susceptibility, preliminary threats and areas for wellhead protection.

6.3.2 Municipal Surface Water Systems Descriptions

Within the Grand River watershed there are 3 surface water intakes related to drinking water that take directly from the Grand River which drains a predominantly agricultural watershed that empties into Lake Erie. The remaining surface water intakes that supply drinking water to municipalities in the Grand River watershed region are located within the Eramosa River, Lake Erie and Lake Ontario.

6.3.2.1 Regional Municipality of Waterloo

Mannheim Water Treatment Plant – Integrated Urban System (IUS)

System Description

The Regional Municipality of Waterloo (RMOW) is responsible for water supply, storage and the operation of the trunk distribution system (including maintenance of pressure zones), while the lower tier municipalities are responsible for local distribution and customer billing. The Kitchener (Mannheim) Water Treatment Plant, operated by the RMOW, is a conventional treatment plant which treats water from the Grand River. This facility was commissioned in the spring of 1992 and has a design capacity of 72,000 m3/day. The Kitchener (Mannheim) Water Treatment Plant serves approximately 20% of the residents on treated water supplies within the RMOW. Raw water is pumped 10 kilometers from the Hidden Valley Low Lift Station located on the Grand River to the Mannheim treatment facility.

The treatment process consists of enhanced coagulation, ozonation, flocculation, sedimentation, filtration (choice of dual media filters or granular activated carbon (GAC) filters) and disinfection. Disinfection is achieved through ultraviolet (UV) irradiation followed by chlorination.

Distribution System

The RMOW Integrated Urban System (IUS) is an interconnected distribution system servicing the communities of Kitchener, Waterloo, St. Jacob's, Elmira and a small portion of north Cambridge (approximately 325,000 persons). Fully treated and disinfected water from the Manheim treatment facility is introduced to the IUS in Kitchener combined with treated water from a variety of groundwater sources and distributed via trunk watermains to the lower tier municipalities for consumption. During the seasons of lower demand, fully treated water is injected via ASR wells for storage and pumped out for use during high demand periods.

Water Quality

The raw surface water supply for the Mannheim Water Treatment Plant has not formally been characterized. This data gap will be filled by the characterization analysis underway by the GRCA.

Annual Reports describing the treatment plant's operations and water quality monitoring results can be found on the RMOW's website (http://www.region.waterloo.on.ca). During the 2004 reporting period no adverse results were found. Additional monitoring information acquired through the Drinking Water Surveillance Program (summary from 2000-02, http://www.ene.gov.on.ca/envision/water/dwsp/0002/) also reported that treated water from the Kitchener (Mannheim) Water Treatment Plant did not have any occurrences of samples with adverse water quality.

Issues & Concerns

Raw water quality in the Grand River is highly variable and presents a number of treatment challenges. The Long Term Water Supply Strategy (Associated Engineering 1993) identifies the need for advanced treatment processes at Mannheim to deal with high levels of turbidity, algae, ammonia and organic carbon.

6.3.2.2 City of Guelph

Eramosa Recharge System (Arkell Springs Collection System)

System Description

During high demand periods (i.e. April to November), surface water from the Eramosa River is used to recharge and enhance the flow of Arkell Springs Collection System. The amount of water that can be taken from the Eramosa River is regulated by the City of Guelph's permit to take water. The water taken from the Eramosa River is pumped into an infiltration trench of which approximately 50% of the water is recovered by the Arkell Springs Collection System and the balance either recharges bedrock aquifers, underflows the collector or is lost to the River. Further information on the Arkell Springs Collection System can be found in the section on groundwater supply.

Distribution System

The City of Guelph is a single tier municipality responsible for water supply, operations and distribution to a population of approximately 121,000 persons. The City maintains all aspects of the distribution system which provides treated water from a combination of surface water and groundwater supplies. The surface water recovered by the Arkell Springs Collector System is combined with groundwater pumped from the Arkell and Carter wells and transported approximately six kilometres downstream by a gravity aqueduct to the F.M. Woods Pumping Station. All raw water sent to the Woods Station is disinfected and distributed to the municipal infrastructure system including five reservoirs (Paisley, Woods (3) and University), three booster pumping stations (Clythe, Robertson and Paisley) and three elevated storage tanks (Speedvale, Verney and Clair) to equalize water demand, reduce pressure fluctuations and provide storage. There are two pressure zones in the distribution system. The high zone to the north is regulated by the Speedvale Tower and the low zone to the south is regulated by the Verney and Clair Towers.

Treated water servicing for the Gazer-Mooney Subdivision (in the Township of Guelph-Eramosa) is provided by an extension of the City of Guelph distribution system directly adjacent to the City's corporation boundary. About 1500m of watermains service the 200 residents of the subdivision, with pressure controlled by the City's high zone tower on Speedvale Avenue.

Water Quality

The raw surface water supply for the Eramosa Recharge System has been characterized, as part of the GUDI studies and Engineer's reports, as good quality due to the lack of large urban centres on the upper reaches of the Eramosa River and Blue Springs Creek. A formal characterization has not been done, but this data gap may be filled with the completion of the IPZ analysis currently underway.

A total of seven adverse water quality results were reported in the City of Guelph's annual report for 2005. In all cases the Health Unit and MOE were notified and re-samples taken. All re-samples resulted in good results. Annual Reports describing the City's Waterworks operations and water quality monitoring results can be found on the City of Guelph's website (http://www.guelph.ca/waterworks).

Issues & Concerns

The majority of threats to Guelph's water supply are related to the well network that provides the majority of the supply, however there are threats to the surface water intake from possible upstream spills at or near river crossings, urban land use in the Villages of Rockwood and Eden Mills and rural land uses throughout the upper portions of the Eramosa-Blue Springs watershed. Guelph has just completed a Water Supply Master Plan that addresses the ability of future water supplies to meet the needs of the community over the next 50 years. One option being considered is surface water taking from Guelph Lake for use as a direct supply or in an aquifer storage and recovery (ASR) system.

6.3.2.3 City of Brantford

Holmdale Water Supply System (Brantford)

System Description

The Branford Water Treatment Plant is owned and operated by the City of Brantford and treats water from the Grand River via the Holmedale Canal. The Brantford Water Treatment Plant is a conventional treatment plant servicing the City of Brantford and the Village of Cainsville with a population of approximately 93,000. This plant has a rated capacity of 100,000 m3/day. The raw water access to the Holmedale Canal is located approximately 1.5 km upstream of the water treatment plant.

The treatment process consists of screening, coagulation, sand ballasted flocculation, sedimentation, dual media filtration, fluoridation and disinfection. Disinfection is achieved through chlorination and the addition of ammonia to convert the free chlorine into a combined (chloramine) residual. As finishing steps to the treatment process, sulphur dioxide is used to dechlorinate and powder activated carbon is added for taste and odour control when required.

Distribution System

The City of Brantford is a single tier municipality responsible for water supply, operations and distribution. The City maintains all aspects of the distribution system including two pumping station/reservoirs (Park Road & Tollgate Road), one pumping station (Albion Street) and an elevated tower (King George) to equalize water demand, reduce pressure fluctuations and provide storage. The City has recently commissioned a new reservoir to service the developing industrial area in the north western area of the city.

There are three pressure districts in the distribution system. The Holmedale Water Treatment Plant services pressure district 1. Pressure districts 2 & 3 have been combined into one district serviced by the Park Road reservoir, the Tollgate Road reservoir and the King George elevated tower.

Treated water servicing for the Village of Cainsville (in Brant County) is provided by the City of Brantford from the Holmedale Water Treatment Plant. A watermain from the plant delivers water to a metering pit in Cainsville where local distribution in managed and pressure is controlled by a 1,514 m3 elevated water storage tank owned and operated by Brant County.

Water Quality

The raw surface water supply for the Holmedale Water Treatment Plant has not formally been characterized. This data gap will be filled by the current characterization analysis underway by the GRCA. In addition to residual chloride and turbidity, pH and temperature are also continuously monitored for compliance.

Annual Reports describing the treatment plant's operations and water quality monitoring results can be found on the City of Brantford's website (http://www.city.brantford.on.ca/). For the January to March 2005 reporting period there was one sample with reported total coliform counts and two samples with chlorine levels above the Ontario Drinking Water Standards (ODWS) within the distribution system. Subsequent corrective measures were taken.

The 2000-02 summary report from the Drinking Water Surveillance Program indicated that the Ontario Drinking Water Standard for N-nitrosodimethylamine (NDMA) had been exceeded 15 times. Upon investigation it was found that the high levels of NDMA were as a result of a particular treatment chemical being used in the plant, which has since been changed.

Issues & Concerns

The majority of threats are related to upstream wastewater treatment effluent quality, agricultural runoff and the risk of spills at major viaducts just upstream of Brantford including Highway #2 and the CNR mainline in Paris and Highway #403 at the top end of Brantford. In addition, the Holmedale Canal diverting source water into the treatment plant is not fenced off to prevent accidental or intentional introduction of contaminants. A variety of seasonal non-point sources pose threats to water quality in the Grand River. Chlorides in the river are in excess of 100 ppm during winter runoff, which is compounded by added risks during the growing seasons from rural land use agricultural practices including manure, fertilizer and pesticide application. The City of Brantford is currently completing a raw water intake characterization report to further understand their issues and concerns.

The Holmedale Treatment Plant has issues with the seasonally high organic nitrogen and ammonia levels, during the coldest winter months when ice cover on the river prevents the loss of these compounds to the atmosphere. Nitrogen and ammonia at these levels can compromise the disinfection process, limit the plant capacity and can create taste and odour problems. Taste and odour problems can also occur during the winter due to the high chloride levels and during the spring and summer months when there is an increase in algal blooms. High turbidity in the raw water is also an issue and can interfere with the process that removes sediments (flocculation) and allow pathogens to break through the filtering system. While the Holmedale Water Treatment Plant can accommodate for these aforementioned issues through the addition of chemicals, it is an operational challenge to maintain the balance between proper disinfection and taste and odour complaints. In addition, managing this situation can be very costly to the operator as the required chemical dosage increases.

Of additional concern is the presence of persistent pharmaceuticals in raw water, which are not specifically treated for by conventional drinking water treatment systems, and for which the effect of long term chronic exposure is unknown. The Canadian Council of Ministers of the Environment (CCME) has identified emerging compounds such as estrogens and pharmaceuticals a priority issue. The presence of trace amounts of pesticides and organic solvents found in the raw water which are not treated for is also of concern.

6.3.2.4 Haldimand County

Hamilton (Woodward) Water Supply – Caledonia, York, Cayuga

System Description

The Hamilton Water Supply System, which supplies drinking water to the communities of Caledonia and Cayuga and the hamlet of York, is owned and operated by the city of Hamilton. This conventional water treatment plant pumps raw water in from Lake Ontario. This plant has a design capacity of 909,000 m3/day and serves a population of approximately 411,500.

The treatment process at the Hamilton Water Supply System consists of coagulation, flocculation, sedimentation, filtration, fluoridation and disinfection. Ammonia is used in the disinfection process to convert free chlorine to a combined chlorine residual (chloramine). Sulphur dioxide is used for dechlorination. Chlorine is added at the mouth of the intake structure for zebra mussel control when the raw water temperature rises above 12°C.

Distribution System

Upon full treatment and disinfection, a portion of the water from the Hamilton Water Supply System is pumped to the Caledonia and Cayuga Reservoirs via the Caledonia/Cayuga Distribution System. The Caledonia/Cayuga Distribution System serves a population of approximately 11,231. Breakpoint Chlorination is carried out on the water entering the reservoirs using sodium hypochlorite to change the disinfection method from chloraminated (combined chlorine) water to a Free Chlorine Residual. The re-treated water is then supplied via the Caledonia/Cayuga distribution systems.

Water Quality

The Drinking Water Surveillance Program (2000-02) found no adverse water quality results for the Hamilton Water Supply System. However, in the 2004 annual compliance report, 5 samples from the treated water and 3 samples from the distribution system tested positive for total coliforms, indicating possible fecal contamination. After subsequent re-testing no bacterial counts were found. In the 2006 Annual Compliance Report had some water quality incidences that were rectified per MOE guidelines.

The 2004 annual compliance report for the Caledonia/Cayuga Water Works System indicated that several times throughout the year, chlorine residuals on water entering the Caledonia reservoir were below the required minimum concentrations set out by the Ontario Drinking Water Standards. It was recommended by the MOE that testing of the distribution system be performed by Hamilton to assess the quality of water they are supplying Haldimand County. Water leaving the Caledonia reservoir for distribution to Caledonia, and Cayuga exceeded MOE requirements for disinfection.

Annual Reports describing the treatment plant's operations and water quality monitoring results can be found on the City of Hamilton's website (http://www.myhamilton.ca/myhamilton/CityandGovernment/) and Haldimand County's website (http://www.haldimandcounty.on.ca/).

Issues & Concerns

Any threats to the Caledonia, York and Cayuga water supply would be related to the general quality of raw water from Lake Ontario, including concerns about possible localized impacts from turbidity and algae growth in the vicinity of the Lake Ontario intake.

Dunnville Water Treatment Plant – Dunnville

System Description

The Dunnville Water Treatment Plant, operated by the Corporation of Haldimand County, is situated on the shore of Lake Erie at the mouth of the Grand River (location shown on Map 35). Raw water is collected from a pumping station 10km away in Port Maitland through an intake pipe located in Lake Erie approximately 460m offshore. Raw water from Lake Erie is pumped and treated with chlorine at the mouth of the intake structure for zebra mussel control when the raw water temperature rises above 12^{oC}. The pumping station has a design capacity of 26,400 m3/day and supplies both the Dunnville Water Treatment Plant and the Port Maitland industrial area. The population serviced thought the Dunnville Plant is approximately 11,300.

The Dunnville Water Treatment Plant is a conventional treatment plant whose treatment process consists of; an aluminum sulphate injection for coagulation, flocculation, sedimentation, filtration, and disinfection using sodium hypochlorite. This plant has a design capacity of 14,500 m3/day.

Distribution System

No information available.

Water Quality

The raw surface water supply for the Dunnville Water Treatment Plant has not formally been characterized. This gap may be filled with the completion of the IPZ analyses currently underway.

No adverse water quality results were reported by the Drinking Water Surveillance Program (2000-02) or noted in the Dunnville Water Treatment Plant's annual report for 2004. Annual Reports describing the treatment plant's operations and water quality monitoring results can be found on Haldimand County's website (http://www.haldimandcounty.on.ca/).

Issues & Concerns

The majority of threats are related to the general quality of lake water; however there are concerns about possible localized impacts from turbidity, algae growth and septic systems.

Turbidity counts increase during seasonal lake turnover and after storm events which can stir up the lake sediments, release phosphorus and create algal blooms. These algal blooms can cause taste and odour issues in the treated water. Water treatment plants use coagulants such as alum to control turbidity.

There is also a concern with the density of cottage lots on questionable septic systems and malfunctioning holding tanks along the Lake Erie shoreline. The Dunnville WTP in Dunnville also has an historic surface water intake that at one time pumped water from the Grand River, but currently is not in use. This intake has not been decommissioned but its use is under review as part of the ongoing Dunnville Master Servicing Plan, from preliminary studies it appears this intake may be decommissioned.

6.3.3 Long-term Municipal Water Supply Capacity Strategies

There is a wide range of long term water supply planning in the Grand River watershed. Some municipalities have planned for future water supplies on an individual water supply system basis, while others have wide ranging plans that cover all of the water systems owned by the municipality. Plans also range in time period, with plans covering from 20 to 50 years. Many water systems have capacity to service the currently forecast population over the next 25 years, while others have development limitations in place to limit growth. There are a few water systems in which limited information could be found on future capacity planning.

Planning in many municipalities of the Lake Erie Watershed Region has recently been affected by Provincial legislation, namely the 2005 Places to Grow Act. Based on the Act, the Province has drafted new Growth Plans for the Greater Golden Horseshoe in June 2006. Those affected municipalities within the Watershed are currently making revisions to their population forecasts contained in their Official Plans which in turn, allow for revisions to their future servicing requirements. All population forecasts and capacity comparisons in this section use information currently available, but it should be noted that some population forecasts are undergoing revision.

The Region of Waterloo and the City of Guelph both have Long Term Water Supply Plans. The Region of Waterloo has had a Water Supply Master Plan in place for a number of years. It is currently being updated to evaluate effects of recent planning, technical, and regulatory changes. The City of Guelph recently adopted a Water Supply Master Plan with plans to 2054.

The County of Haldimand is currently exploring a long-term municipal water supply strategy in conjunction with a number of municipal partners. The Nanticoke Grand Valley Area Water Supply Project is examining the feasibility of expanding the Nanticoke WTP located on the north shore of Lake Erie and extending the water service to communities within Haldimand County and to communities external to the County within the Grand River watershed.

Other municipalities have water supply plans for a number of their water systems through the Environmental Assessment process. For growing communities the planning period is often 20 or 25 years. For smaller communities the water supply system has been sized for the maximum development of the community under the municipality's Official Plan. A few water systems that will need an increase in capacity within 25 years are conducting Environmental Assessments, such as Rockwood, Arthur, and Lynden. The City of Hamilton has completed a Comprehensive Water Servicing Master Plan (Phases 1&2) for the Lynden Rural Settlement Area and a Municipal Class EA (Phases 3&4) process to site a second source well is underway.

There are a few water systems that do not have a formal plan in place for future capacity. Some of these water systems have capacity to service forecast population over the next 25 years. Other water systems have source water available, but will need upgrades to treatment systems to increase supply, such as Brantford and Dunnville. The rest may not have capacity to service forecast populations and do not have source water identified. Municipalities that have identified this issue and have started planning for future water supplies, include Centre Wellington for Fergus-Elora and Oxford County for Bright. Information on future capacity plans was not available for water systems in Brant County.

7.0 SUMMARY OF IDENTIFIED POTENTIAL ISSUES

7.1 Known Drinking Water Issues

7.1.1 Groundwater Issues

7.1.1.1 County of Grey

- Pesticides in Dundalk: Elevated levels of pesticides were found in shallow groundwater samples at Well #2 in 2000.

7.1.1.2 County of Dufferin

- Fluoride in Waldemar: The Village of Waldemar has a naturally high level of fluoride in their groundwater supply.

7.1.1.3 County of Wellington

- Hardness and manganese in Arthur
- Iron in Rockwood
- TCE in Fergus
- Sodium in Drayton

The Township of Wellington North uses Calsequest to address hardness issues in Arthur Well 7B, and manganese has been detected in Wells 8A&B.

The Township of Guelph-Eramosa does iron sequestering at the Station Street wells in Rockwood.

Well F1 in Fergus treats for TCE as a result of historical industrial site contamination.

Sodium levels in Drayton have been as high as 19 ppm but are dropping. The County salt shed behind the wells was used to store salt outside.

7.1.1.4 County of Perth

- Manganese in Milverton

The Village of Milverton's 2003 Water Supply Class EA recommended decommissioning some smaller wells and the aging water tower. As a result of infrastructure upgrades, changes in system wide water pressures have stirred up sediments in the distribution system creating aesthetic issues. Decommissioning of the municipal water tower has created pressure issues (stirring up manganese and rust) leading to weekly "brown water" calls. It has been determined that the system requires new pressure tanks to maintain stable pressures.

7.1.1.5 City of Guelph

- Increasing nitrates in rural source wells
- Increasing chlorides in urban source wells
- Contaminated site influence on wells (Chlorinated organics, TCE, DCE and chlorides)
- Site remediation influence on wells (shifting plumes and capture zones)

The City of Guelph has conducted a range of studies to ascertain the status of its ground water quantity and quality, and continues to work with a range of partners to identify issues and eliminate specific threats. Current issues relate to the source and quantity of contaminants (ie. VOCs, nitrates, chlorides, PRC's, etc.) that have forced the closure of some wells and the need to maintain close surveillance of all other water sources. While much has been identified already, some questions remain unanswered regarding threats at certain existing and historic land uses. The City will continue to work to collect data at the level of detail necessary to ensure protection of its groundwater supply.

7.1.1.6 Regional Municipality of Waterloo

- Work is underway to confirm and document any groundwater issues.

7.1.1.7 County of Oxford

- Benzene in Bright (well decommissioned): a former well in Bright was decommissioned due to benzene contamination.

7.1.1.8 County of Brant

- High nitrates in Paris and Burford area
- Sulphate & iron in bedrock formation
- Sodium and chlorides in Mt. Pleasant

Private septic systems have been identified in the capture area of the Paris overburden wells. Some County community systems in Burford (Library) and Oakland (Satellite Office) exceed nitrate levels. Natural groundwater characteristics in the bedrock formation contain iron and sulphates. The County treats for high iron levels with sodium silicate at the Paris Scott Well. Sodium and chlorides present in Mt. Pleasant wells from nearby municipal salt storage.

7.1.1.9 City of Hamilton

- Hydrogen sulfide and turbidity in Lynden

Hydrogen sulfide is naturally occurring in the Lynden well and is being diffused by aeration in the well reservoir. Turbidity is likely a treatment precipitate and therefore is an aesthetic problem rather than a health issue.

7.1.2 Surface Water Issues

7.1.2.1 City of Guelph

- Chlorides, bacteria, pathogens and pesticides are potential issues in the Eramosa-Blue Springs watershed

Guelph's surface water intake is under the influence of urban land use in the Villages of Rockwood and Eden Mills and rural land uses throughout the upper portions of the Eramosa-Blue Springs watershed. Both urban and rural sources may be contributing to the issues identified above.

7.1.2.2 Regional Municipality of Waterloo

- Turbidity, algae, ammonia and organic carbon in the Grand River

Raw water quality in the Grand River is highly variable and presents a number of treatment challenges. The Long Term Water Supply Strategy (Associated Engineering 1993) identified the need for advanced treatment processes at Mannheim to deal with high levels of turbidity, algae, ammonia and organic carbon.

7.1.2.3 City of Brantford

- Ammonia, chlorides, bacteria, pathogens and trace organics (e.g. pesticides, industrial contaminants, etc) in the Grand River

Treated wastewater effluent and runoff from urban and agricultural areas contribute to elevated ammonia, chloride, pathogen and trace organic concentrations in raw water. Ammonia and pathogens may be present in raw water due to natural processes (e.g. ammonia from decomposition of organic matter in sediments and pathogens from wildlife and birds). The raw water characterization will provide a systematic evaluation of water quality that will be used to improve the understanding of surface water issues and concerns.

7.1.2.4 Haldimand County

- Turbidity in Lake Erie source water at Dunnville intake

Turbidity counts increase during seasonal Lake Erie turnover and after storm events creating an aesthetic water quality issue. Water treatment plant uses alum to control turbidity.

7.2 Sources for Identifying Potential Issues

7.2.1 Groundwater Concerns

7.2.1.1 County of Dufferin

- Water quantity conflict in Amaranth.

The quantity of water bottling in upper Amaranth Township identified in MOE PTTW and monitoring reports.

7.2.1.2 County of Wellington

- Manganese in Arthur
- Nitrates in Rockwood
- Well interference in Fergus
- Manure spreading around Drayton

The Town of Arthur has a historical problem with iron and manganese in their water supply. The majority of Arthur's old wells were replaced due to water quality concerns. The 2003 Class EA for Wells 8A&B identified manganese was present, but not to what extent it could become an issue. Testing has commenced to determine what level of treatment is required. Dirty water complaints were received in 2006 that could be a result of the historic water quality problem.

The Township of Guelph-Eramosa has concerns about the potential impact of old septic systems in the Rockwood and the spread of biosolids outside the town.

The Township of Centre Wellington currently has Well F2 off line due to interference with private residential services. The municipality plans to bring full services to this neighbourhood in the future and will then consider the cost/benefit of bring Well F2 back on line.

The Village of Drayton's wells are located in the Conestoga River floodplain. Manure is spread in the farms all around the village. However, there has not been a need for any boil water advisories. The well casings have been extended and could only be overtopped by a major storm event.

7.2.1.3 City of Guelph

- Quantity of groundwater supply

The City has identified the need to expand its long term water supply due to growth projections and potential loss of existing supplies to contamination or climate change impacts.

7.2.1.4 Regional Municipality of Waterloo

Work is underway to confirm and document any groundwater concerns.

7.2.1.5 County of Oxford

- Manganese in Plattsville

Elevated levels of manganese in the Plattsville wells occasionally result in water quality complaints. (pers. com. Marg Misek-Evans and Deb Goudreau July 25, 2006).

7.2.1.6 County of Brant

- GUDI conditions in Paris
- Landfill leachate in Mt. Pleasant
- Hydrocarbons from abandoned gas station storage tanks

The Gilbert Wells in Paris are GUDI under regional storm conditions. The County is conducting additional studies to identify any actual threats to the water supply. (pers. com. Alex Davidson June 29, 2006).

7.2.1.7 City of Hamilton

- Lead in Rockton

MOE has provided an e-mail to the City notifying water supply operators of the presence of lead in Rockton monitoring wells. Lead was not found in any of the municipal wells, and therefore is not a health concern to the municipal supply.

http://www.myhamilton.ca/myhamilton/Cityandgovernment/HealthandSocialServices/PublicHealth/SafeWater/QA-Lead.htm.

7.2.2 Surface Water Concerns

7.2.2.1 City of Guelph

- Spills in upstream Eramosa-Blue Springs watershed

There are threats to the surface water intake from possible upstream spills at or near river crossings, urban land use in the Villages of Rockwood and Eden Mills and rural land uses throughout the upper portions of the Eramosa-Blue Springs watershed.

7.2.2.2 Regional Municipality of Waterloo

- Spills in upstream Grand River
- Industrial discharges to surface drainage network
- Upstream wastewater treatment effluent

Waterloo Region is developing strategies to identify and address potential upstream risks and hazards to the Manheim intake on the Grand River.

7.2.2.3 City of Brantford

- Spills in upstream Grand River

- Vandalism or accident at intake canal

- Potential influence of effluent quality and persistent pharmaceuticals from upstream wastewater treatment

There is the potential for container spills at high level bridges over the Grand River (Hwy #2 Paris, CNR Bridge Paris, Hwy #403 above Brantford) which could be within critical IPZ range. The accuracy of predicting plumes from upstream sources is critical for intake closure decision making. The Holmdale water supply intake canal is not fenced against the introduction of contaminants from an accident or vandalism. There is also a concern about the threat of persistent pharmaceuticals potentially remaining in treated WWTP effluents (Kitchener Record, June 2, 2004). Growth pressure upstream of Brantford, as a result of the provincial “Places to Grow” policy, could also lead to higher discharge loads to the river above Brantford. (pers. com. Terry Spiers June 26, 2006)

7.2.2.4 Haldimand County

- Aesthetic water quality from Dunnville water treatment plant
- Uncapped gas wells

Haldimand County received phone calls in 2003 complaining about taste and odour concerns with treated lake water. The County also has concerns with the density of cottage lots on questionable septic systems along the Lake Erie shoreline (pers. com. Brian Pett July 27, 2006). Uncapped gas wells and pipelines should also be researched (Ontario Oil, Gas and Salt Resources Library – MNR)

7.3 Data and Knowledge Gaps

7.3.1 Groundwater Gaps

7.3.1.1 County of Grey

A study is currently in progress to update the groundwater model and capture zones for Dundalk's municipal wells. This study will also include 5-year capture zones for the municipal wells. There is currently a study in progress to update the threats assessment once capture zones have been re-modeled.

7.3.1.2 County of Dufferin

The Townships of Amaranth, East Garafraxa and East Luther – Grand Valley have identified aquifer susceptibility and areas for wellhead protection as part of the 2001 Orangeville and Surrounding Areas Groundwater Modeling Study and are currently assessing threats and the vulnerability of the bedrock municipal supply aquifer.

7.3.1.3 County of Wellington

As a part of the 2005 County of Wellington Groundwater Protection Study, numerical groundwater flow models were developed for the Townships of Wellington North, Centre Wellington, Guelph–Eramosa and Mapleton.

The Townships of Mapleton and Guelph-Eramosa are updating their vulnerability mapping across the municipalities to enhance a set of maps for the 'first significant aquifer' and also for the deeper municipal supply aquifers. A detailed threats inventory is in the process of being completed within the 25-year capture zones for each of the municipal wells in these Townships. This inventory will include a review/compilation of existing data and a field investigation on a parcel-by-parcel basis. Additionally, groundwater issues for each municipal well and 'preferential pathways' will be compiled and evaluated.

The Township of Centre Wellington is currently updating the threats inventory, completing an inventory or preferential pathways and an issues assessment within the Fergus and Elora capture zones, with the most effort focused within the 2-year capture zone. The Township also recognizes the need to quantify rural loadings and to establish an MOE records interface to track contaminated site identification and remediation.

In North Wellington, the completion of the Class Environmental Assessment for Wells 8 A&B has answered most of the outstanding water supply questions. However there still exists the need to gain a better understanding of manganese treatment options for Arthur.

7.3.1.4 Perth County

Perth County conducted a groundwater study in 2003 to identify aquifer susceptibility, preliminary threats and areas for wellhead protection and is currently assessing threats and updating the vulnerability of the municipal supply wells in Milverton.

7.3.1.5 City of Guelph

The City of Guelph has identified a lack of site specific data that outlines the day to day impacts to the quality of the groundwater supply. These include broader contaminated site details (ie. types of spills at "brownfield" sites) and understanding the levels of contamination from suspected sources (ie. Did fuel tanks actually rupture at old gas station?). In order to facilitate this work, the MOE, GRCA and the City of Guelph have commenced a "Data Pilot" to assess the efforts required to discover and access MOE data and information related to issues assessment and threat identification required to develop Assessment Reports under the proposed Clean Water Act.

On a larger scale, the City would like to quantify the local water balance in order satisfy requests for future water takings. This will be achieved through the completion of Tier 3 Stress Assessments on the Lower Speed watershed. Additional work is currently underway for the Eramosa River and Blue Springs Creek and the development and implementation of detailed monitoring strategies (ie. Arkell Spring Grounds Adaptive Management Plan).

7.3.1.6 Regional Municipality of Waterloo

Work is underway to confirm and document any gaps in groundwater understanding.

7.3.1.7 County of Oxford

Possible threats to groundwater supplies may relate to historical wells. These wells may act as preferential pathways for contamination to enter the aquifer. Preferential pathways and the land uses surrounding them should be investigated further to determine the potential risk to groundwater quality. The County is currently updating the threats inventory, identifying hazards at a property scale and establishing time of travel to sources of supply. The County has also identified the need to get better coordination of data collection with provincial ministries.

7.3.1.8 County of Brant

The 2004 County of Brant Municipal Groundwater Study identifies threats to existing water supplies and develops strategies for wellhead area protection. The County is currently assessing threats and the vulnerability of the bedrock municipal supply aquifers. There is also a need for a more detailed threats inventory of properties within the identified capture zones, more information on former land uses and to identify levels of contamination from suspected sources.

7.3.1.9 City of Hamilton

The City of Hamilton has completed its 2006 Groundwater Resources Characterization and Wellhead Protection Study which identifies aquifer susceptibility, preliminary threats and areas for wellhead protection. The City is now developing five year capture zone mapping, a vulnerability assessment, a twenty-five year threats inventory and issues evaluation and identification of preferential pathways.

7.3.2 Surface Water Gaps

7.3.2.1 City of Guelph

An IPZ analysis is being completed for the area of the Eramosa River upstream of the Arkell Springs recharge system intake to identify potential threats to the raw water source from upstream river inputs and/or spills and to develop a response strategy. A formal characterization of the raw water supply consistent with recent MOE Guidance Modules has not been done, but this data gap may be filled with the completion of the IPZ analysis.

7.3.2.2 Regional Municipality of Waterloo

Work is underway to confirm and document any gaps in surface water understanding.

7.3.2.3 City of Brantford

The City of Brantford needs to know the source of raw contaminants (many possible sources are hard to pinpoint). These include upstream farm use practices and details about spills from the Paris WWTP (operated by OCWA). The City also lack knowledge of proposed upstream sewage works upgrades and expansions as well as an awareness of what the Moe is doing to monitor and control spills and excessive discharges from upstream wastewater treatment plants.

7.3.2.4 Haldimand County

Haldimand County is studying cottage lot use to generally identify the potential for septic systems to impact raw surface water quality. There is also the need for biological assessments of the Lake Erie shoreline to measure algae. IPZ studies will be conducted to identify Lake Erie currents and consider TSS impacts to source waters.

8.0 CURRENT SOURCE WATER PROTECTION ACTIVITIES

8.1 Spills Early Warning

The MOE has the regulatory authority and mandate to receive reports of spills, assess the potential environmental impacts, enforce applicable regulations, and notify potentially affected parties. Under Provincial law, all spills are required to be reported immediately to the Ministry of the Environment's Spills Action Centre (SAC), a 24 hour call centre.

The GRCA, municipal surface water intakes and local health units are notified by the SAC of spills to surface water in the Grand River watershed. GRCA's role is to provide information, as requested, on watershed conditions and time of travel to municipal drinking water intakes. GRCA staff use their knowledge of the watershed to provide relevant information to SAC, ensuring that the appropriate municipal surface water intakes are notified. In rare cases, spills may result in changes or modifications to water management operations by GRCA. GRCA staff are available to receive spill notification or provide information 24 hours a day, 7 days a week through the Duty Officer paging system.

The GRCA, in cooperation with the City of Brantford, is in the process of bringing a continuous water quality monitoring station on-line upstream of the Brantford drinking water intake. It is envisioned that this station, once fully operational, will provide a measure of early warning of unusual or abnormal water quality that could indicate a spill or other condition that might impact the operation of the drinking water treatment plant.

A similar continuous water quality monitoring station is proposed on the Grand River at Victoria Street in Kitchener. The location of this station is such that it may provide a similar early warning function for the Region of Waterloo's riverbank infiltration system and the surface water intake for the Mannheim Water Treatment Plant.

8.2 Point Source Load Restrictions

There are numerous point sources discharging directly into the Grand River and its tributaries including municipal and industrial wastewater treatment plants as described in **Section 3.6.2**. In all cases, the amount and quality of the effluent from these sources is regulated by the MOE through a Certificate of Approval for each plant. Point source load reductions typically occur when a Certificate of Approval is amended or replaced, for example when a wastewater treatment plant is upgraded or expanded. When this happens, the MOE may require more stringent effluent quality criteria, which ultimately translates into reduced pollution loading from the plant.

Many of the municipal wastewater treatment plants in the Grand River watershed have sufficient capacity to service anticipated population growth, at least in the short term, and therefore, have no plans to expand or upgrade their wastewater treatment plants. Other municipalities are nearing capacity or considering replacement of aging infrastructure that will require a new or amended Certificate of Approval, which may result in a reduction in effluent loading.

The Region of Waterloo owns twelve wastewater treatment plants that discharge to surface water in the Grand River watershed. These wastewater treatment plants range in size from small communal systems serving a single sub-division to large plants servicing cities such as Kitchener or Waterloo. The Region of Waterloo is currently carrying out a Wastewater Treatment Master Plan to evaluate wastewater treatment projects, technologies and servicing strategies to meet long-term needs to 2031 and 2041. The plan is expected to determine how much wastewater capacity will be required, identify what plant expansions or new technologies/facilities will be needed and recommend a preferred approach to provide wastewater treatment in the Region of Waterloo. The Wastewater Treatment Master Plan is expected to be completed in 2007.

In addition to the Wastewater Treatment Master Plan, the Region of Waterloo is currently expanding and upgrading the wastewater treatment plant servicing the community of Ayr to increase hydraulic capacity and add tertiary effluent filtration. These upgrades are expected to result in a reduction in pollution load to the Nith River.

Planning and engineering of a treatment upgrade to include nitrification at the Waterloo Wastewater Treatment Plant has been initiated and is expected to begin construction in 2009. Once implemented, this upgrade will result in lower ammonia loads to the Grand River.

The City of Guelph initiated an update of their Wastewater Treatment Strategy in 2005 under the Class Environmental Assessment process. This project is nearing completion and will recommend suitable technologies for pilot-testing to meet the requirements of the Phase 2 expansion of the Guelph Wastewater Treatment Plant. The Phase 2 expansion is expected to provide adequate sewage capacity to service expected population growth to 2016. Guelph has also recently started a Wastewater Master Plan for long-term planning of wastewater treatment needs over the next 50 years.

A recently completed Growth Management Strategy for the City of Brantford identified a need to increase the capacity of drinking water and wastewater infrastructure in Brantford to meet anticipated population growth. The Growth Management Strategy identified the need for a major upgrade and expansion of the Brantford Wastewater Treatment Plant in 2026.

The Township of Centre Wellington began an Environmental Assessment process in late 2005 to identify options for additional wastewater treatment capacity and improved effluent quality at the Elora Wastewater Treatment Plant. Following the completion of the EA process in 2007, it is expected that a preferred alternative will be identified and eventually implemented.

The village of Grand Valley in the Township of East Luther-Grand Valley carried out an Environmental Assessment in 2005, which recommended the decommissioning of the existing wastewater treatment plant and construction of a new facility. The municipality is proceeding with design of the new facility and construction should begin before 2009.

The wastewater treatment system serving the community of Drayton in the Township of Mapleton has been recently upgraded and expanded. The Township wishes to increase the current rated capacity of the plant from 750 to 950 m3/d, as recommended by a Class Environmental Assessment in 1996.

Several projects have been or will be undertaken by Haldimand County to improve effluent quality. Additional storage capacity was recently added to the Ouse Street Pumping Station in Cayuga, which historically experienced high inflow exceeding the capacity of the pump station and resulting in discharge of untreated sewage to the Grand River. The added capacity should eliminate or significantly reduce future bypasses from this pump station. Construction will begin in 2007 of a septage receiving facility, emergency power generator and effluent dechlorination system at the Dunnville Wastewater Treatment Plant.

The County of Brant is currently undertaking a Class Environmental Assessment of the Cainsville Lagoon System. It is expected that this lagoon system will be replaced by a wastewater treatment plant within the next 5 to 10 years.

8.3 Contaminated Sites and Brownfield Rehabilitation

The City of Guelph has developed a Community Improvement Plan (CIP) that outlines a framework for implementing the City's Brownfield Strategy. The framework will:

- operationalize the key financial components of the City's Brownfield Strategy to stimulate private sector investment for brownfield site development, which include establishing an Environmental Study Grant (ESG) Program and establishing a 'Tool Box' approach. The Tool Box approach will incorporate the following financial incentives to off-set the costs associated with site assessment and remediation of brownfield sites:
    - Tax Increment-Based (or Equivalent) Grant Program
    - Tax Arrears Cancellation
    - Tax Assistance Policy During Rehabilitation (relevant brownfield legislation not yet proclaimed under the Municipal Act)
    - Consideration of Possible Development Charge Incentives
- establish a financial framework to facilitate the redevelopment/re-use of municipally-owned brownfield sites (City of Guelph, 2004).

The City of Hamilton has two programs regarding contaminated sites and brownfield remediation: The Contaminated Sites Management Program for Municipal Works (CSMP); and the Environmental Remediation and Site Enhancement (ERASE) Community Improvement Plan.

The Contaminated Sites Management Program for Municipal Works (CSMP) provides a systematic process for City of Hamilton staff to identify and manage the risks associated with contaminated sites. The Program is focused on departments and staff who routinely work in the planning, design, land acquisition, construction or maintenance of municipal works projects.

The intent of this Program is to provide staff with confidence and direction for assessing the risk related to contamination on municipal works projects and deal with the possibility for subsurface contamination consistently. The program consists of three components:

- The Manual, a procedural document which specifies responsibilities and processes to ensure staff manage contaminated sites in a diligent and appropriate manner consistent with the scope of work undertaken.

- Training, a component offering formal classroom training for staff annually as well as ongoing refresher and introductory training in the interim.

- Monitoring, a monitoring body has been established to ensure the continual improvement of the program.

The program is not intended to influence or support development of private property; however it is a mandatory requirement for all staff to apply when undertaking municipal works associated with private property development (e.g. service extensions, land acquisitions, etc.)

The City of Hamilton's Environmental Remediation and Site Enhancement (ERASE) Community Improvement Plan is a comprehensive set of programs designed to encourage and promote brownfield redevelopment in the older industrial area of the City. As its name suggests, the Plan is designed to "erase" brownfields by providing financial incentives to clean them up and replace them with productive economic land uses, thereby improving both economic opportunities and environmental conditions in the City. Properties within the ERASE Community Improvement Project Area are eligible for ERASE programs, subject to meeting the program requirements contained in the ERASE Plan and all other requirements of the City.

In 2002, Brantford City Council approved a Brownfields Strategic Action Plan outlining the various activities that the City is willing to undertake to assist with brownfield redevelopment. The primary goal of the plan is "to facilitate the remediation and redevelopment or reuse of brownfield sites through the stimulation of private sector initiatives and strategic municipal action" (City of Brantford, 2002).

The initiative includes:

- offering incentive programs designed to encourage the involvement of private property owners in the cleanup and redevelopment of brownfield properties;

- being more aggressive in pursuing property tax sales on eligible properties taking advantage of recent changes to the Municipal Act;

- land acquisition;

- conducting environmental investigations;

- preparing redevelopment strategies;

- discouraging further deterioration of properties; and
- consulting with stakeholders.

8.4 Rural Non-Point Source Load Reductions

Within the Grand River watershed, the Rural Water Quality Program has become a very successful source water protection program, providing financial assistance and technical advice to rural landowners to implement best management practices to improve and protect surface water and groundwater. Although the program has gained momentum and profile since the unfortunate events in Walkerton, it was initiated well before source water became a media buzzword. The development of the Rural Water Quality Program represented the first time in Ontario, if not Canada, that municipalities started working directly with the agricultural community to share the cost of protecting and improving water quality.

The Rural Water Quality Program, delivered by the Grand River Conservation Authority, originated in 1998 when the Region of Waterloo committed one and a half million dollars from their user rate budgets to a five-year program to protect source water. Today all three levels of government as well as private foundations and stewardship organizations have provided funding to the program that covers the entire Grand River watershed. The Region of Waterloo have contributed $300,000 annually since 1998. The County of Wellington and City of Guelph have committed approximately $300,000 annually since 1999 while the County of Brant and the City of Brantford have provided $100,000 per year since 2002. There has been more than five and a half million dollars provided to landowners in the Grand River watershed to implement over 1,600 projects that improve and protect water quality.

The long-term sustainability of the current water supply system depends on the quantity and quality of recharge received by the aquifers, and the quantity and quality of flows in the Grand River. The importance of water led the Region of Waterloo to develop a comprehensive Water Resources Protection Strategy (WRPS) during the mid 1990s. The overall objectives of the WRPS were to limit the risk to water resources from historic, existing or future land use practices. The Rural Water Quality Program was part of the initiative aimed at improving and protecting source water upstream of the surface water intake and the regional recharge zone. The Region of Waterloo recognized the important role that the upstream rural areas play in protecting water quality. Staff at the Region also realized that for many landowners best management practices were not being implemented due to cost. The Region of Waterloo committed to sharing the cost of clean water with farmers.

A program to cost-share agricultural best management practices to improve water quality is not a new concept. Previous programs include the Clean Up Rural Beaches (CURB), and the Land Stewardship Program. The Rural Water Quality Program is unique in both its source of funding and development process and ongoing implementation. The main source of financial support comes from the local municipalities and the vision and commitment of staff and local councils has ensured the longevity of the program. The involvement of the agricultural community and partners organizations in the development, design and implementation of the program has ensured that the Rural Water Quality Program has remained relevant to the landowners in the Grand River watershed.

The development of the Rural Water Quality Program has been a collaborative process involving input from more than fifty local farm organizations as well as provincial organizations on the Steering Committees. The steering committees designed the program to address the challenges faced by local farmers to protect and improve water quality while at the same time remaining vibrant and viable agricultural operations. The Steering Committees selected the best management practices, the eligibility criteria and the grant rates needed in their municipality. The program provides financial assistance for a variety of beneficial management practices such as manure storage and handling facilities, nutrient management plans, fencing livestock from watercourses, wellhead protection and proper abandonment, pesticide, fertilizer and fuel storage and handling facilities and retirement of fragile lands. The financial incentives range from 50 to 100 percent. The specific best management practices available in each municipality reflect both the agricultural community and the goals and objectives of the municipality or funding agency. The funding rates have recently been harmonized with the Canada Ontario Farm Stewardship Program.

The Waterloo and Wellington Rural Water Quality Programs also provided a three year payment for changes in land management practices such as conservation tillage and cover cropping. Landowners were also eligible for a performance incentive to off set the maintenance involved in retiring land from production and planting trees. This payment is very similar to the Environmental Goods and Services payments that are currently discussed through the Alternative Land Use programs. Unlike ALUS payments these performance incentives were designed to provide recognition of the landowner’s efforts to change practices, the payments were not developed to be ongoing payments.

At the request of the Steering Committee the program uses an extension model based on site visits and one on one service delivery. The stakeholders spoke very strongly on the need for the program delivery to be based on “people not paper”. They requested that extension staff be available to work with landowners to develop their solutions. The Grand River Conservation Authority provides a team of extension specialists to work with landowners. In addition to this the stakeholders also insisted that the cost-share dollars only be available to landowners who had participated in the Environmental Farm Plan program and had an EFP deemed appropriate. In order to maintain confidentiality program delivery staff are not required to see the EFP, only to seek confirmation of completion from the landowner. This requirement increases the landowner’s level of environmental knowledge and provides a level of societal assurance on the expenditure of public money.

A Review Committee consisting of agricultural producers and municipal representatives make the decisions on allocating funds to projects. These members review information presented by staff on each project proposal and vote on the funding request. This removes the direct decision making process from the technical staff and places it in the hands of the stakeholders. This has reduced the burden of stress on staff and provided an opportunity to have projects more widely reviewed. All projects are brought to the committee anonymously to protect the applicant’s privacy.

The dollars are delivered as efficiently as possible to landowners with four field staff and a project coordinator. The watershed municipalities through the Conservation Authority levy structure support the delivery and administration of the Rural Water Quality Program.

This process has been the model used across the watershed. Since 1998 when the Region of Waterloo launched this program they have continued to support the program with a total commitment of three million dollars. The City of Guelph and County of Wellington have committed more than $2.4 million and the County of Brant and City of Brantford committed $500,000. The municipal dollars have also attracted more than one million dollars in provincial funding through the Ontario Ministry of Agriculture and Food's Healthy Futures Program. Approximately $400,000 has been provided through various programs of Agriculture and Agri-Food Canada through the Agricultural Adaptation Council. The Grand River Conservation Authority has received more than $300,000 from organizations such as the Great Lakes Renewal Foundation.

There has been over seven million dollars committed to the Rural Water Quality Program over the past ten years. The Grand River Conservation Authority is continuing to work with municipalities and other funding partners to ensure a long-term program is available to landowners.

To date the program has provided technical assistance to over 1,200 landowners in the watershed. The program has provided approximately five and a half million dollars in cost-share to over 1,600 completed projects. The total investment in water quality improvement projects has been more than $14 million with landowners contributing over eight million dollars. The projects funded have included 200 manure storage facilities and 196 fences to exclude more than 8,500 livestock from 100 kilometres of watercourse. Landowners have retired more than 320 hectares of land along streams and in recharge areas and planted trees. Landowners have also implemented more than 215 Nutrient Management Plans, upgraded more than 90 wells and plugged approximately 100 old wells, in addition to many other projects.

There has been a great deal of interest in the Rural Water Quality Program and requests for funding have continued to increase. The calibre and availability of extension staff has created a very high level of trust in the Grand River watershed among rural landowners. Many traditional barriers are being broken including work with conservative Mennonite groups. There are many lessons that have been learned from this process. The need to involve all stakeholders is critical to the success of this program as is the investment of time to cultivate a common understanding and language amongst the partners. There is a need to have champions and to develop "believers" in not only the farm community but at the municipal staff level and political level. Consistency and continuity are also important to success. The five year commitment by the municipalities was extremely important in developing the program. It provided the agricultural community with a concrete commitment to the process which allowed the program to grow and develop.

The true measure of success comes in the type and number of projects completed by landowners and the pride that they have in their projects. Unfortunately the coverage of the watershed has been achieved for a very limited time period and the challenge is to develop long term programs that will provide a sustainable funding source to fund best management practices on rural lands in the watershed. The Rural Water Quality Program has shown that landowners are willing to share the cost of clean water with society. This has been achieved through a collaborative development process and a people based delivery model. To overcome barriers programs need to have long horizons. This allows landowners to develop trust in the process and to properly plan for their investments. It also instills a level of credibility in the staff, the funding program and the organization. As an organization the Grand River Conservation Authority is committed to finding continued support for landowners to share the cost of clean water in the Grand River watershed.

The City of Hamilton has completed a Stormwater Master Plan and management strategies have been recommended for the watersheds which include rural Best Management Practices (BMPs).

8.5 Urban Non-Point Source Load Reductions

Changes on the land due to urbanization impact the hydrologic processes of a watershed. Typically the problems associated with urbanization have included: increased potential for flooding and stream erosion, reduced groundwater recharge, and impacted water quality. Various Stormwater Management (SWM) measures are typically applied to mitigate the effects of urban development upon the hydrologic cycle and receiving system.

Under the legislation of the Conservation Authorities Act, the GRCA is involved with the coordination of water and related land management including the control of flooding, pollution, and conservation of land. The vision of the GRCA is one of a health and sustaining relationship between the natural environment of the watershed and the demands of all forms of life on the environment. Its mission is to work with partners to conserve these resources and processes for future generations in the watershed.

The GRCA developed SWM guidelines in 1982, and these have shaped the SWM program since that time. Objectives of the program include:

- Developing comprehensive Watershed Studies which address water and resource management issues including flooding, water supply, and water quality on a broad scale,

- Developing water and resource policies such that development can be provided in a watershed on a sustainable basis,

- Encouraging the establishment of suitable resource and SWM policy statements in Official Plans,

- Encouraging and assisting in the coordination of Subwatershed Plans and Master Drainage Plans with municipalities for developing areas prior to Secondary Planning,

- Establishing suitable drainage criteria and guidelines which meet drainage constraints and resource objectives and that these can be accommodated within a plan of subdivision prior to approval of the draft plan,

- Ensuring that all major drainage system components are designed to accommodate the greater of the 100 year or Regional Storm,

- Encouraging use of Best Management Practices to address local and downstream constraints including water quality, groundwater recharge, erosion control, and flood control based on cumulative effects of watershed development,

- Encouraging the understanding and use of natural drainage design in new developments,

- Encouraging awareness of the concepts and benefits of Storm Water Management programs in the watershed.

The direction provided by these objectives is still current and progressive today in defining the GRCA SWM program.

SWM systems are designed to meet SWM criteria for a given site. The SWM review program is involved with setting the criteria to be met at a site, and ensuring criteria are met through the design. These criteria typically address:

- Control of peak flow rates to control flooding

- Water balance and groundwater recharge requirements

- Water quality based on the receiving system needs including fisheries and water supply,

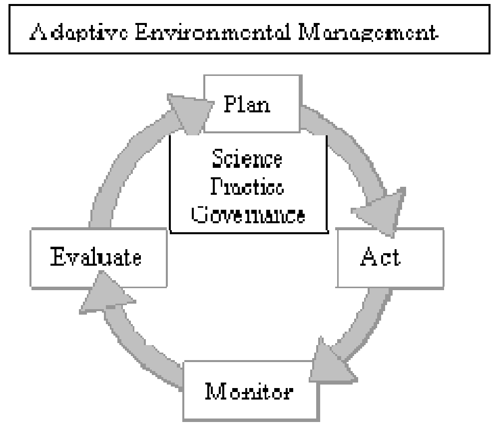
- Control of runoff volumes and frequency for stream stability.

While storm water management basins are the features most commonly associated with SWM, components of the overall system are incorporated into all aspects of development to control and convey runoff to the receiving system.

The current SWM review program of the GRCA addresses obligations to plan input and review in implementation of SWM policy and guidelines, to fulfill municipal review agreement obligations delegated by the province, and DFO review agreements. Through municipal agreement, the GRCA currently reviews subdivision proposals throughout the watershed to provide advice on the interpretation of the Provincial Policy Statement and implementation of provincial guidelines. Most notably, the Ministry of Environment has issued and updated detailed Stormwater Management Planning and Design Guidelines in 1994 and 2003. These guidelines form the standard for design and implementation of SWM facilities.

Another item under the planning advisory service delegation is in ensuring a watershed and subwatershed perspective is incorporated into the design of the site. While the provincial guidelines are available as a reference for facilities design, the sensitivity of the receiving system must be considered in application of appropriate SWM measures. Targets are best identified in consideration of the downstream receiving system and full potential for change within the watershed. The majority of the focus of the Subwatershed planning and SWM review program is in expansion of urban areas into greenfield areas. The majority of urbanizing municipalities carry out development of Subwatershed Studies in conjunction with Community Planning prior to designation of new urban areas.

The Watershed Planning and Storm Water Management programs follow an Adaptive Environmental Management Planning principle. Planning and design are done on the basis of best understanding and requirements at the time. Future adjustments are made over time as understanding of the science, integration of the science into the state of practice, and legislative requirements evolve.



While the objectives of SWM have been fairly well defined, considerable evolution has occurred in the past 20 years regarding the state of the science and practice in SWM.

The recent update was supported by research into the effectiveness of various SWM measures through the Stormwater Assessment Monitoring and Performance Program (SWAMP).

On a more local level, monitoring of stormwater facility performance and receiving systems has been carried out to various degrees in several municipalities. This has been helpful providing some confidence in design innovation. Often these monitoring requirements are set out in subwatershed studies to address specific issues in the area. Industry liaison groups have also been set up with Homebuilders development consultants to address implementation issues in SWM planning, design, and review.

The areas of greatest concern currently in SWM implementation is protection of headwater streams especially in moraine areas. These systems can support cold water fish species, important groundwater recharge and discharge functions, and groundwater supplies. Even well planned SWM measures will result in changes to stream flow regime and stability, groundwater quality due to road salting, and stream temperatures.

The majority of the focus of the subwatershed planning and SWM review program is in expansion of urban areas into greenfield areas. While this is intended to prevent negative impacts to the receiving system in these areas, this new development related review does not address the large portions of existing development within the cities, which have historically developed without current SWM controls. It is expected that the vast majority of urban drainage areas within the watershed currently drain to watercourses without the benefit of water quality controls. Water quality controls for urban SWM began to be implemented in the 1980's, most notably in the City of Guelph as part of implementation of the original Hanlon Creek Watershed Study. Implementation of water quality controls generally began later in other portions of the watershed, but has included some retrofit of earlier water quantity control facilities.

Watershed municipalities typically have developed policies, guidelines, and standards for implementation of SWM within their jurisdictions. Plan and policy updates have been undertaken in many municipalities and include items such as Master Servicing Studies, Master Drainage Plans, and Comprehensive SWM Studies to understand the municipal drainage systems, address specific drainage issues, and provide guidance to Capital work programs.

The City of Kitchener has been implementing a city wide SWM plan since 2002 which incorporates SWM controls in existing developed areas. One of the driving interests in the program was to establish a cash-in-lieu of site SWM control program. Revenue collected through the program, in addition to capital funds, is used to construct municipal facilities in strategic priority areas rather than on private lots. Strategic placement and retrofit of existing facilities provides a greater overall benefit to the receiving system in addition to ensuring facilities will be maintained. The overall program also includes a coordinated monitoring program. The Cities of Waterloo and Kitchener have been investigating alternative funding mechanisms for financing their SWM programs.

The City of Hamilton has completed a Stormwater Master Plan and management strategies have been recommended for the watersheds which include rural Best Management Practices (BMPs).

8.6 Groundwater Remediation Programs

There are several active groundwater remediation programs in the City of Guelph. These remediation programs are being implemented by the property owners to address legacy contamination issues in the groundwater. Generally, the MOE monitors the progress of several of these remediation projects and continues to monitor known groundwater contamination to determine if groundwater remediation is necessary.

The City of Hamilton has a closed municipal landfill located on 810 Jerseyville Rd., lot 35 Concession 3 in the former town of Ancaster. The site is currently equipped with a leachate collection system.

8.7 Groundwater Protection Programs

The municipalities throughout the Grand River watershed consist of predominantly rural/agricultural land uses in the upper and lower portions with the majority of urban development located in the central portion. Most of this urban development (Kitchener, Waterloo, Cambridge and Guelph) is situated within an area of sand plains and moraines which account for much of the watershed’s recharge functions. As a result, groundwater protection programs have focused on both rural and urban strategies. **Section 8.4** outlines a number of government funding programs that have been developed at the federal and provincial levels that encourage best management practices around nutrient management, product storage and handling, septic maintenance and well decommissioning. The GRCA administers rural water quality programs leveraging federal, provincial and municipal funding to deliver best management programs across Waterloo Region, Wellington, Oxford, Brant and Haldimand counties.

At the municipal level, Grey, Dufferin, Wellington, Perth, Oxford, and Brant counties, the Region of Waterloo and the Cities of Guelph and Hamilton are using the results of their municipal groundwater studies to establish well head protection areas for integration with their Official Plans. This allows for protection of water supplies from the start of the land use development process and sets the stage for future administration of programs by planners and provides tools for by-law officers to check compliance. In addition to their pioneering role in the development of the rural water quality program, the Region of Waterloo has implemented the Business Water Quality Program to provide financial assistance to businesses who introduce spill prevention and management projects. The Region also works with their partner municipalities, taking steps to reduce road salt application by 25% within the boundaries of the Region. Municipalities also serve on the front line of informing land owners about their opportunities to get involved in groundwater protection. For example, the Region of Waterloo has established awareness programs to inform water users of best practices for water protection. As a result, the Region is recognized internationally as a leader in the implementation of municipal groundwater source protection programs.

8.8 Private Well Protection

Since the Walkerton tragedy in 2000, stringent guidelines have come into place dealing with large and small scale municipal groundwater systems. However, private water wells are equally susceptible to contamination, and with thousands of private wells province-wide, the aquifers which they access are also susceptible. In light of this fact, it becomes increasingly apparent that private landowners need the knowledge and capabilities to maintain their wells in a safe and healthy manner for themselves and their neighbours.

A variety of water testing and education programs exist throughout the province to ensure that private well owners have access to safe drinking water. Within the Grand River watershed, both the municipalities and the local health units are taking action to ensure these programs are available.

The provincial Well Aware program, provided by Green Communities Canada, helps private well owners protect their wells from contamination, in an effort to keep both private drinking water supplies and Ontario's groundwater supplies clean. Well Aware provides educational material to land owners on how to protect private wells; and offers home visits by trained staff to help identify priority actions to keep private wells clean (www.wellaware.ca).

Local public health units provide private well owners with sample bottles and laboratory testing for total coliforms and E. coli free of charge. The health units also provide residents with informative literature regarding well maintenance, water quality testing, and dealing with contaminant exceedances in their wells.

8.9 Water Conservation and Demand Management

Municipalities throughout the Grand River watershed have long recognized the need to protect and manage their water supply through the development of a variety of pro-active and reactive water conservation and demand management activities. A strong culture of municipal water conservation is evolving around the understanding that water use reductions can extend existing water supply capacity to their growing populations. Recognizing the importance of conserving surface and groundwater resources has led to the development and implementation of a variety of municipal water use and awareness programs that range from information on indoor and outdoor water conservation activities to subsidies for toilets and rain barrels by the City of Guelph and Region of Waterloo. The success of water use reduction programs is being tracked by these municipalities and reported as reductions in per capita water use. In addition, most municipalities have established by-laws or guidelines for lawn watering and outside use restrictions (ie. car washing) to manage peak demands for outside water use during summer months.

The GRCA administers the Ontario Low Water Response (OLWR) program for the Grand River watersheds. The OLWR program was initiated in 2000 following low water conditions experienced from 1997 through 1999. Water users from both the public and private sector have formed a committee to deal with water use during times of low water or low precipitation conditions. Three flow levels have been identified:

- Level 1 – Flows are about 70 percent of normal summer low flow. Water users are asked to voluntarily reduce consumption by 10 percent.

- Level 2 – Flows are about 50 percent of normal summer low flow. MOE will send letters to holders of Permits to Take Water to ask them to voluntarily reduce consumption by 20 percent.

- Level 3 – Flows are about 30 percent of their normal summer low flow and there is potential for economic harm to water takers and/or significant harm to the ecosystem. Water Response Team may ask the province to impose mandatory restrictions on those holding Permits to Take Water.

One means of addressing water conservation and demand management in the rural/agricultural portions of the watershed is the creation of irrigation committees. Portions of the Whitemans Creek and MacKenzie Creek watersheds are situated within the Norfolk Sand Plain. Irrigation Advisory Committees in this area provide information and assistance to rural land owners in regards to water conservation and provide demand management as best irrigation methods are talked about and conflict issues are addressed.

8.10 Education and Outreach

The City of Hamilton's Public Works Department has created a new Source Protection Planning group. The group will coordinate various community outreach programs and work with other divisions within the City and the conservation authorities to communicate with the public.

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