Wilmot Creek Background Report: Abiotic, Biotic and Cultural Features

for preparation of the
Wilmot Creek Watershed Plan

October 2009

Prepared by Ganaraska Region Conservation Authority

The Wilmot Creek Background Report: Abiotic, Biotic and Cultural Features was written to document the historical and current conditions of the Wilmot Creek watershed. This document creates the foundation of the Wilmot Creek Watershed Plan. The Ganaraska Region Conservation Authority would like to thank the many seasonal staff that provided field assistance and the landowners who granted permission to collect data from their property.

This document was written by Ganaraska Region Conservation Authority (GRCA) staff members Pam Lancaster, B.Sc., Jenny Dai, M.Eng., Brian Morrison, B.Sc., Mark Peacock, P.Eng., Mike Smith, B.Sc., Ken Towle, M.E.S., and Magdi Widaatalla, M.Sc., P.Geo. for the residents, communities, municipalities and stakeholders of the Wilmot Creek watershed. Maps were created by the GRCA GIS Department, Brian Curran, B.Sc., Steve Nowak, B.A. and Jeff Moxley. This document represents the first of its kind for the Wilmot Creek watershed and complements the 1966 and 1976 Ganaraska Region Conservation Reports (Department of Energy and Resources Management 1966, Ontario Ministry of Natural Resources 1976). Certain sections of this report have been summarized from peer reviewed or consultant documents, and review and input into this document by committee members, stakeholders and residents occurred in 2009.

The Ganaraska Region Conservation Authority envisions that this document will serve to aid in the conservation, enhancement and sustainable management of the Wilmot Creek watershed and its resources.

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The Wilmot Creek Background Report: Abiotic, Biotic and Cultural Features Executive Summary

The Wilmot Creek Background Report: Abiotic, Biotic and Cultural Features documents historic and current conditions of the Wilmot Creek watershed. This document creates the foundation for the Wilmot Creek Watershed Plan. It is envisioned that the Wilmot Creek Background Report and the forthcoming Wilmot Creek Watershed Plan will serve to aid in the conservation, enhancement and sustainable management of the watershed and its resources.

The Wilmot Creek watershed flows through the Municipality of Clarington in the Regional Municipality of Durham and has its uppermost headwaters in the City of Kawartha Lakes (Figure 1). Historic events have shaped the watershed into its present-day condition. Most notable are the effects of dams and settlement patterns caused by the location of road and rail corridors. Today, the watershed supports a population of 8,258 people, a productive agricultural community, and a mix of natural resources and recreational uses. In addition, residents depend on water from the watershed for domestic and economic use; however residents of Newcastle rely on Lake Ontario for its source of water.

Shaped thousands of years ago by glacial activity, the watershed lies on Paleozoic bedrock and its topographic and hydrogeological features include the Oak Ridges Moraine, the South Slope and the Iroquois Plain physiographic regions (Figure 2). Corresponding surficial geology and soils help dictate groundwater flows, aquifer locations, and groundwater is recharge and discharge areas (Figures 3 and 4).

The main branch of Wilmot Creek is joined by four other tributaries; Orono Creek, Hunter Creek, Stalker Creek and Foster Creek (Figure 5). The entire watershed is 98 square kilometers (km^2). Protection of the Wilmot Creek watershed has been influenced by surface water studies such as floodplain mapping and hydraulic studies. Regulations are also in place to protect people and property from flood waters, and to protect some of the natural features of the watershed. Flows in Wilmot Creek are generally resilient to stresses such as drought and water use, and adequately provide for aquatic habitat and human use.

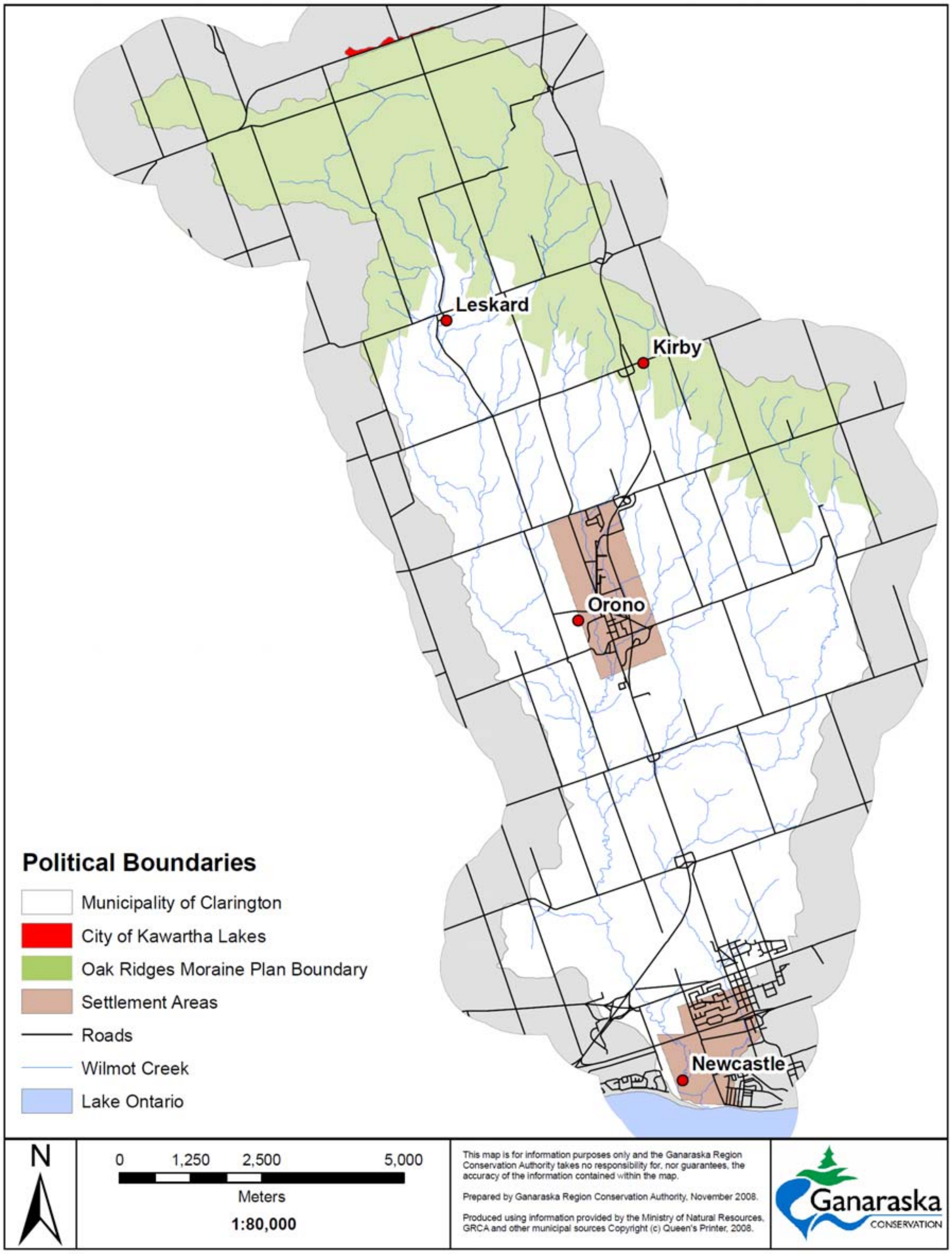

Figure 1: Wilmot Creek

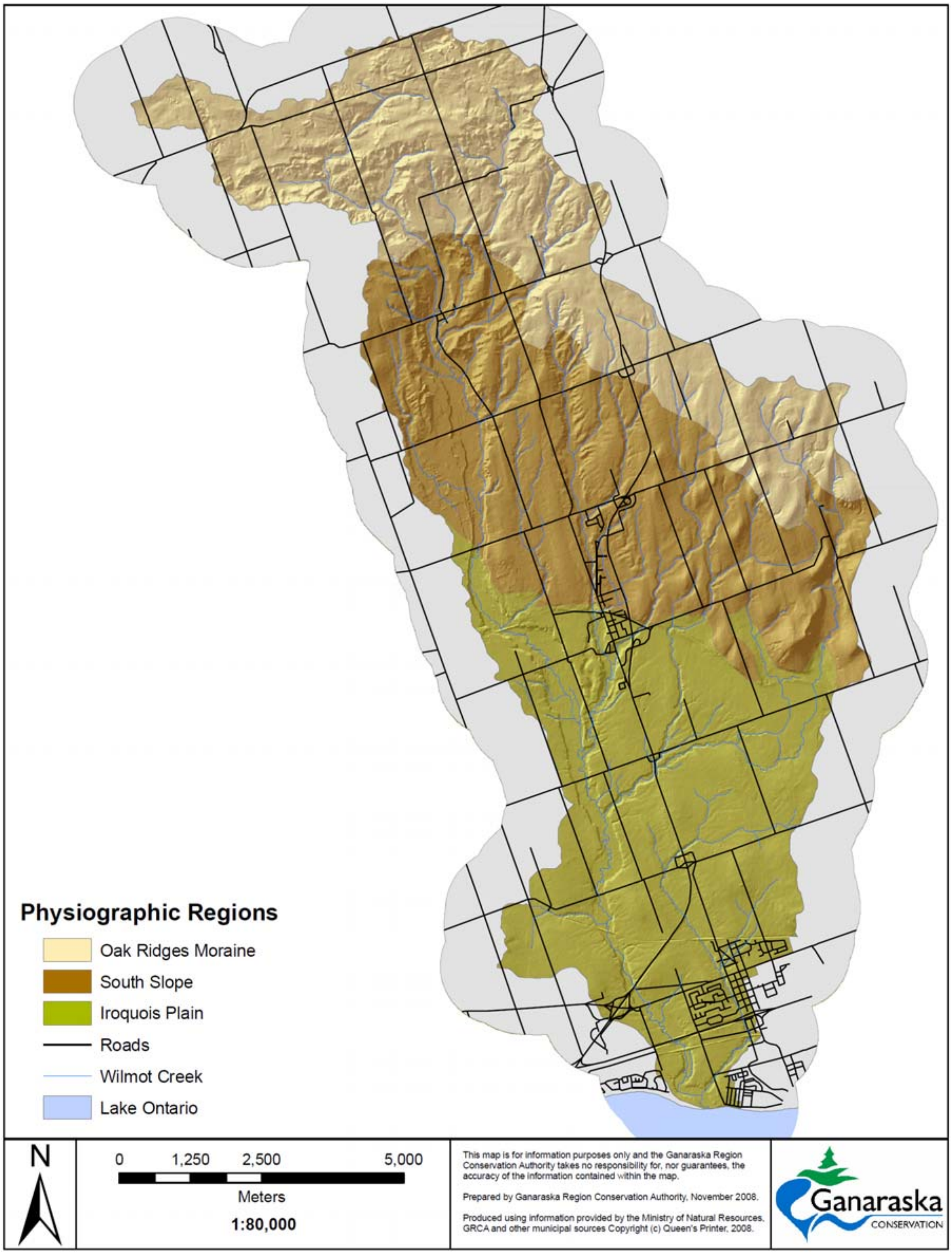

Figure 2: Physiographic regions

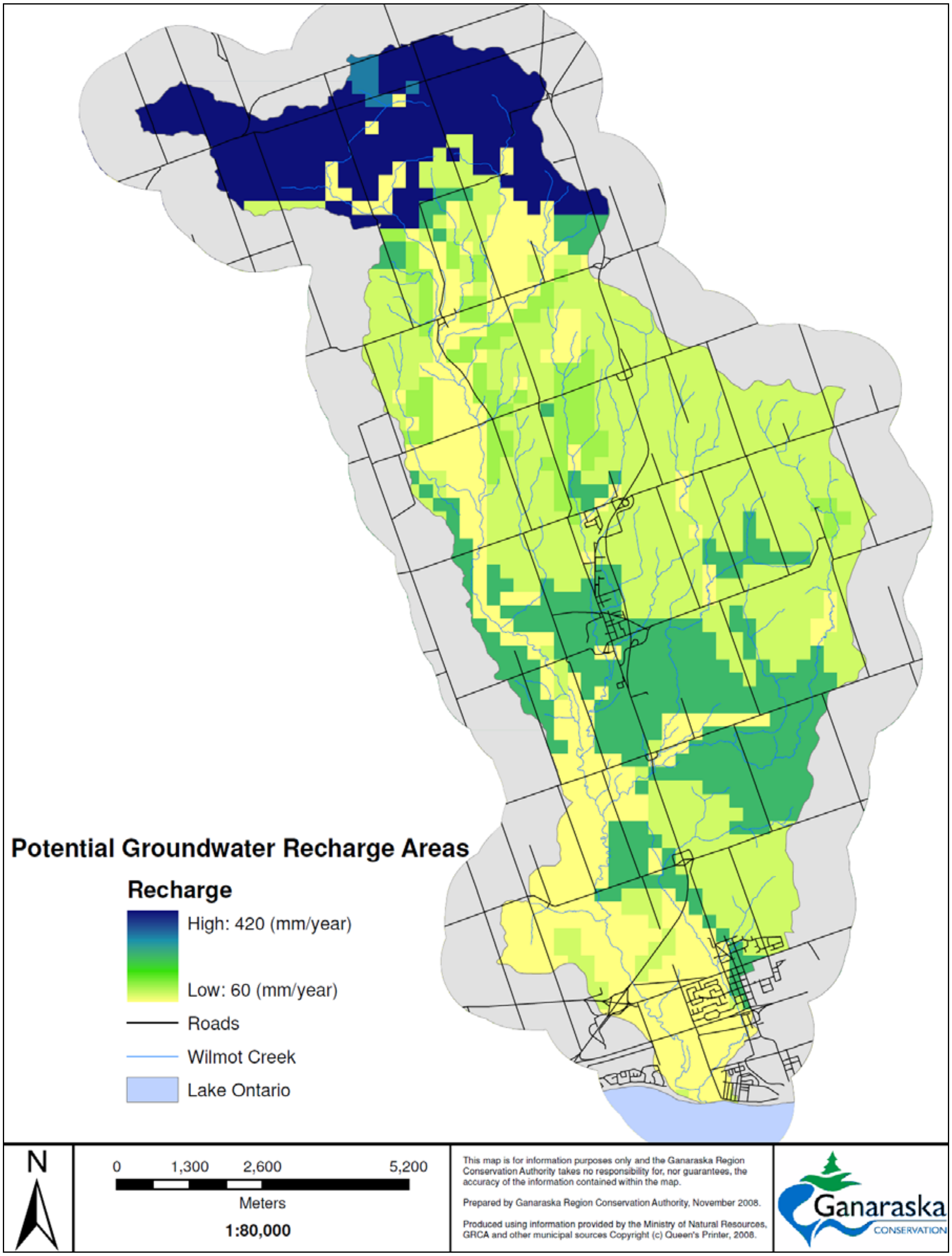

Figure 3: Potential groundwater recharge

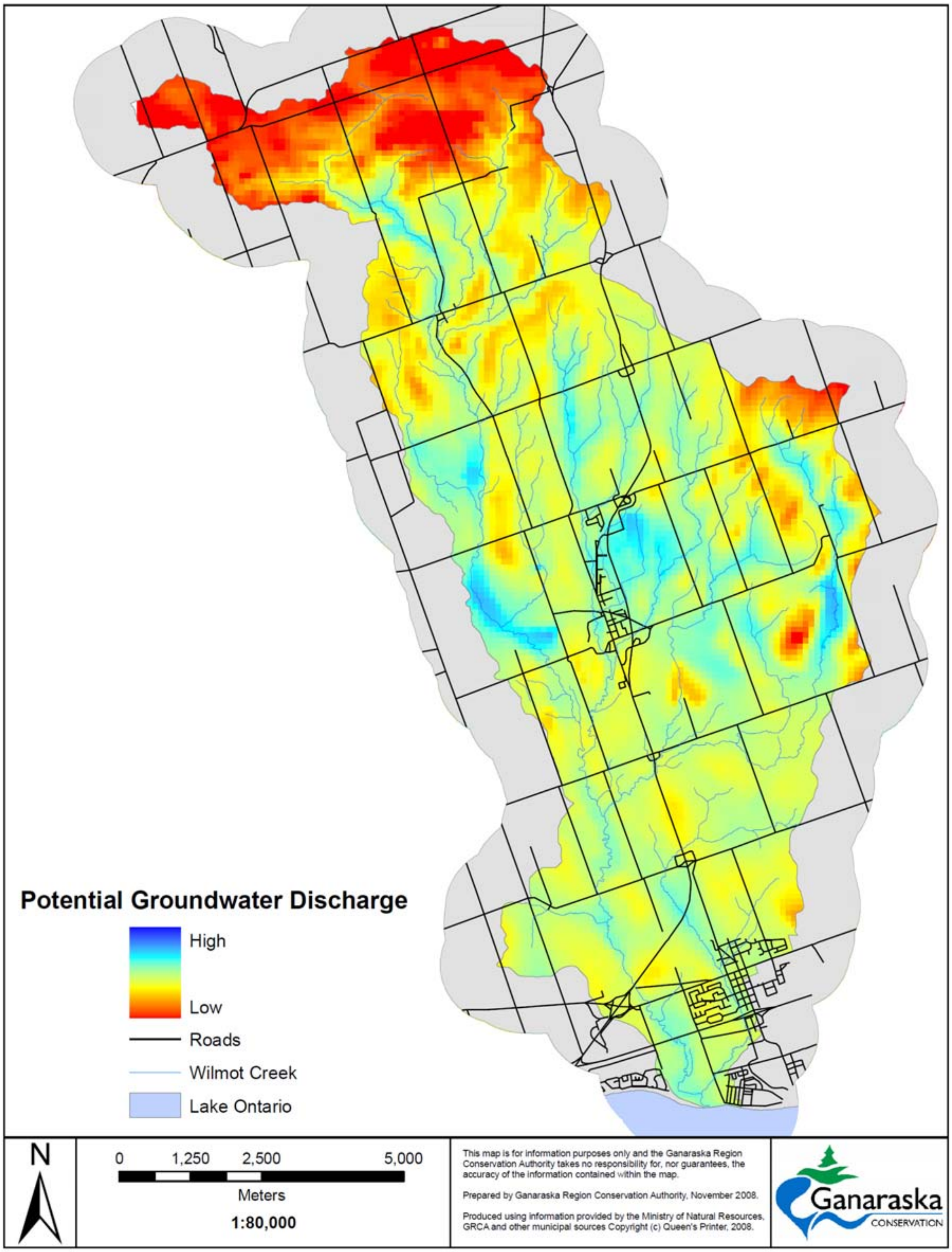

Figure 4: Potential groundwater discharge areas

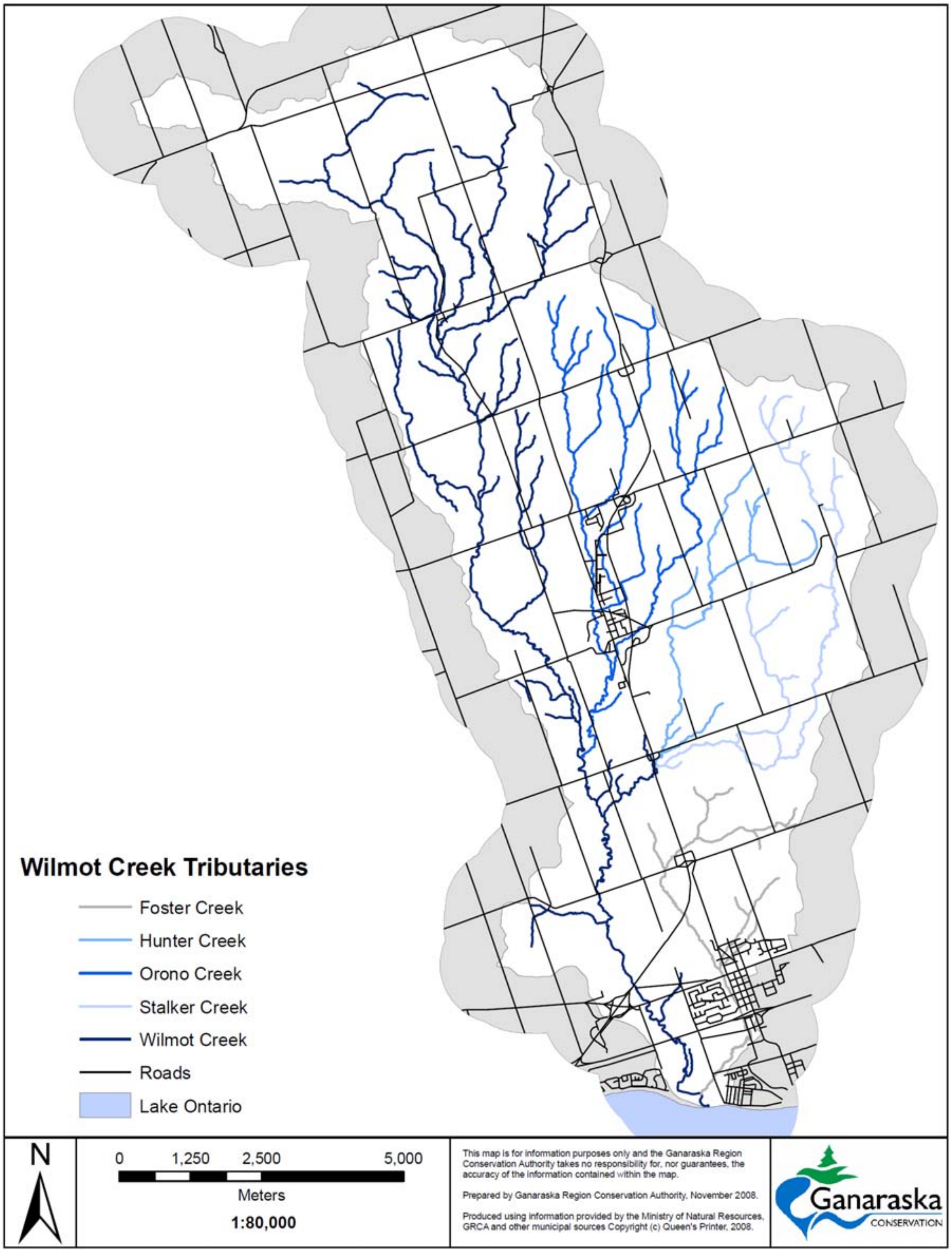

Figure 5: Wilmot Creek tributaries

Surface water quality as a whole in is generally good, with only localized problems. Physical parameters (dissolved oxygen, pH, conductivity and alkalinity) indicate that surface water quality can be resilient to acidification, eutrophication and chemical additions. Chloride has been increasing significantly since the 1960s and 1970s, as indicated at the long-term provincial monitoring stations. Within the Orono Creek tributary there is a difference in chloride concentrations between months dominated by rain (May to October inclusive) and months dominated by mixed precipitation and snow (November to April inclusive).

Total phosphorus exceeds the Provincial Water Quality Objective (PWQO) more often then any other nutrient, but never more than 45% of the time. Since 1964 total phosphorus has declined at the Squair Road Provincial Water Quality Monitoring Network (PWQMN) station, and there has been a decline since 1973 at the Regional Road 2 station. Unionized ammonia has been greater than the PWQO of 0.02 milligrams per litre (mg/L) 19% of the time as sampled through the Ganaraska Region Water Quality Monitoring Network.

At the Squair Road and Regional Road 2 PWQMN stations nitrate-N has been increasing since 2002, and exceeded the Canadian Water Quality Guideline (CWQG) 36% of the time at the Squair Road station. At the Regional Road 2 PWQMN station, nitrite-N concentrations have been declining since 2002, and concentrations have never exceeded federal guidelines since 2002 when sampled through the two monitoring programs. Nutrients therefore can be considered the water quality parameter most capable of fluctuating beyond recommended guidelines; however exceedences may be related to high runoff due to storm events, or land use.

Groundwater quality data is limited on a watershed scale. Information from water well records, the municipal water system and the Provincial Groundwater Monitoring Network (PGMN) indicates that there are naturally occurring groundwater quality parameters that can be aesthetically unpleasing from a human consumption standpoint. However, the quality of surface water is also reflective of groundwater inputs, indicating that groundwater quality in the Wilmot Creek watershed is generally good.

Wilmot Creek supports a diverse biological community. The fisheries are supported by a sustainable habitat of cold to cool water within the upper three-quarters of the watershed, with warm water communities in the lower main branch of the watershed (Figure 6). Riparian habitats provide buffering capacity to human influences in many of the stream reaches. Wilmot Creek supports a fish community dominated by Brook Trout *(Salvelinus fontinalis)*, Brown Trout (*Salmo trutta*), Rainbow Trout *(Oncorhynchus mykiss)*, scuplins (*Cottidae* species), darters (*Etheostoma* species), and cyprinids. Migratory Chinook Salmon (*Oncorhynchus tshawytscha*) spawn in the lower reaches.

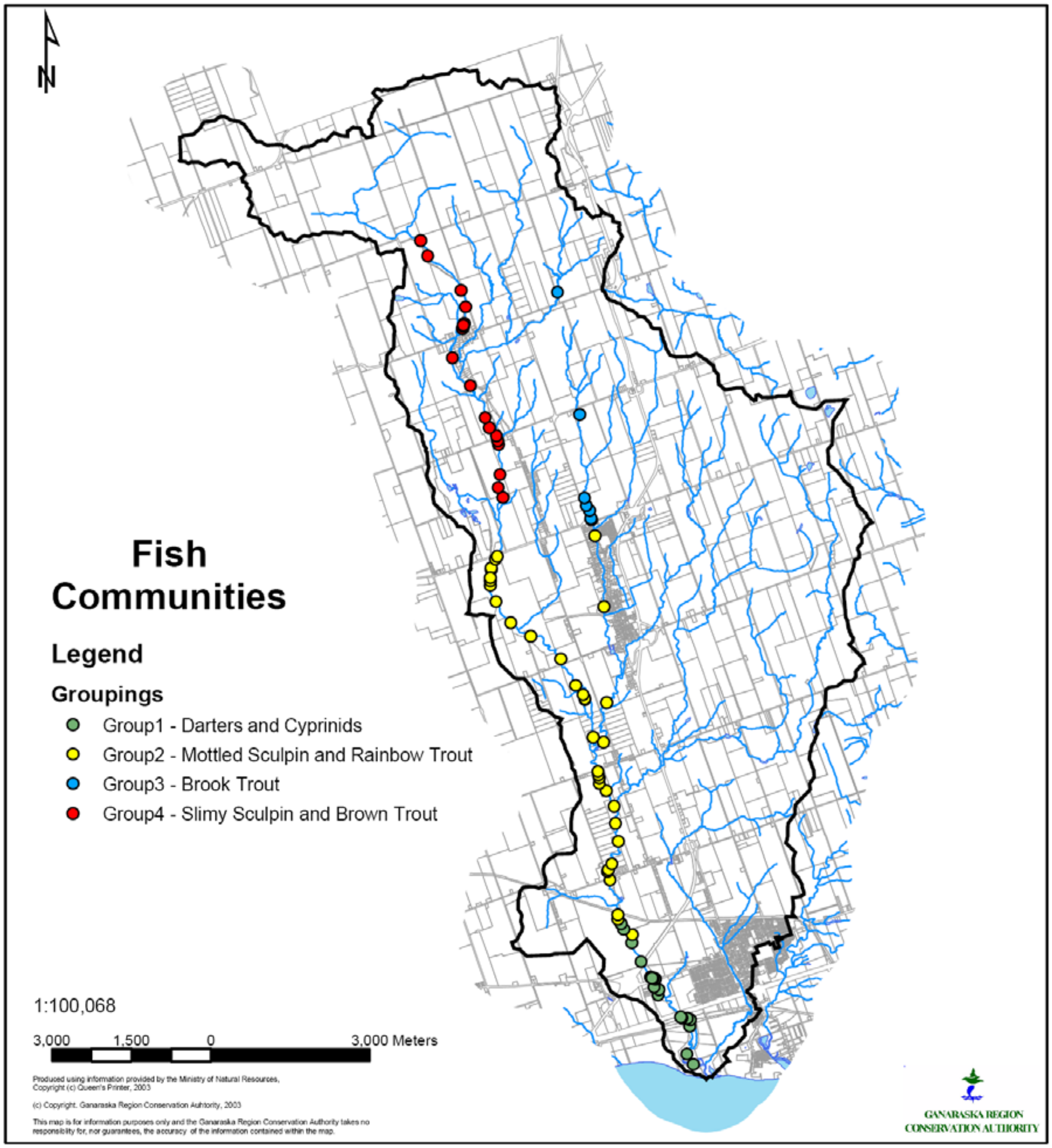

Figure 6: Fish communities within Wilmot Creek

The terrestrial natural habitat of Wilmot Creek includes forest, meadows and wetlands (Figure 7). At 25%, forest cover is below the commonly used guideline of 30%. Interior forest habitat is found in only about 12% of the forested watershed, primarily in the rural landscape. Forests are primarily found in the headwaters and river valleys, and located on private and public lands, such as the Orono Crown Lands. Indicator species such as birds and frogs can indicate the health of forest and wetland habitats. Numerous species at risk may inhabit the Wilmot Creek watershed and therefore should be considered in management planning. Invasive species such as Dog-strangling Vine (*Cynanchum rossicum)*, European Buckthorn (*Rhamnus cathartica)*, and Garlic Mustard (*Alliaria petiolata)* pose a threat to terrestrial habitat health.

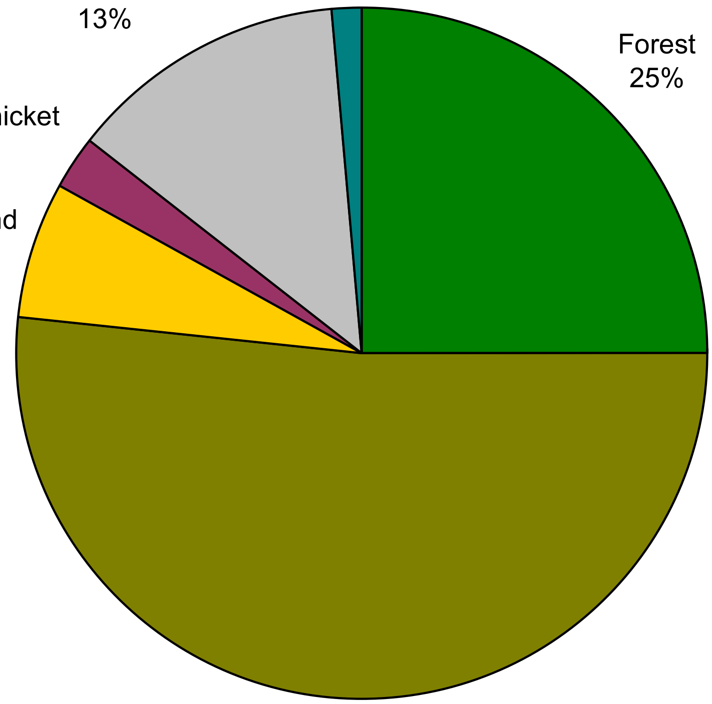

Figure 7: Land cover based on ecological land classification

The Wilmot Creek watershed is not only an important environmental feature to the communities of the watershed; it plays an important role in a larger context. For example, Wilmot Creek contributes to the health and resources of Lake Ontario. In addition, Lake Ontario is a drinking water source for thousands of Ontario residents. However, Wilmot Creek has the potential to be influenced by future stresses such as climate change and the extension of Highway 407.

The Wilmot Creek watershed is recognized for its fisheries resource, aquatic habitat, terrestrial natural heritage and recreational opportunities. The development of a watershed plan, which is required under the *Oak Ridges Moraine Act, 2001*, will aim to conserve and sustainably manage the Wilmot Creek watershed for current and future generations.

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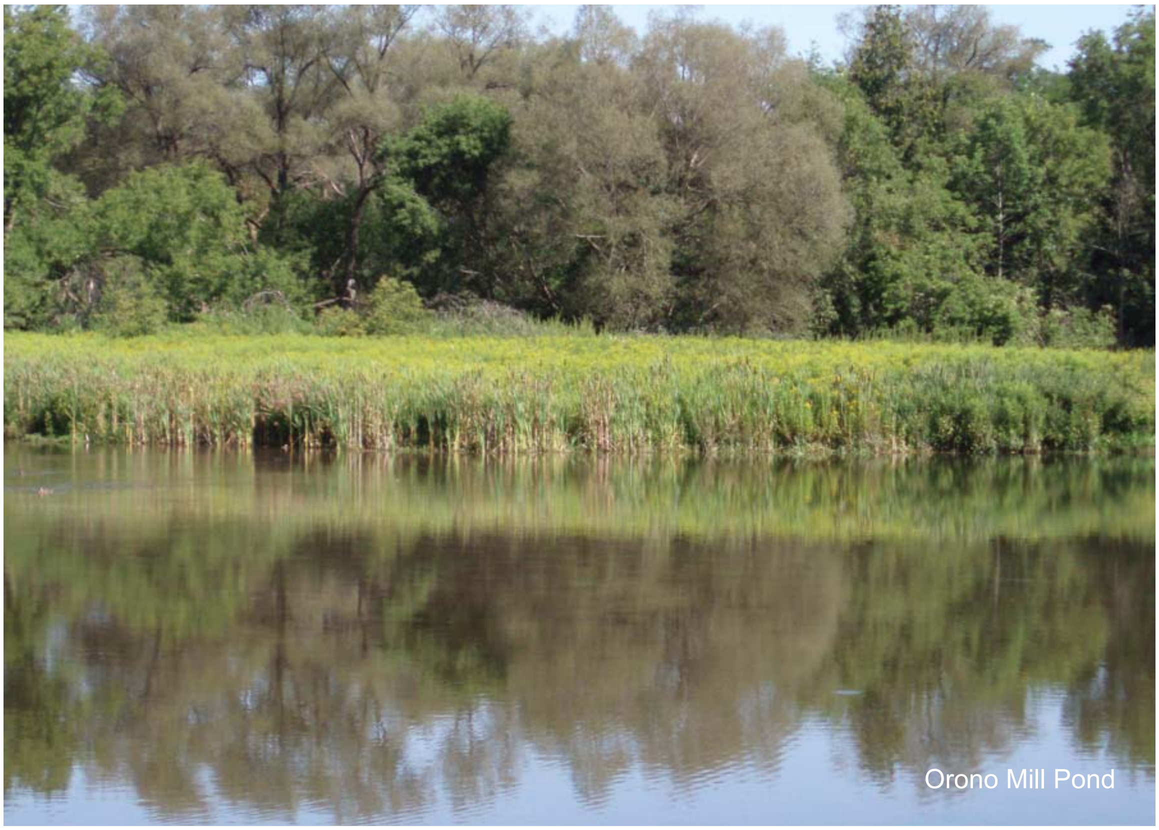


Chapter 1 - Introduction

1.0 WILMOT CREEK WATERSHED PLAN

Throughout the Province of Ontario there is a need to manage and plan for the appropriate use of our natural environment and its resources. As development continues across the landscape, sustainable management and planning of human settlement is required to ensure that current and future actions do not degrade, alter or destroy the natural environment. A watershed plan is one way to ensure that current and future generations are able to progress while acknowledging and addressing effects on the local ecosystem.

The study area of a watershed plan is a watershed: an area of land that drains to a common body of water. Watersheds are defined by topographical boundaries and may cross political jurisdictions. The Ganaraska Region Conservation Authority (GRCA), formed in 1946, was established to manage local watersheds including Wilmot Creek, Graham Creek, the Ganaraska River, Gages Creek, Cobourg Creek, and smaller streams draining to Lake Ontario and Rice Lake (Figure 1.0).

The Wilmot Creek watershed within the Ganaraska Region Conservation Authority drains to Lake Ontario (Figure 1.0) as it passes through the Municipality of Clarington. The Wilmot Creek watershed has been delineated by the topography. Heights of land form the drainage basin in the rural areas of the watershed (Figure 1.1). A watershed is a logical environmental planning area given that many natural functions are interconnected. Natural cycles within a watershed need to be protected for the benefit of our local environment and communities.

In 2001 the Province of Ontario enacted the *Oak Ridges Moraine Conservation Act*, which in 2002 established the *Oak Ridges Moraine Conservation Plan*. The purpose of the *Oak Ridges Moraine Conservation Plan* is to provide land use and resource management planning direction to provincial ministers, ministries, agencies, municipalities, municipal planning authorities, landowners and other stakeholders on how to protect the Moraine's ecological and hydrological features and functions (Ontario Ministry of Municipal Affairs and Housing 2002). As a result of the legislated requirements of the *Oak Ridges Moraine Conservation Act*, the Regional Municipality of Durham, the Municipality of Clarington and the City of Kawartha Lakes require a watershed plan to be created for the Wilmot Creek watershed, which originates on the Oak Ridges Moraine.

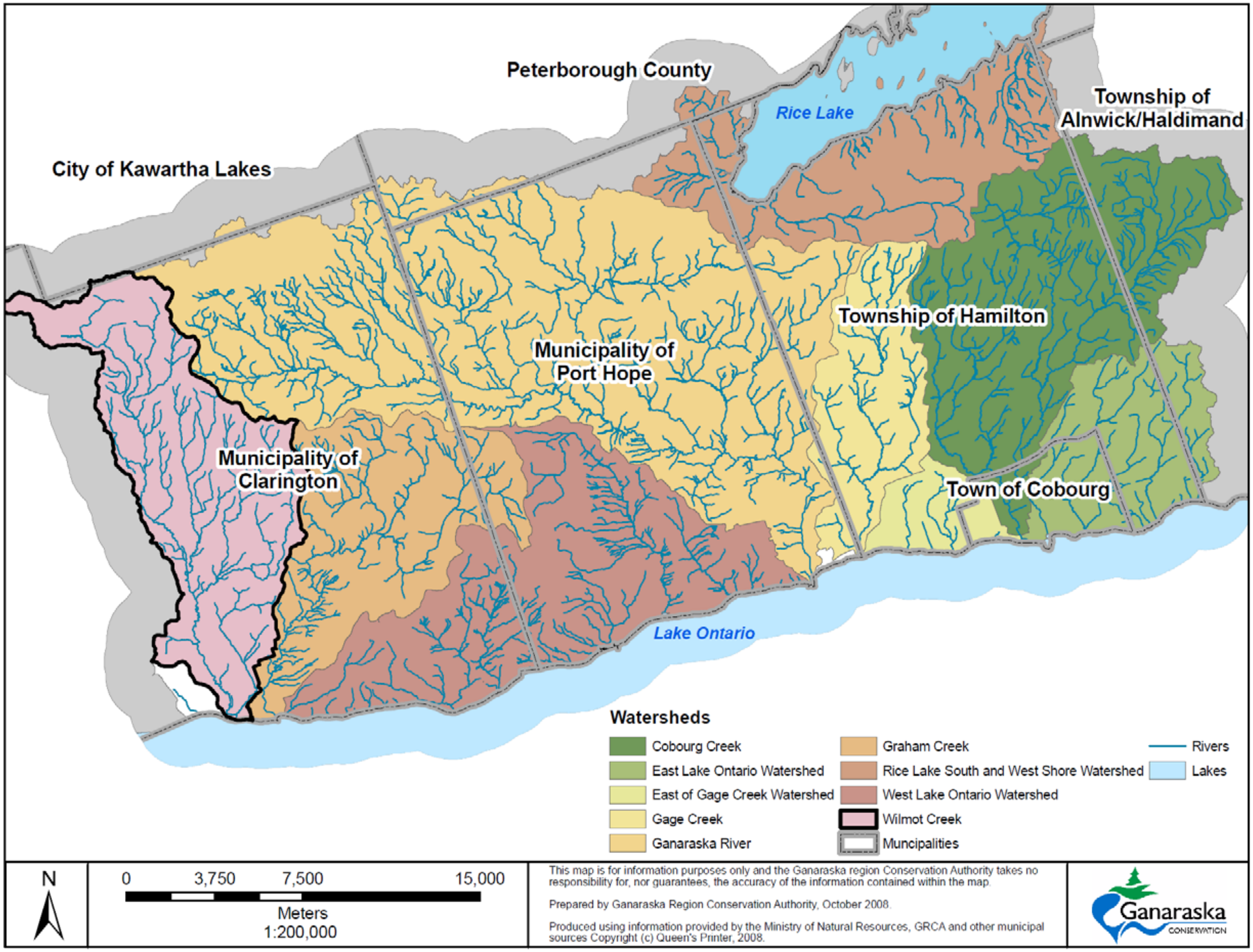


Figure 1.0: Wilmot Creek watershed within the Ganaraska Region Conservation Authority

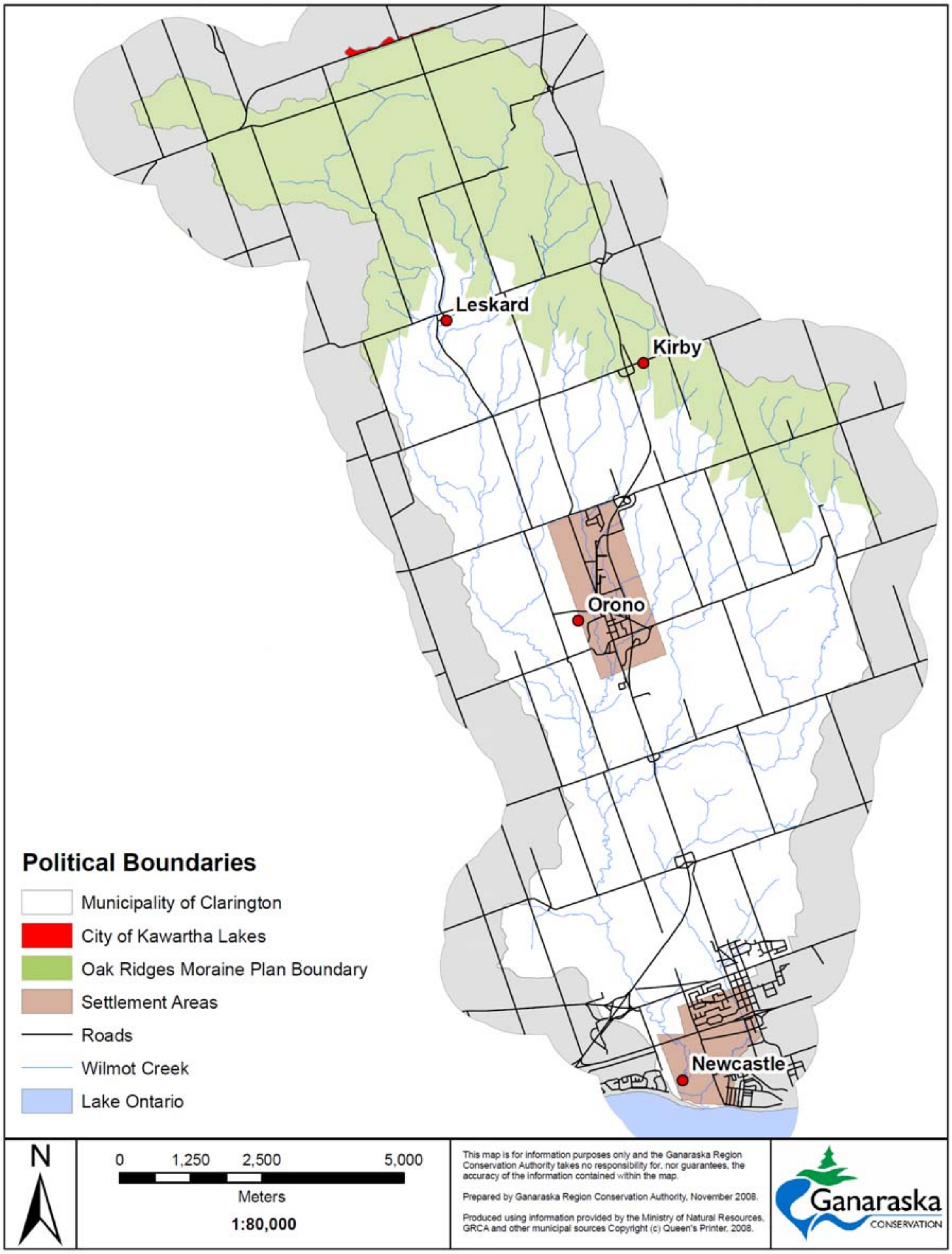
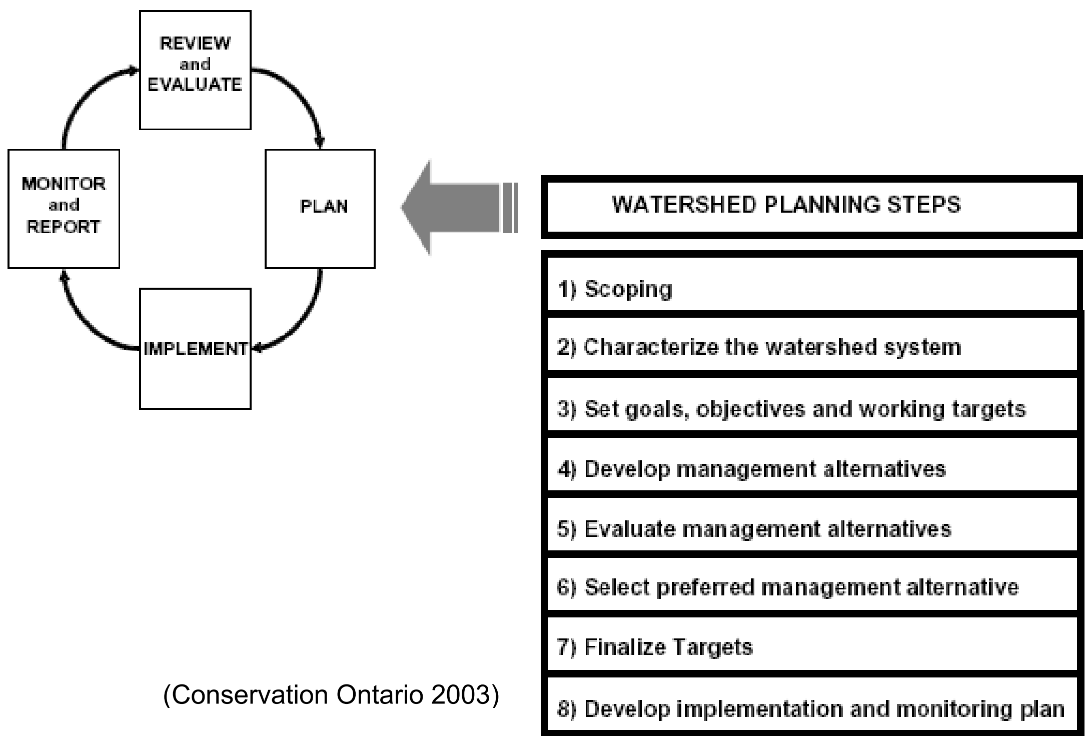


Figure 1.1: Wilmot Creek watershed

1.0.1 Watershed Planning Process

The watershed planning process is one stage in the ongoing program of watershed management. The basic principles of watershed management have changed little since formally described in the early 1990s (Ontario Ministry of the Environment and Energy, and Ministry of Natural Resources 1993). As illustrated in Figure 1.2, the process of watershed management has four phases, including plan development, plan implementation, monitoring and reporting, and reviewing, evaluating and updating the plan. Conservation Authorities in Ontario commonly follow this process, although each authority may have slightly different terminology associated with individual steps, suited to local watershed needs.

Watershed plans are usually prepared in response to a trigger, such as public concern about environmental conditions, a municipal Official Plan requirement, or, as in this case, the requirements set out by the *Oak Ridges Moraine Conservation Act*.



(Conservation Ontario 2003)

Figure 1.2: Watershed management phases and watershed planning steps

The "plan" phase can be described according to eight steps as shown in Figure 1.2. The key to success is public, community and stakeholder input into milestone steps (e.g., characterization and alternative steps). Steps 1 and 2 have been completed. Scoping requires choosing a study area, creating a terms of reference and managing data. A terms of reference has been created for the Wilmot Creek watershed (Ganaraska Region Conservation Authority 2003, updated in 2009).

Characterizing the watershed describes the history and current conditions of the study area. This document reflects the characterization step of the Wilmot Creek watershed plan process. It contains current information for making informed management decisions regarding the conservation and environmentally sound management of the watershed, and creates the foundation for the Wilmot Creek watershed plan.

The Wilmot Creek watershed plan will address steps 3 to 8. Based on the information presented in this document, as well as computer models used to evaluate the watershed's response to alternative land use management scenarios, the Wilmot Creek Watershed Plan can be created. The plan will contain recommendations, implementation strategies, and roles and responsibilities. The plan will also address requirements of the *Oak Ridges Moraine Conservation Act*. The watershed plan will be completed in late 2009 or early 2010.

1.0.2 Wilmot Creek Fisheries Management Plan

The *Wilmot Creek Fisheries Management Plan* was approved in 2008 (Ganaraska Region Conservation Authority and Ontario Ministry of Natural Resources 2008). This plan is a resource document written for the citizens and stakeholders of the Wilmot Creek watershed. The purpose of the plan is to create a framework to guide the conservation, rehabilitation and enhancement of the fisheries resource in the watershed. It is hoped that this document will encourage stakeholders to follow the recommended management actions provided and subscribe to an ecosystem first approach regarding resource use and watershed development.

The goals of the plan were developed through stakeholder consultation to support the Wilmot Creek watershed in the following ways:

1. to protect and enhance the biological integrity of the aquatic ecosystem
2. to achieve "no net loss" of fisheries habitat
3. to promote the sustainable utilization of fisheries resources
4. to develop a greater knowledge of fish populations, fish habitat and aquatic ecosystems
5. to describe the existing conditions of the fish community to establish a benchmark of ecosystem health
6. to provide a framework for fisheries management at subwatershed, reach and site scales
7. to rehabilitate degraded fish communities and fish habitat, for self-sustaining, native stocks
8. to promote public awareness, appreciation and understanding of fisheries resources and the aquatic habitats on which they depend
9. to involve organized angling associations, environmental interest groups and the general public in fisheries management activities.

1.0.3 Foster Creek Subwatershed Planning Study

The *Foster Creek Subwatershed Planning Study* was created in 2001 under development requirements of the Municipality of Clarington Official Plan. Gartner Lee Limited, Greenlands International and Stantec Consulting Limited were retained by the Municipality of Clarington and the Ganaraska Region Conservation Authority to complete the subwatershed study (Gartner Lee Limited and Greenlands International 2001). The vision of the Foster Creek Subwatershed Plan was defined as follows:

> *"To maintain and enhance the health and quality of the Foster Creek Subwatershed and its ecosystem by developing a strategy to ensure that impacts associated with future and existing growth within the Subwatershed are minimized and that existing land use activities degrading the ecosystem's health can be identified and addressed."*

Issues of concern addressed within the subwatershed study include the following:

- maintenance and enhancement of riparian corridors and linkages for aquatic conveyance and wildlife movement
- identification of Core Natural Areas
- aquatic and terrestrial habitat maintenance and potential enhancement
- maintenance of terrestrial corridors and linkages for wildlife movement
- baseflow augmentation during drought sequences to sustain wetland and aquatic resources within Foster Creek
- maintenance of storm drainage systems, including a Highway 115 ditch
- inlet/storm sewer/outfall structure that has been washed-out - causing erosion of a ravine slope next to Foster Creek
- verification of Regulatory Flood hazard/risk zones, as a result of potential land use encroachment within the Village of Newcastle after fill and floodline policy mapping was prepared in the late 1970s
- water quality maintenance and potential enhancement.

The *Foster Creek Subwatershed Management Plan* provided recommendations and implementation strategies on the following topics:

- Greenlands System Development Controls
- Stormwater Management
- Stewardship and Conservation Practices
- Capital Works Projects Implementation Strategy Framework
- Monitoring and Adaptive Environmental Management.

1.0.4 Lake Ontario Shoreline

In the late 1980s focus was given on the Lake Ontario shoreline in relation to land use, hazard land identification and proper management. Sandwell Swan Wooster Incorporated (1990) completed a Lake Ontario Shoreline Management Plan for the Central Lake Ontario, Ganaraska Region and Lower Trent Region Conservation Authorities. The overall objective of the study was to develop a comprehensive shoreline management plan to allow the Conservation Authorities to implement long-term development objectives. Sandwell Swan Wooster Incorporated (1990) listed specific objective of the study that were intended to:

- Establish a program for the prevention of flooding and erosion damages and the protection of existing development from flooding and erosion.
- Evaluate hazard areas, investigate littoral processes, and to identify and assess potential damage centres and protection strategies along the shoreline.
- Provide background information useful to planning authorities in developing waterfront plans.
- Assess the characteristics of the shoreline including sensitive areas, recreational opportunities, wildlife habitat and the Lake Ontario fishery in terms of potential use or preservation of these resources.
- Determine the optimum management strategy for the shoreline in terms of flood and erosion mitigation and other resource management concerns.
- Identify the role of Conservation Authorities and that of other relevant agencies in managing the shoreline.

Along with the identification of erosion setback limits, 100-year flood lines, erosion rates, sediment characteristics, damage centres and erosion monitoring stations, Sandwell Swan Wooster Incorporated (1990) recommended the following actions, many of which have been carried out:

- Municipalities should recognize shoreline hazard lands in appropriate official plan and zoning provisions.
- Measures should be taken to protect environmentally sensitive areas along the shoreline.
- Acquisition of the shoreline should be considered in order to protect the environmental characteristics and acquired lands should include the limits of erosion and/or flooding setbacks.
- Implementation of shoreline protection structures should be examined on a site-specific scale, and carried out using coastal engineering studies.
- Conservation Authorities should operate existing shoreline monitoring stations and establish additional sites.

Specific and additional information regarding the Lake Ontario shoreline within the regional study area is found in Sandwell Swan Wooster Incorporated (1990) and in section 4.1.7 of this document.

1.0.5 407 East Environmental Assessment

The Ontario Ministry of Transportation is currently undertaking an individual Environmental Assessment study to address long-term transportation needs in the Region of Durham and surrounding areas. The study supports the transportation objectives of the provincial *Growth Plan for the Greater Golden Horseshoe* by providing for the efficient movement of people and goods within the study area.

In May 2006, a new transportation corridor extending Highway 407 easterly from its current terminus at Brock Road in Pickering to Highway 35/115 in Clarington, with two north-south connecting Highway 401 to the proposed extension of Highway 407, was recommended as part of a number of transportation improvements (Totten Sims Hubicki Associates Limited 2005). The extension of the 407 is proposed to cross Wilmot Creek through concession 7 and 8 and connect to Highway 35/115 and Kirby (Figure 1.3). The Ganaraska Region Conservation Authority is participating in the planning process to extend the 407, through providing technical advice and comment to the Environmental Assessment process.

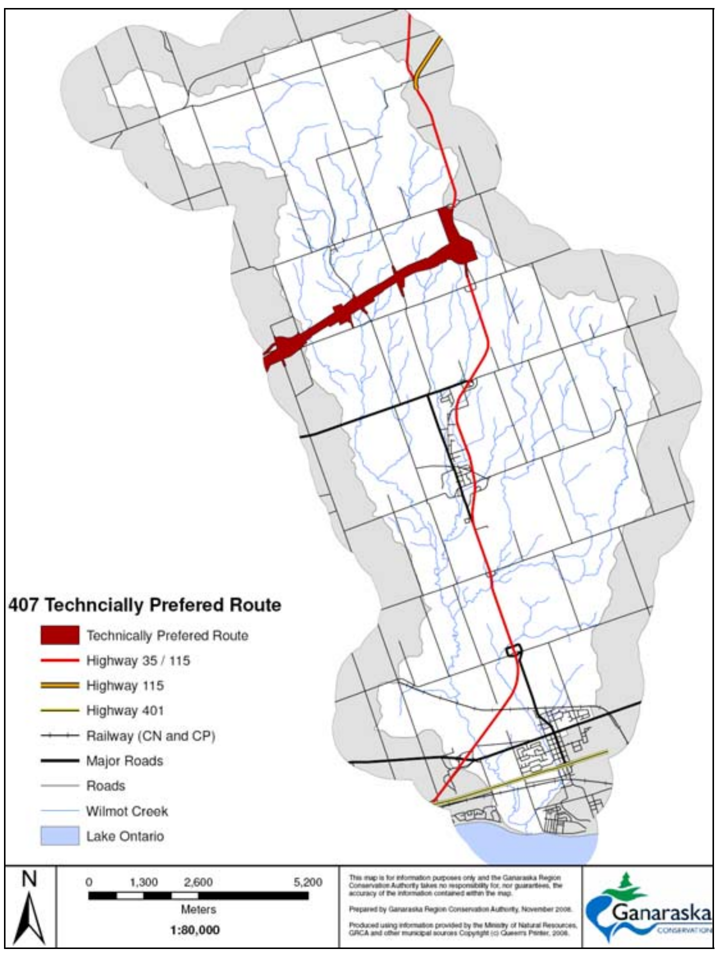
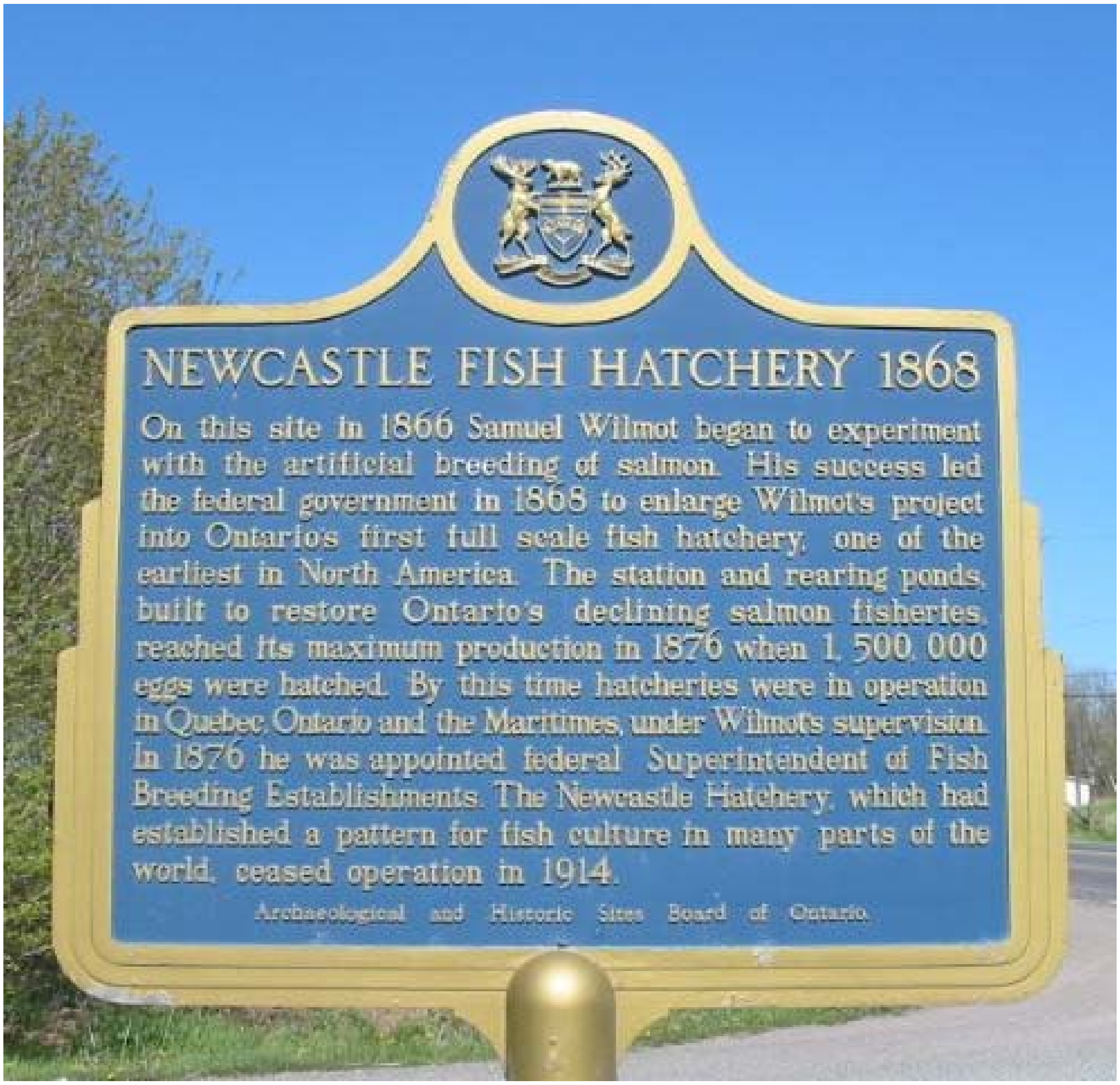


Figure 1.3: Proposed 407 route



Chapter 2 – History of Wilmot Creek Watershed

2.0 CULTURAL HISTORY OF THE WILMOT CREEK WATERSHED

Historical settlement patterns, communities and natural resource uses play an important role in shaping current communities, land resources and natural environments. Understanding historical events will aid in understanding current land uses and settlement areas. This knowledge will guide management decisions while providing an appreciation for the rich local history.

2.0.1 Settlement

Prior to European settlement, numerous aboriginal groups inhabited the region around and in the Wilmot Creek watershed. The Hurons resided in the region from Lake Ontario to Georgian Bay until the late 1600s, when the Iroquois forced the Hurons to move as far north as Lake Superior (Martin et al. 1986). After 1660 the Cayuga tribe of the Iroquois established outposts in the Rice Lake area and at Ganaraska (Port Hope), thus controlling the fur trade in the area. In the early 1700s the Iroquois were forced out of the surrounding area by the Mississaugas, a stem of the Ojibwa-Algonkins from the Lake Superior region (Martin et al. 1986). The Mississaugas did not settle in any one place, and were nomadic in the area (Schmid and Rutherford 1975).

The Wilmot Creek watershed, located in close proximity to Lake Ontario, is typical of an area used as native travelways and summer fishing grounds. A prehistoric archaeological site (Fennell site) has been documented on the lands just east of the Wilmot Creek Wetland, south of the Durham Region Water Pollution Control Plant (Ganaraska Region Conservation Authority 2000). Artefacts found on the Fennell site confirm native occupancy in the area as far back as the Late Archaic period (2500 to 1800 B.C.), to the Late Woodland period (A.D. 800 to 1650).

The Clarke Township survey was initiated 1796, and was named for Major General Alured Clarke, Lieutenant Governor of Lower Canada. The "Nine Mile Forest" lay between the 3rd and 4th Concessions, the headwaters of Foster, Stalker and Graham Creeks (Gartner Lee Limited and Greenlands International 2001). This large expanse, noted as being part swamp, made the work difficult for the surveyors and was likely responsible for the uneven sizes of farms.

The earliest settlement in the Foster Creek subwatershed was Trickey's Corner, where the present Highway 115 and Concession 3 intersect today. Joseph Miller Trickey was a blacksmith and ran Zimri Baker's axe factory with the power of a small water wheel on Foster Creek (Gartner Lee Limited and Greenlands International 2001). Pioneer homesteads and early farms in the Wilmot Creek watershed were occupied by several notable families including Robert Baldwin who served as a justice of the peace and a commissioner of road for the Newcastle District (Schmid and Rutherford 1975). His son, Robert Baldwin Jr. was joint premier with Louis Lafontaine of the Province of Canada (Schmid and Rutherford 1975). The Baldwin homestead was located at the mouth of Wilmot

Creek where a commemorative historic plaque was erected in 1963 to recognize the significant heritage site. Unfortunately, the plaque was subsequently vandalized and removed.

Other notable pioneers to the area were Richard Lovekin who also developed a homestead at the mouth of Wilmot Creek, which in the 1700s was called Baldwin Creek (Belden and Company 1974). In 1816, Samuel Wilmot, a famous surveyor purchased 400 acres of land (later obtaining even more land) on the banks of the creek north of the present day Regional Road 2 (Desjardins and Stanfield 2005).

The main settlement areas within Wilmot Creek included Newcastle, Orono, Kirby and Leskard. Newcastle was settled in the early 1800s, yet merged with the neighbouring community of Bond Head in 1851 (Schmid and Rutherford 1975). Newcastle was founded on industry, with the most prominent business being Newcastle Agricultural Works. The Newcastle Agricultural Works in 1849 manufactured plows, scufflers, harrows, potash and sugar kettles (Schmid and Rutherford 1975). In 1864 the business burnt down, but being a necessary employer in the community it was rebuilt, and by 1868 the Massey family employed more than 100 men and established 20 agencies in Ontario (Schmid and Rutherford 1975). In 1891 Newcastle Agricultural Works amalgamated with Harris Implement to become Massey Harris and latter Massey-Ferguson.

In 1872, the Newcastle Woollen Manufacturing Company, one of the largest woollen mills in Upper Canada, was located in Newcastle, and employed 60 people (Schmid and Rutherford 1975). However times changed with the woollen mill burning, the Massey family moving to Toronto, and the loss of Northrop and Lyman, which later become the largest dealers in patent medicines (Schmid and Rutherford 1975). The most populous settlement area of Clarke Township slowly declined due to the numerous setbacks faced by the community.

Orono was the next largest settlement area within Wilmot Creek. The first settlers were Asa and Harriet Baldwin, who in 1832, experienced the great resources of the area when they scooped two speckle trout (Brook Trout) in their water pail (Schmid and Rutherford 1975). With the harnessing of water power, many mills were built to serve a population of approximately 1000 people in 1865 (Schmid and Rutherford 1975).

The villages of Leskard and Kirby were also settled within the watershed in the early 1830s. Kirby lacked the necessary streams that could power mills, and therefore did not grow in size like the neighbouring village of Leskard. In the mid to late 1800s Leskard was home to two stores, an inn, a carriage maker and a blacksmith shop; by 1900 however, there was only one store and the blacksmith shop (McGregor 1977). The differences in settlement patterns within Wilmot Creek reveal the importance of a combination of industry, transportation and water power to a settlement area.

2.0.2 Historical Natural Resources

When settlers arrived in Clarke Township, Black Walnut grew along the shores of Lake Ontario, cedar swamps lined the wet lowlands, and the uplands were covered with maples, beech, White Pine, and oaks (Schmid and Rutherford 1975). Among the forests and swamps, wildlife was abundant. A 25 pound lynx was trapped north of the 6th concession in the Wilmot Creek watershed, American Eagles nested within the river valleys, and in the 1800s fish were plentiful in the streams (Schmid and Rutherford 1975). Large predators also inhabited the Wilmot Creek watershed, including bears and wolves (Belden and Company 1974).

Fish, such as Atlantic Salmon, Brook Trout, and Lake Whitefish were an abundant and important protein source for early settlers. Atlantic Salmon spawned in the fall in the creek, while Lake Whitefish utilized a large lacustrine wetland at the mouth of Wilmot Creek (Desjardins and Stanfield 2005). Salmon were so plentiful in the stream that settlers harvested them with clubs and pitchforks and women seined them with their petticoats (Schmid and Rutherford 1975).

Once settlers harvested their shelter and food requirements from the plentiful flora and fauna in the area, they moved onto harnessing water power for milling. In 1823, the first sawmill was built at Regional Road 2, followed by another 15 mills (Figure 2.0).

The villages of Leskard and Orono both had a large number of dams compared to their size, indicating an economic and community need and dependence on water power. Leskard, located in the headwaters of Wilmot Creek utilized all of the small streams coming into the village.

> *"Leskard* [is] *situated on three streams of water. One creek coming from the north was unique: early in the spring it ran across the road at the top of the swamp road and in the summer it disappeared. We are told it ran under the ground for some distance. The "school" creek so called because it was near the school, started from springs not far away and ran along the east and south part of the village. A dam was built where the two creeks met and was known as the upper dam. A creek coming from the east along with the two from the north formed the lower pond."* (Schmid and Rutherford 1975)

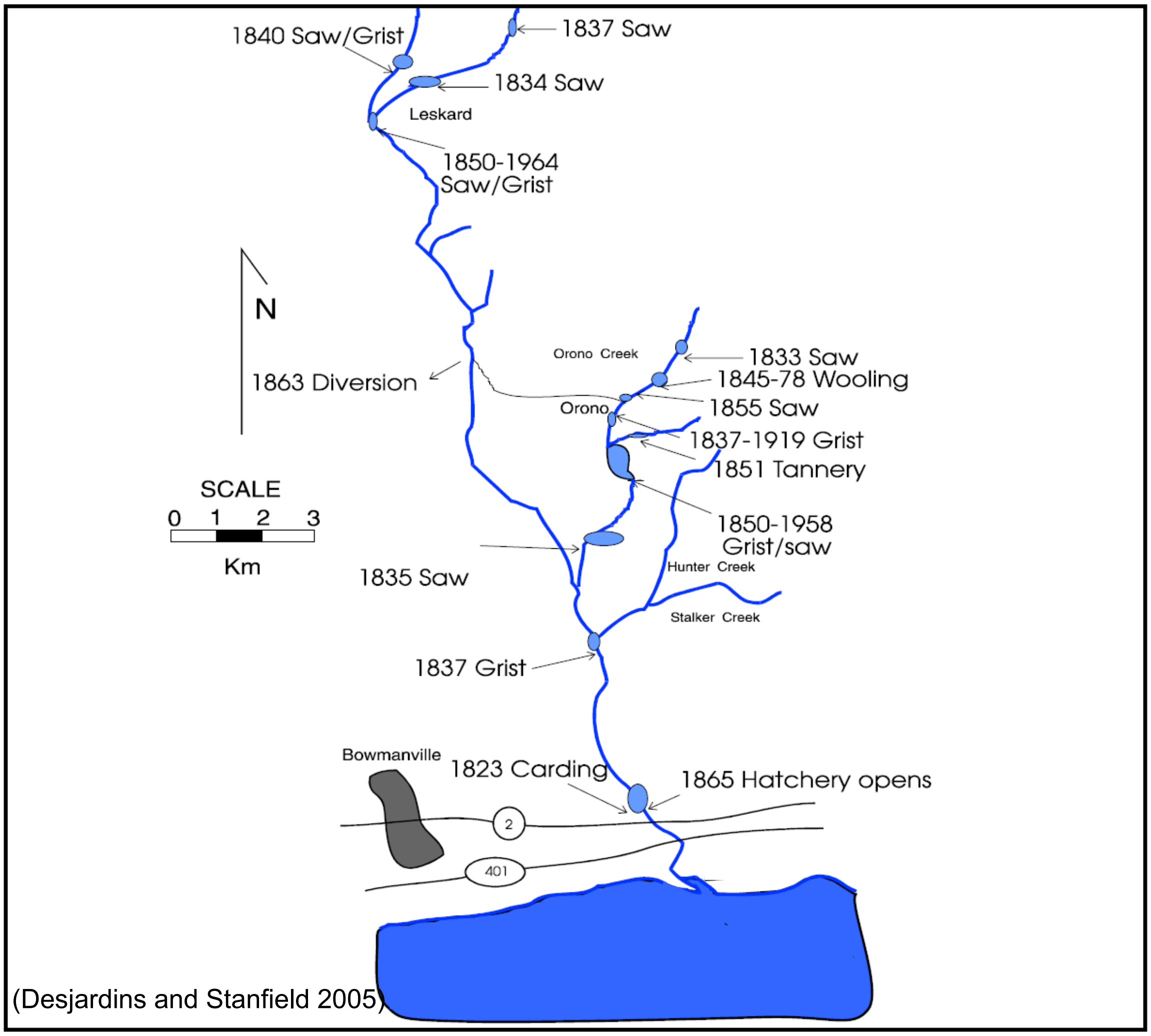


Figure 2.0: Historic dams in Wilmot Creek

Orono housed all of the necessary mills (saw, grist and woollen) required to run a community. The Tucker Grist Mill aided in changing the flows of Wilmot Creek in the late 1800s. In the early 1860s the flows of Orono Creek had diminished from deforestation, so much so that the mill would no longer work properly. As such a canal was constructed in 1863 to divert water from the main branch of Wilmot Creek to supplement the volume of water in Orono Creek (Squair 1927; Schmid and Rutherford 1975). It passed along the old railroad tracks to the creek that passes behind the business section of the Orono (Figure 2.0). Today the canal in behind downtown of Orono resembles a ditch. The mill closed when the Co-op officially opened a new mill and warehouse in 1958 (Schmid and Rutherford 1975) yet the mill pond still exists today.

Forestry was also a large economic component of Clarke Township. In order to clear the land for agriculture, which was the main motivation of the settlers, large tracts of land were harvested for timber. In fact Newcastle was one of the chief wood depots east of Toronto with thousands of cords of wood loaded on boats at

Port of Newcastle every year for use in Toronto (Schmid and Rutherford 1975). As forests were removed and replaced with wheat and fruit trees, the landscape was altered and forced to adapt. In the late 1930s, 17% of the watershed above Concession 7 was forested (Carman 1940). Deforestation created open land on the high ridges of the area, however, over the years, the erosion and the leaching of nutrients from the fields cause the farms to be abandoned (Schmid and Rutherford 1975).

Coinciding with the increase in development, creeks were dammed, sedimentation of streams increased, and the natural state of the watershed was altered so much that populations of Atlantic Salmon stopped spawning in Wilmot Creek and surrounding watersheds. During the time of population declines, pioneers realized an important resource was at risk. As a result landowners took steps to protect what they considered their fish on their property. These increasing confrontations initiated the “Salmon War” of 1842. One landowner was determined to keep the remaining fish for himself and his neighbours and forbade all parties from fishing for them (except the Indians who had prior rights). Settlers from upstream areas, adjacent watersheds and 100 French workers (who were working in nearby lands were paid to participate) took on the local community and were able to drive them off the land after a bloody ordeal (Desjardins and Stanfield, adapted from Schmidt and Rutherford, 1975).

2.0.3 Restoration

With the loss of forests and the decline of flows in the streams to power the mills, reforestation was necessary to control land erosion and surface water runoff. Gully erosion was minimized by installing check dams. Stanley Chapman who farmed on Lot 26, Concession 7 installed a check dam that was 9 feet tall by 75 feet long (Figure 2.1). By 1929 the area behind the dam was completely full of sediments eroded from the surrounding slopes (Carman 1940), thus preventing downstream sedimentation.

Figure 2.1: Historic watershed management using a check dam

F.L. Squair at Lot 7, Concession 3 in the Township of Darlington was the first landowner to reforest his land, with the aid of Edmund Zavitz (Schmid and Rutherford 1975). In 1912, W.L. Smith planted thousands of pine seedlings on his property south of Orono (Schmid and Rutherford 1975). This momentum of private land reforestation was followed with the establishment of the provincially run Orono Tree Nursery. Meredith Linton, an Orono native, aided the establishment of the nursery in 1920, with the purchase of 175 acres of land (Schmid and Rutherford 1975). As the Orono nursery became established, permanent plantations were established in the northern part of Clarke Township. In the 1970s the nursery sat on 1,350 acres, providing trees to reforest local watersheds (Schmid and Rutherford 1976). In 1996 the nursery was closed and as a result of community consultation in 2001, the Ministry of Natural Resources partnered the Orono Crown Lands Trust to manage the property. The Orono Crown Lands Trust is comprised of volunteers that assist the Ministry in the management and maintenance of the property.

With the declines of the Atlantic Salmon spawning in Wilmot Creek, Samuel Wilmot realized that action needed to occur to prevent the loss of this important fish. Samuel Wilmot tried various experiments with harvesting fertilized eggs from Wilmot Creek to be reared and hatched in a controlled setting. He then took mature adult salmon and fertilized the eggs stripped from the females with the milt from males (Schmid and Rutherford 1975). After these successful experiments showed that Atlantic Salmon could be raised through artificial methods, the Newcastle Hatchery was formed. For more than 50 years the hatchery produced more than 155 million fish of a number of varieties (Schmid and Rutherford 1975). Although Samuel Wilmot's efforts did not save the Atlantic Salmon from disappearing from the tributaries of Lake Ontario, his work and research created a foundation for fish hatcheries and the future work of restoring Atlantic Salmon to Lake Ontario and its tributaries.

2.0.4 Changing Landscape

Rail travel helped shape the current day natural landscape. In 1856 the Grand Trunk Railway connected Toronto to Cobourg (Richardson 1944), thus changing the travel corridor to the south end of Wilmot Creek. The railway provided for diverse employment within Clarke Township. Much of the timber harvested was used to fuel the steam locomotives. Today the Canadian National Railway operates on in the same track corridor, moving freight and passengers on two sets of tracks through Newcastle, and the south end of Wilmot Creek.

The Canadian Northern Railway company constructed a railway that ran through the middle of the Wilmot Creek watershed. In October of 1911 the Canadian Northern Railway opened passenger services, with the Orono Station being a prominent stop, and by 1917 the boom of freight and passenger service was realized (Schmid and Rutherford 1975). In 1919 the Canadian Northern and Grand Trunk Railway companies amalgamated, causing the lakeshore route to be the main passenger service line, and the construction of a second track along the lakeshore route (Schmid and Rutherford 1975).

As with any settlement, the natural environment is changed through the use and exploitation of natural resources and the transformation of land from forests to agriculture, or wetlands to towns and villages. Figure 2.2 depicts a timeline of the events that transformed the wetlands and forests of the Wilmot Creek watershed to the towns and villages we se today. Today the Wilmot Creek watershed is radically different from the pre-settlement days, both in appearance and in the natural resources that exist.

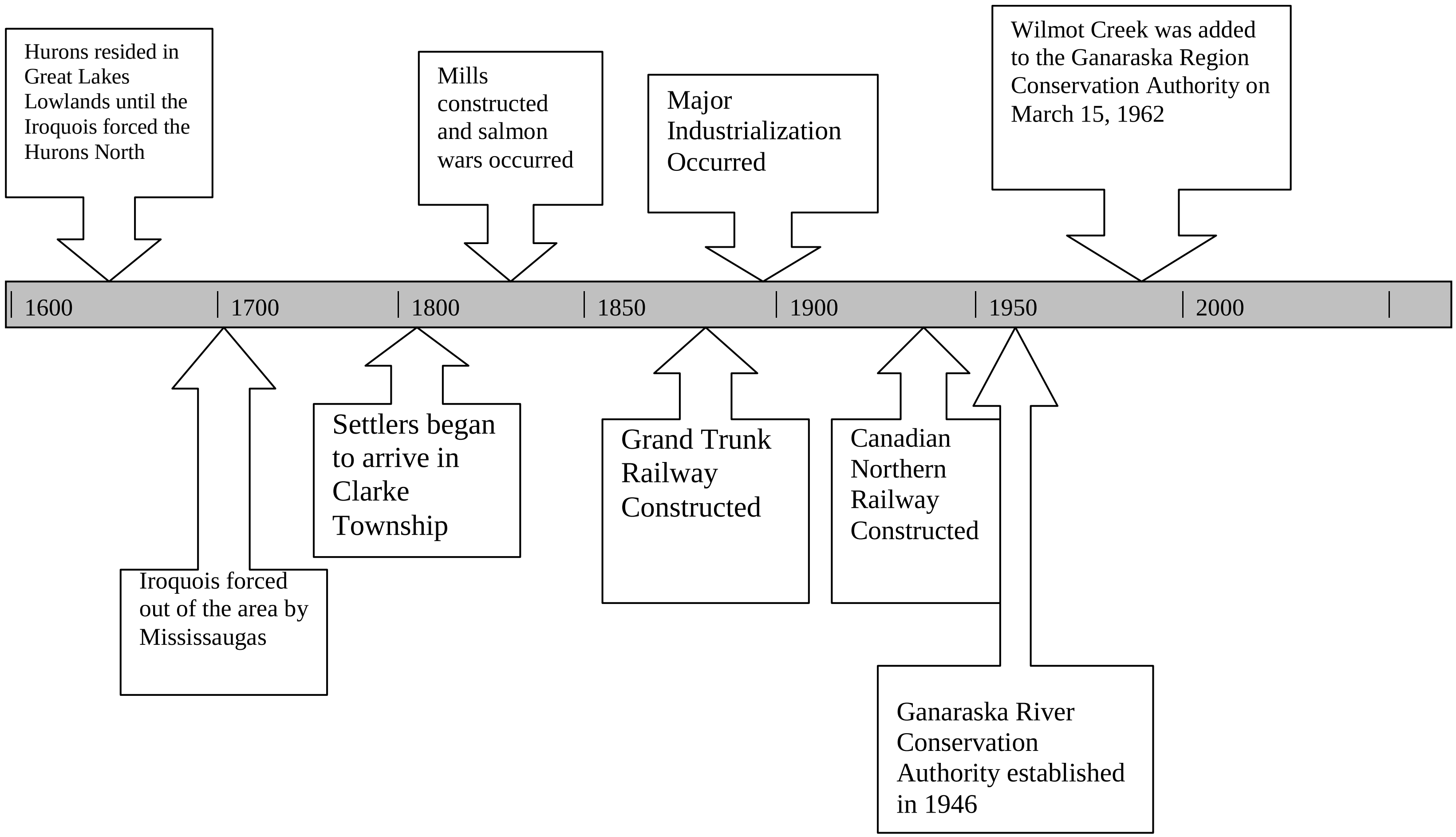


Figure 2.2: Post settlement events

Chapter 3 - Abiotic Features

3.0 Regional Climate

Climatic elements such as precipitation (rain and snow), evaporation and temperature have a dominant effect on various components of the hydrologic cycle (Figure 3.0). Understanding these elements and their patterns plays a key role in developing water budgets and understanding how natural systems will respond to changes in climate and drought conditions. The climate of an area depends on its location within the worldwide circulation of the atmosphere. Local climates may also be profoundly affected by the proximity of an area to large water bodies and local topographic relief.

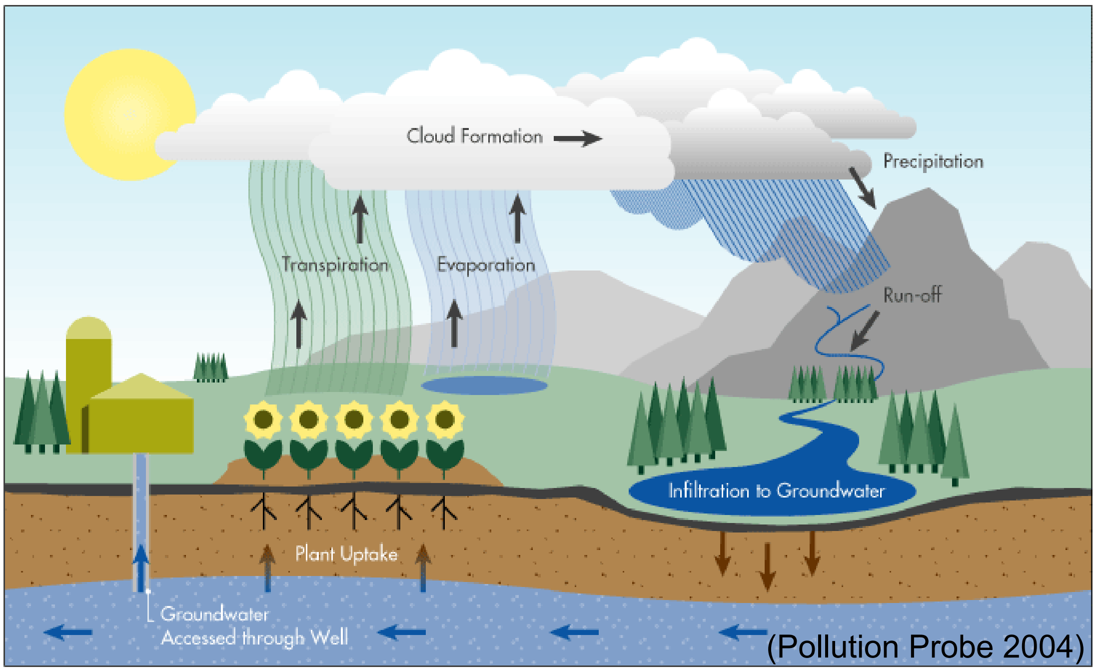


Figure 3.0: Hydrologic cycle

Topography influences local temperature and precipitation. Average annual temperature and precipitation show only minor variation across the Ganaraska Region Conservation Authority due to the small geographic scale. The climate in the Ganaraska Region Conservation Authority is continental, with cold winters and warm summers. The most significant factor affecting the climate is Lake Ontario. A definite moderating effect due to lake influence is seen in the immediate vicinity of the Lake Ontario shoreline, while the modification in climate diminishes as one ascends the northern inland slopes. On the Oak Ridges Moraine the climate is colder, exhibiting harsher winters and later springs than the rest of the drainage area.

Climate data from Environment Canada is available from 20 stations in (four stations) and nearby the Ganaraska Region Conservation Authority and can be used to determine precipitation and temperature, and estimate infiltration and evapotranspiration. In addition to the climate data from Environment Canada, the

Ganaraska Region Conservation Authority operates five meteorological stations (Figure 3.1 and Table 3.0) that provide 15-minute interval climatic data. In 2008 rain gauges were installed on three Provincial Groundwater Monitoring Network wells. These wells are located near Leskard in Wilmot Creek, on Newtonville Road in Graham Creek and in the Rice Lake Conservation Area (Figure 3.1). Data is not yet available for these rainfall stations.

According to the climatic information provided (Table 3.1), the mean annual daily temperature in the Ganaraska Region Conservation Authority ranges from about 5.9 to 7.3°Celsius (C). January is the coldest month with mean daily temperatures in the -8°C range. July is the warmest month with a mean daily temperature of approximately 20°C.

According to climate data from several local Environment Canada climate stations, precipitation in the Ganaraska Region Conservation Authority shows local variation (Figure 3.2). In the lakeshore region the mean annual precipitation varies from 755 to 830 millimetres (mm), while on the northern upland slopes it varies from 875 to 900 mm. There is greater precipitation (up to 1000 mm) on the Oak Ridges Moraine upland area than on the slope and low regions of the Ganaraska Region Conservation Authority.

Precipitation varies seasonally, with the September to December period generally being the wettest. Between December and March most precipitation falls as snow, whereas in the months of November and April precipitation is mixed, with most being rain. Depending on location, either February or July is typically the driest month of the year, however in 2009, the month of February received more rainfall than normal. The mean annual precipitation ranges from about 830 mm/year at Port Hope in the south to about 880 mm/year in Orono in the west. About 70 to 85% of precipitation falls as rain. Figure 3.3 and Figure 3.4 show the annual meteorological trends based on the records of two meteorological stations in and near the Ganaraska Region Conservation Authority.

Table 3.0: GRCA-operated climate stations

Station Name	Location	Year Established	Type of Measurements
GRCA Main Office	2216 County Road 28, Port Hope	2002	Rainfall, Air Temperature, Wind Speed and Direction, Relative Humidity
Cobourg Creek*	609 William Street, Cobourg	2003	Rainfall, Air Temperature
Wilmot Creek	Concession Road 3, Newcastle	1999	Rainfall
Forest Centre	10585 Cold Springs Camp Road, Campbellcroft	2001	Rainfall, Snowfall, Air Temperature, Wind speed and Direction
Baltimore Creek	4494 County Road 45, Baltimore	1999	Rainfall, Air Temperature, Wind Speed and Direction

*Replaced the Cobourg Pump Station climate station that operated since 2000.

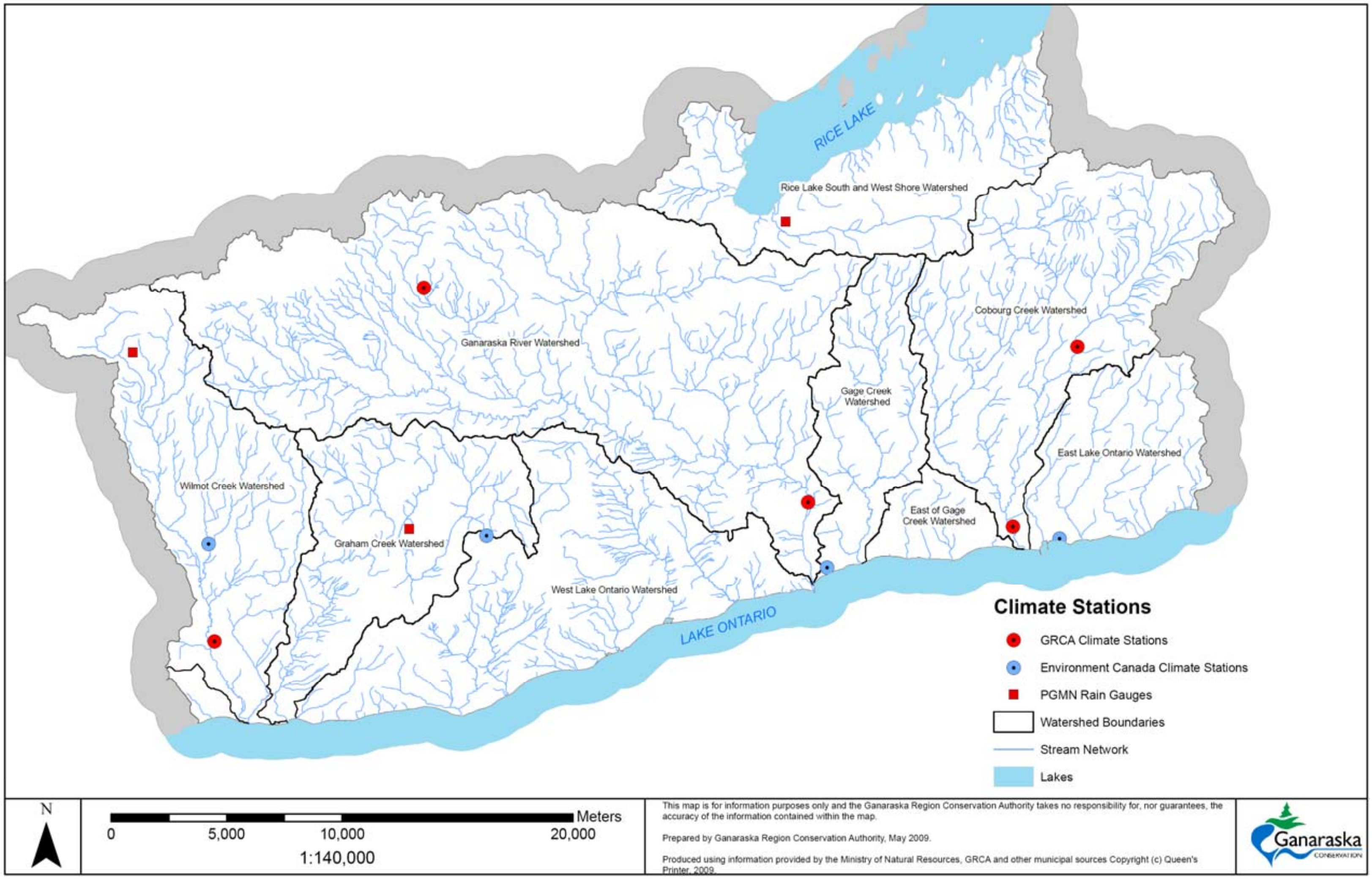


Figure 3.1: Climate stations

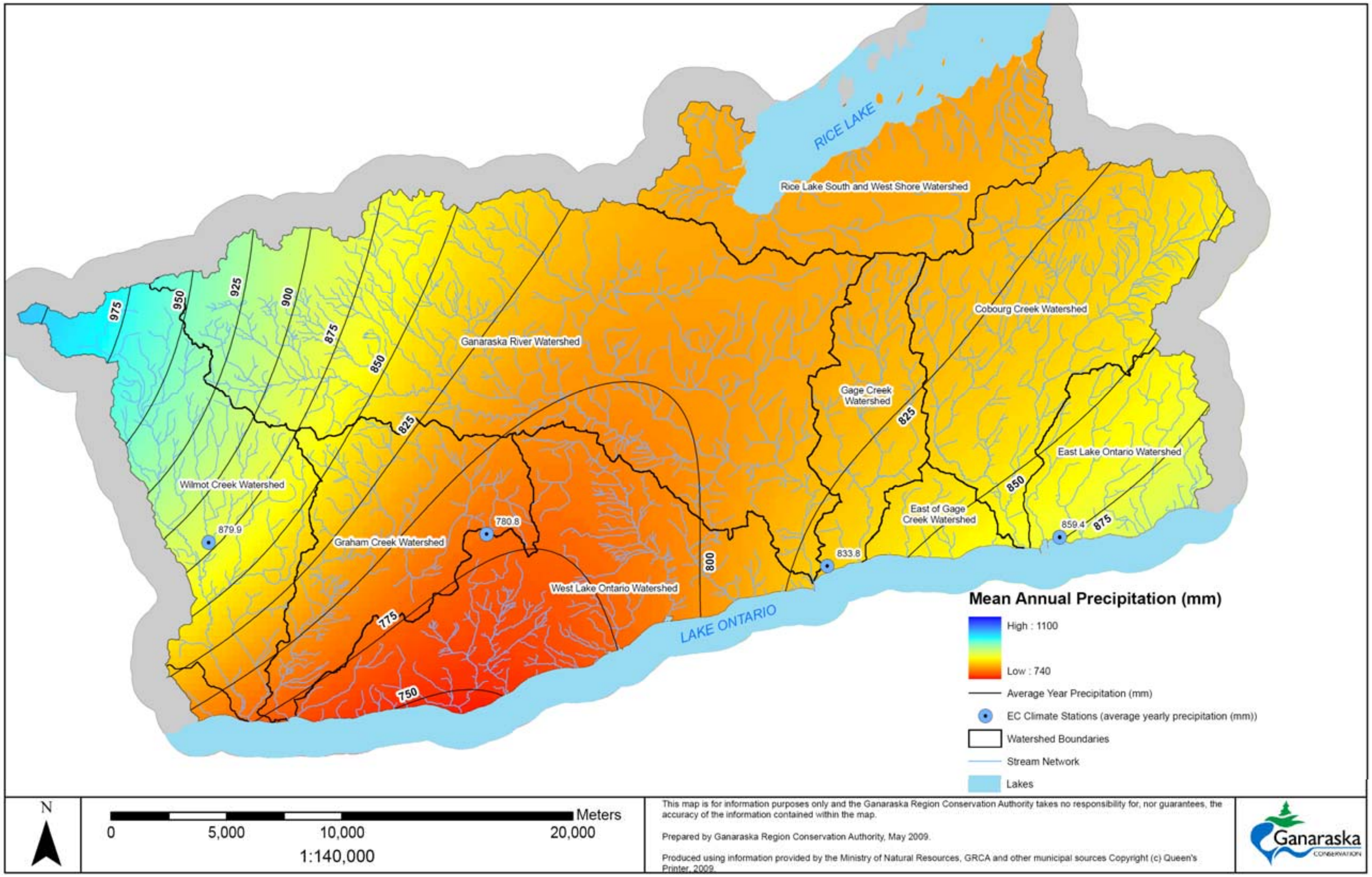


Figure 3.2: Precipitation distribution

Table 3.1: Precipitation and temperature data summary

	Campbellford*	Cobourg	Port Hope	Orono	Peterborough*
Elevation (masl)	146	79.2	80.8	148	191.4
Total Precipitation (mm)	836.7	871.1	832.0	879.9	840.3
Rain (mm)	684.1	765.8	709.0	724.5	682.0
Snow (mm)	149.3	106.0	122.0	152.6	162.0
Wettest Month (mm)	December, 82.1	September, 90.0	December, 80.5	September, 76.3	August, 83.2
Driest Month (mm)	July, 58.3	February, 54.0	July, 53.3	February, 63.8	February, 50.6
Mean Year Temperature (^oC)	--	7.1	7.3	6.8	5.9
Warmest Month (^oC)	--	July, 19.6	July, 20.0	July, 20.1	July, 19.4
Coldest Month (^oC)	--	January, -6.0	January, -5.8	January, -6.9	January, -8.9

* Stations located outside of the Ganaraska Region Conservation Authority, but near enough to have relevant data. Data range from 1971 to 2000 from selected weather stations.

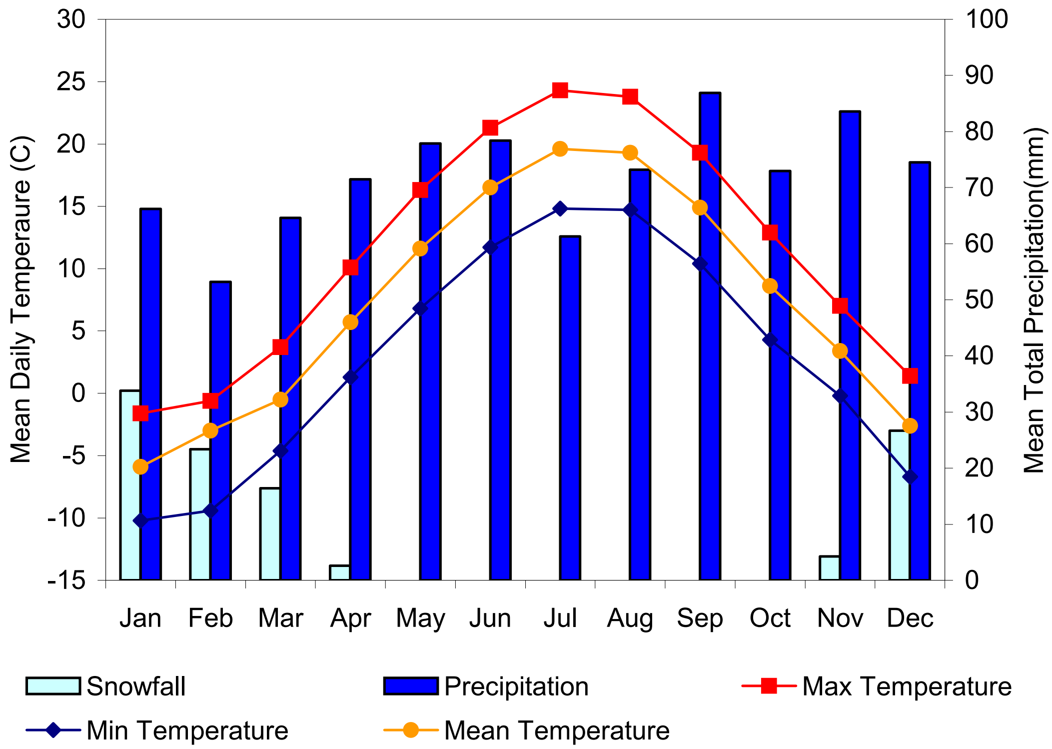


Figure 3.3: Cobourg STP meteorological station (6151689), 1970 to 2003

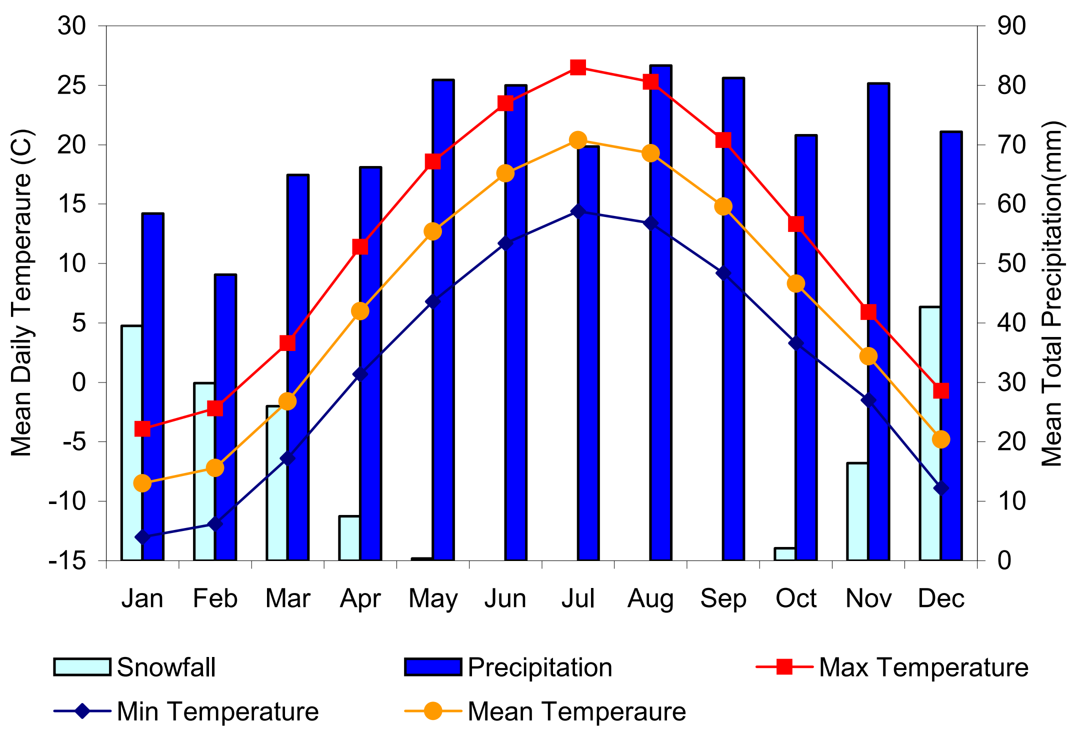


Figure 3.4: Peterborough, Trent University meteorological station (6151689), 1968 to 2000

3.1 GEOLOGIC CHARACTERISTICS

Geology is the scientific study of the Earth, its origins and evolution, the materials that make it up, and the processes that act on it. The following section defines the bedrock, glacial deposition, topography, physiographic regions, surficial geology and soils of the Wilmot Creek watershed.

3.1.1 Bedrock

The bedrock beneath the Wilmot Creek watershed is Palaeozoic bedrock that is 550 to 350 million years old (Earthfx Incorporated 2006). Palaeozoic bedrock was created from the eroded materials of mountains being lithified on top of the Canadian Shield. Across southern Ontario there are five Palaeozoic Bedrock types. The bedrock unit that represents the lower geologic formation in the Wilmot Creek watershed is the Lindsay Formation from the Simcoe Group, composed of coarse-grained limestone; and the Whitby Formation from the Georgian Bay Group of the Upper Ordovician Age. Limestone bedrock, which can be highly fractured, has the potential to create productive aquifers or aquitards when it is poorly fractured with low permeability (Earthfx Incorporated 2006).

The surface of the bedrock was created as a result of historical erosion. Erosion created depressions and channels in the bedrock surface and topographic highs were created from rocks that were not eroded (Jagger Hims Limited 2007). The bedrock in the Wilmot Creek watershed is completely covered by a mantle of Quaternary deposits. The bedrock elevation ranges from about 50 to 80 metres above sea level (masl) along the shore of Lake Ontario to about 160 to 200 masl below the Oak Ridges Moraine (Figure 3.5).

3.1.2 Glacial Depositions

Geological activity during the Wisconsin Glaciation period formed the major deposits that sit on limestone bedrock. The Late Wisconsinan ice advance occurred 25,000 to 12,000 years ago, in which the Laurentide ice sheet deposited a thick sheet of till, known locally as Bowmanville Till (Brookfield et al. 1982), which has a regional correlation with Newmarket Till or Northern Till in the western part of the Oak Ridges Moraine (Earthfx Incorporated 2006). The Bowmanville Till lies on the thick lower sediments comprised of Port Hope Till, Clarke Deposits, and a thin layer equivalent to the Scarborough Formation (Brookfield et al. 1982, Earthfx Incorporated 2006, Jagger Hims Limited 2007, YPDT-CAMC Groundwater Study [website] 2006, Ganaraska Region Conservation Authority 2007).

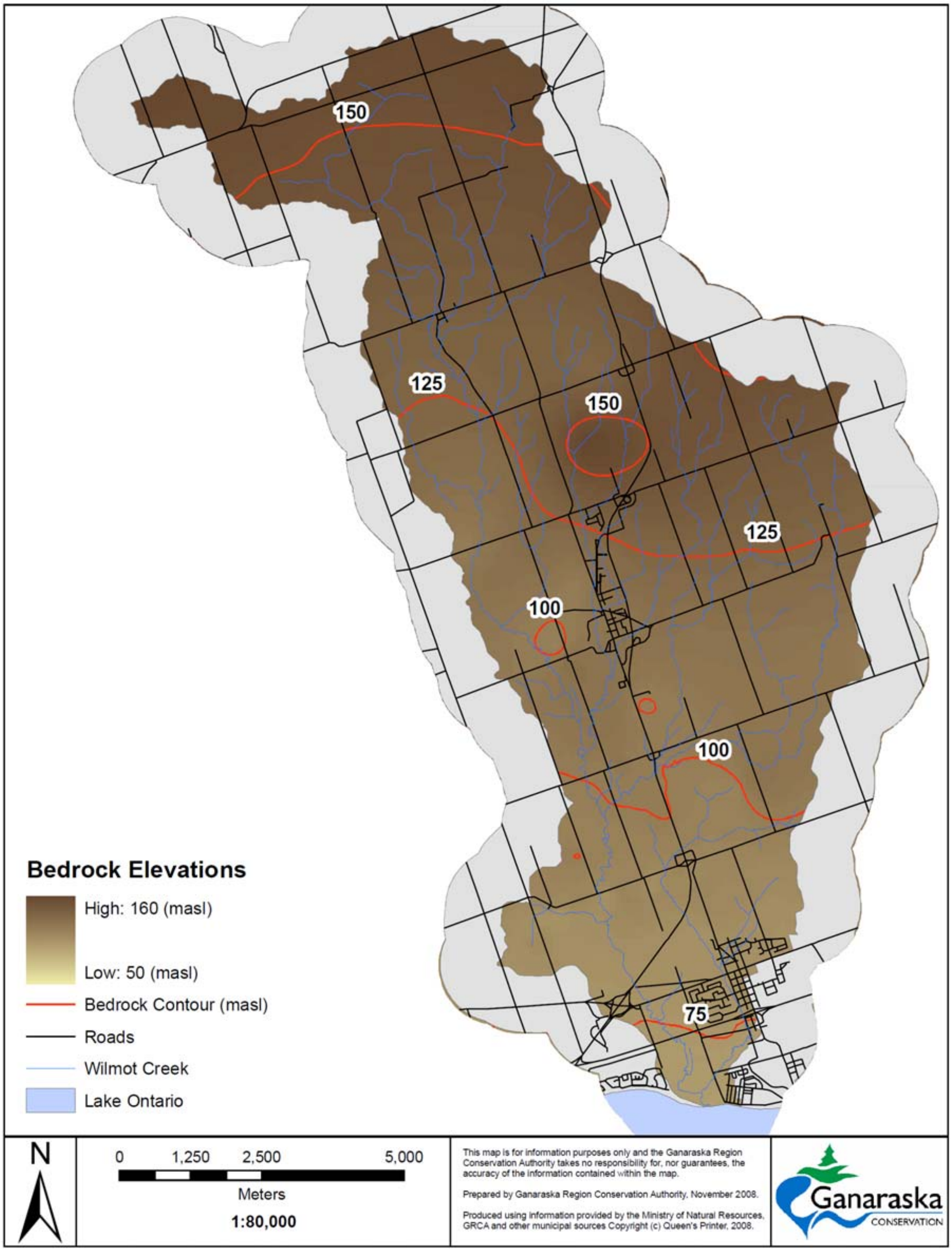


Figure 3.5: Bedrock elevation

The sediments of the Oak Ridges Moraine, which formed approximately 12,000 to 13,000 years ago, are found in the northern end of the Wilmot Creek watershed. The sediments, deposited by glacial meltwaters, travelled through a glacial lake between the Simcoe and Ontario ice lobes that covered southern Ontario (Earthfx Incorporated 2006).The youngest deposits in the Wilmot Creek watershed consist of glaciolacustrine sediments (glacial till, river deposits and Lake Iroquois deposits), left behind from glacial lakes that form a thin layer over the Bowmanville Till and Oak Ridges Moraine sediments (Earthfx Incorporated 2006). Many regional and local Geological names exist (Table 3.2).

Table 3.2: Geologic units in order of youngest to oldest deposition

Geologic Units Derived from the Regional Model (Based on 5 layers)	Geologic Units Derived from the Core Model (Based on 8 layers) Figures 3.7 and 3.8 (Earthfx Incorporated 2006)	Geologic Units Derived from Brookfield et al. 1982, and Singer 1981 (used in GRCA studies)	Description
	Late stage sediments (glacial/fluvial)		Aquifer or Aquitard
Halton Till	Halton Till or equivalent (upper glacial unit)	Halton (Bouchette) Till	Aquitard
Oak Ridges Moraine Complex	Oak Ridges Moraine Deposits	Oak Ridges Moraine Complex	Aquifer
Newmarket Till	Bowmanville Till (middle glacial unit)	Bowmanville Till	Aquitard
Lower Sediments	Clarke Deposits or equivalent	Clarke Deposits	Upper Aquifer
	Port Hope Till (lower glacial unit)	Port Hope Till	Aquitard
	Scarborough Formation or equivalent	Scarborough Formation or equivalent	Lower Aquifer
Bedrock	Weathered Bedrock	Fractured (Weathered) Bedrock	Aquifer
		Unweathered Bedrock	Aquitard

A vertical cross-section of the geological characteristic of the Wilmot Creek watershed can be viewed using data from Ministry of the Environment water well records. Using Viewlog software, two cross-sections were generated from northwest to southeast and from east to west (Figure 3.6). Eight geological layers are seen in the cross-sections (Figure 3.7 and Figure 3.8) and are in chronological order as described in Table 3.2. The thickness of the overburden deposits increases from south to north, with the thickest deposits occurring in the Oak Ridges Moraine area, and the thinnest near the Lake Ontario shoreline. Each geological layer is described in more detail below. It should be noted that geological units across southern Ontario vary considerably in structure and therefore local geological units exist throughout Ontario. In this document the localized names referenced from many studies completed in the area will be used

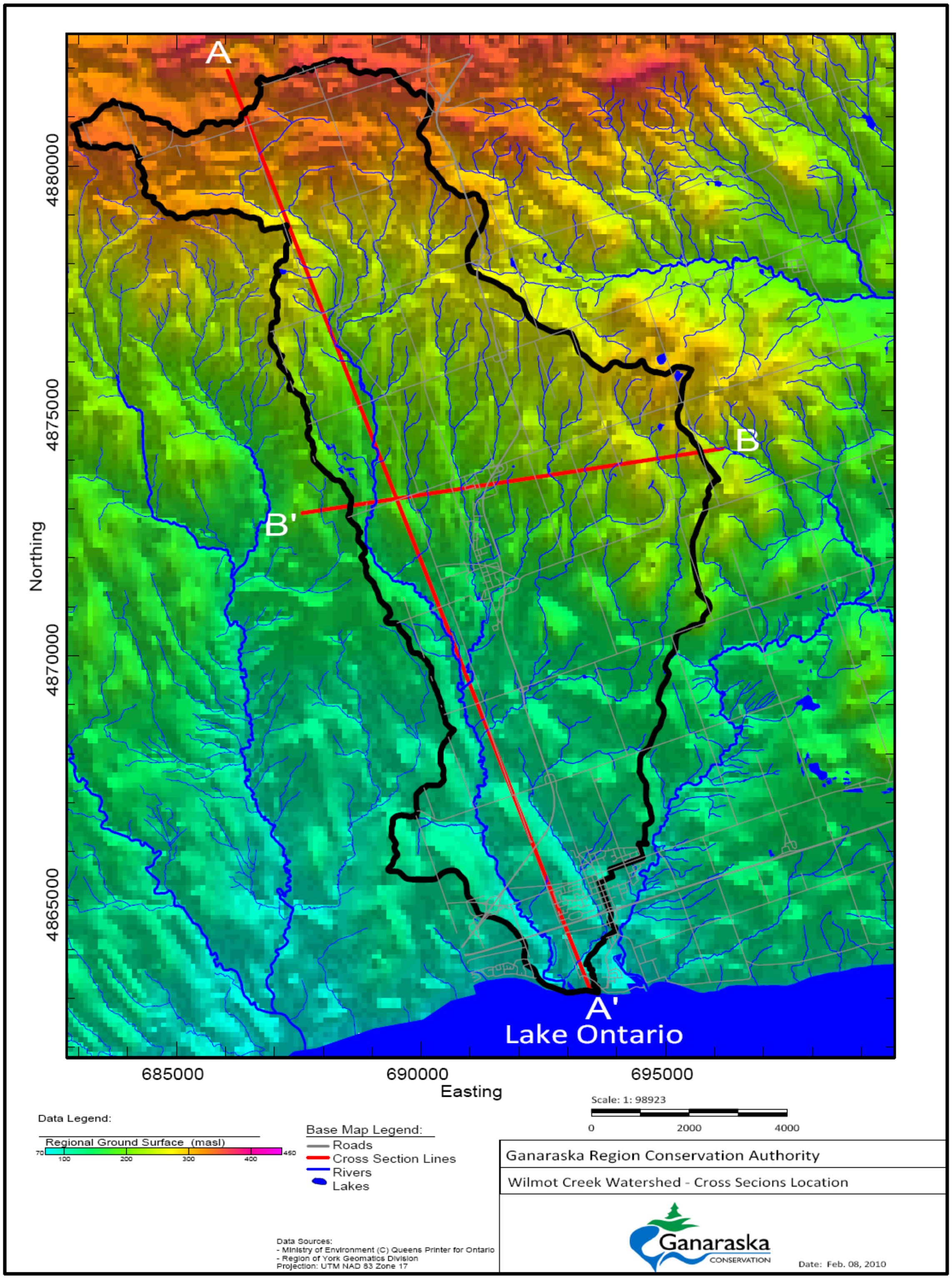


Figure 3.6: Wilmot Creek watershed cross-section locations

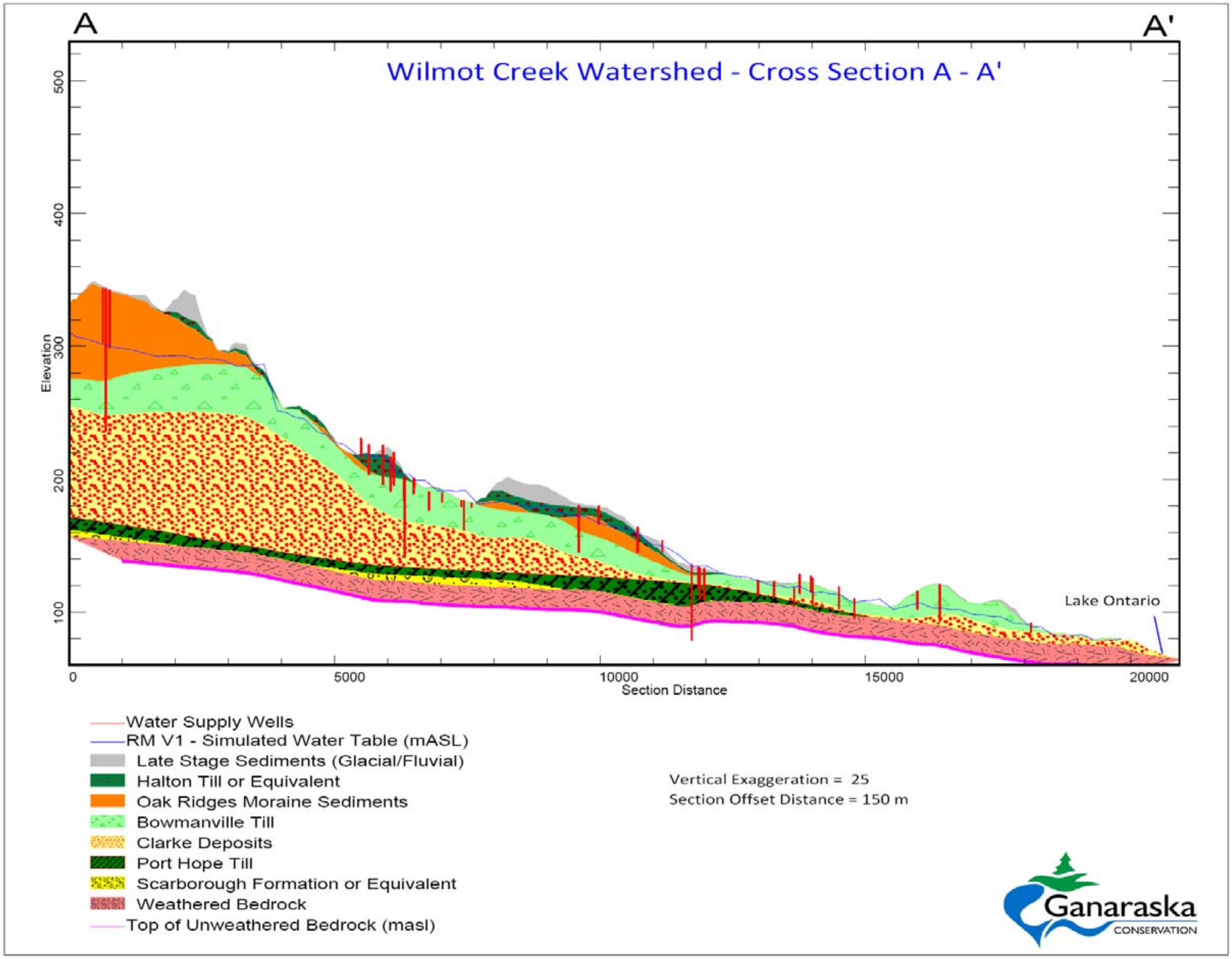


Figure 3.7: Wilmot Creek watershed cross-section A – A'

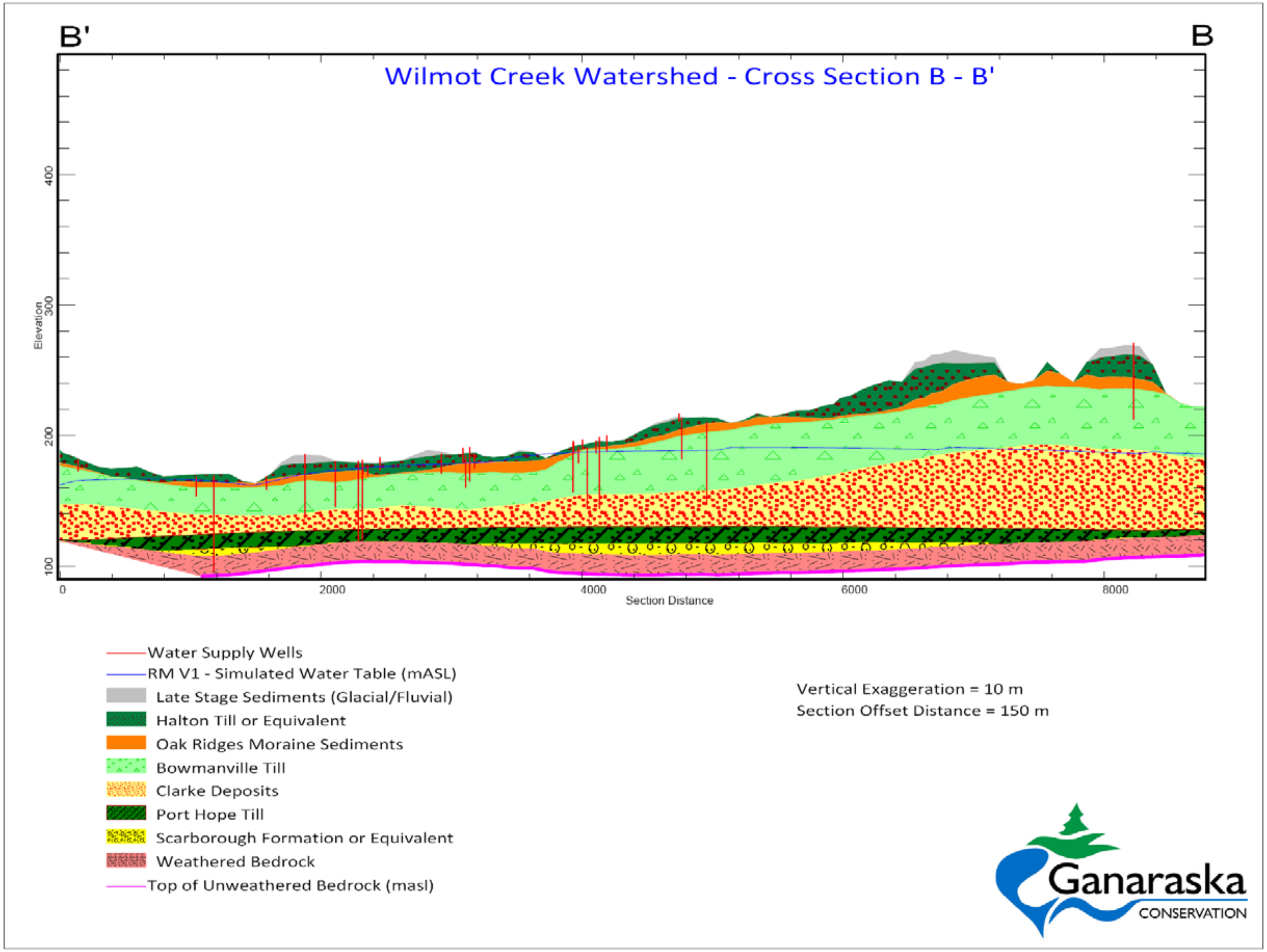


Figure 3.8: Wilmot Creek watershed cross-section B – B’

Scarborough Formation or Equivalent
The Scarborough Formation or its localized equivalent sits on top of the bedrock and was formed by a deltaic deposit at the mouth of a very large historic river (Eyles 2002). It is described as a sequence of sediments ranging from fine clay/silts to channelized coarse cross-bedded sands that become vertically coarser (Jagger Hims Limited 2007). As a result of the coarse-grained sediments in this formation, deep overburden aquifers are found in some localized areas.

Geologists feel that the regionally known Scarborough Formation does not extend into the Wilmot Creek watershed, however an equivalent formation that sits on top of the bedrock. As shown in Figure 3.7 and Figure 3.8 the Scarborough Formation or equivalent unit is very thin and is not seen in the northern or southern areas of the watershed. This geological unit, equivalent to the Scarborough Formation, creates a highly productive sand and gravel aquifer.

Port Hope Till (Lower Glacial Unit)
The Port Hope Till (equivalent to the regional Sunnybrook Drift) was deposited in glacial and proglacial lacustrine areas (Jagger Hims Limited 2007). Sediments that form the Port Hope Till were deposited as mud on the floor of a cold, deep glacial lake and pebbles were dropped into the sediments by floating ice (Eyles 2002; Earthfx Incorporated 2006). These fine, compactable sediments cause the Port Hope Till to be an aquitard. Brookfield et al. (1982) correlated the regional Sunnybrook Drift to a localized Port Hope Till that contains less clay and more silt than the Sunnybrook Drift. Figure 3.7 shows that the Port Hope Till declines in thickness toward the south end of the Wilmot Creek watershed.

Clarke Deposits or Equivalent
The Clarke Deposit (regionally correlated to the Thorncliffe Formation) includes glaciofluvial deposits of sand, silty sand, silt and pebbly silt, and clay (Earthfx Incorporated 2006). This geological unit was deposited by glacial meltwaters entering a deep, ice-dammed ancestral Lake Ontario. The Clarke Deposit is highly variable and serves as an aquifer (Jagger Hims Limited 2007). Singer (1981) correlated the regional Thorncliffe Formation to a localized Clarke Deposit, which contains less clay and more silt (Brookfield et al. 1982). Figure 3.7 and Figure 3.8 show that the Clarke Deposit is found beneath the Bowmanville Till.

Bowmanville Till (Middle Glacial Unit)
The Bowmanville Till is a distinct, dense glacial deposit of fine sediments (Jagger Hims Limited 2007) left behind by the Laurentide Ice Sheet. This till unit is the most dominant in the Wilmot Creek watershed. The Bowmanville Till is correlated to the regionally known Newmarket or Northern Till (Earthfx Incorporated 2006; YPDT-CAMC Groundwater Study [website] 2006). With variable pavement layers in the Bowmanville Till, this geological unit acts as an aquitard. Brookfield et al. (1982) correlated the Newmarket Till to the localized Bowmanville Till, which contains less clay and more silt.

Oak Ridges Moraine Deposits
The sediments of the Oak Ridges Moraine are complex and contain predominantly coarse-grained glacialfluvial and terminal outwash materials (Jagger Hims Limited 2007. The Oak Ridges Moraine deposits were left behind between two lobes of the Laurentide Ice Sheet when they retreated, therefore the Oak Ridges Moraine can be referred to as an interlobate moraine, meaning between two lobes (Eyles 2002). The Oak Ridges Moraine is a well-known physiographic feature that contains sediments with variable thickness, texture and distribution, all of which function as regional aquifers and aquitards.

Halton Till or Equivalent (Upper Glacial Unit)
Halton Till is a fine-grained, clay-rich till and contains few stones (Jagger Hims Limited 2007). Found on the southern flanks of the Oak Ridges Moraine, the Halton Till was laid down by the last glacial ice advance over the Oak Ridges Moraine (Earthfx Incorporated 2006). This variable cap of finer sediments over the Oak Ridges Moraine causes the Halton Till to act as an aquitard.

The regionally known Halton Till does extend into the Wilmot Creek watershed and acts as an aquitard. As shown in Figures 3.7 and 3.8, the Halton Till or equivalent unit sits on top of Oak Ridges Moraine Deposits and extends into the south end of the watershed. The Halton Till does act as an aquitard where it exists.

Late Stage Sediments (Glacial/Fluvial)
Following the Wisconsinan deglaciation, deposits formed in the glacial lakes and rivers. Recent deposits are not as significant in relation to the underlying geologic units (Jagger Hims Limited 2007). Where they do occur, they are in lower elevations and floodplains. In Wilmot Creek, the late stage deposits include gravelly beach deposits formed along the former shores of Lake Iroquois.

3.1.3 Topography

Topography refers to the shape, form and physical features of the Earth’s surface (Eyles 2002). In the Wilmot Creek watershed the land generally slopes from north to south. The maximum topographic elevation is approximately 375 masl and it declines to an elevation of approximately 75 masl at Lake Ontario. Topography is best understood when observed in the field. Figure 3.9 displays the topographic features of the Wilmot Creek watershed along with differing elevations. This figure was created using a digital elevation model with a five-metre grid. Hummocky topography is the major physical feature in the Oak Ridges Moraine and in the northern part of the Wilmot Creek watershed. Topographic features are important in promoting groundwater recharge and minimizing surface water runoff.

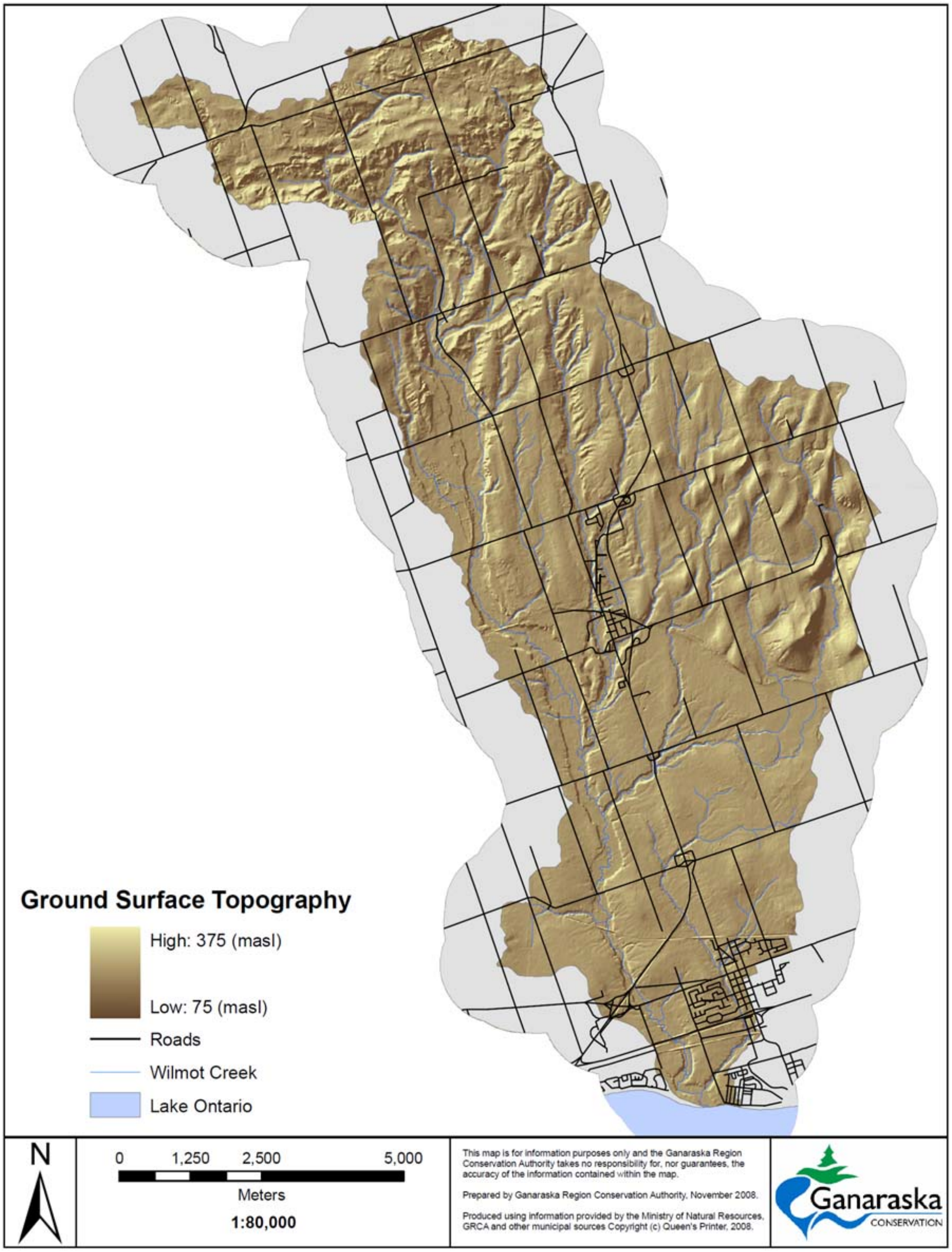


Figure 3.9: Ground surface topography

3.1.4 Physiographic Regions

Physiography refers to areas of similar geological form and includes the physical features of the Earth's surface. The three physiographic regions found in the Wilmot Creek watershed from north to south are the Oak Ridges Moraine, the South Slope and the Iroquois Plain (Figure 3.10).

Oak Ridges Moraine

The Oak Ridges Moraine is located in the north end of the watershed and it occupies 28.7 km^2 or 29.4% of the Wilmot Creek watershed. The Oak Ridges Moraine extends regionally over 160 km from the Niagara Escarpment to the Trent River. As described in Chapman and Putnam (1966), the Oak Ridges Moraine is hilly with a knob-and-basin relief comprised of sandy or gravelly materials. This coarse, permeable material provides recharge areas in Wilmot Creek. Water drains vertically through the sand and gravel, moving laterally until it reaches less pervious material, and reappears as springs along the slopes of the moraine (Chapman and Putnam 1966). The portion of the watershed in the Oak Ridges Moraine has a hummocky, irregular surface and closed depressions, with glaciofluvial sands and gravels making up the surficial deposits.

The sand of the Oak Ridges Moraine is comprised predominantly of limestone, and as soil-building material, it is fairly high in phosphorus and low in potash content (Ganaraska Region Conservation Authority 2007). Due to the physical characteristics of the Oak Ridges Moraine sediments (e.g., erosion potential, high permeability, lower water-holding capacity due to absence of clay material, etc.), agricultural activity is limited and often unproductive.

South Slope

The South Slope lies between the Oak Ridges Moraine and the Iroquois Plain and it occupies 34 km^2 or 35% of the watershed area. This area has an average slope of about 17 metres per kilometre (m/km) (Singer 1981). The topography of this till plain varies from gentle to steep slopes. It represents a noticeable contrast to the irregular features of the Oak Ridges Moraine to the north and the flatter, rolling surface of the Iroquois Plain to the south. Both the Halton Till and Bowmanville Till are found in the Wilmot Creek watershed, with noticeable distributions of till materials in central and southern portions. The presence of the till materials at the surface represents a major factor in the distribution of groundwater recharge in the watershed as described below. Three regional till deposits have been identified in this region.

- Halton Till (or the equivalent Bouchette Till) is a sheet of clayey silt till deposited by the last major glacial advance in the area.
- Bowmanville Till (equivalent to Newmarket Till) is a deposit of sandy silt till that lies beneath the Oak Ridges Moraine.

- Port Hope Till (Sunnybrook Till equivalent) is a deposit of fine silt and clay sediments found beneath the Clarke Deposits.

<u>Iroquois Plain</u>

The Iroquois Plain is located south of the South Slope and occupies 35 km^2 or 36% of the watershed. The Iroquois Plain is a relic of the lowland bordering Lake Ontario that was inundated with water during the late Pleistocene period by Lake Iroquois (Chapman and Putnam 1966). The Iroquois Plain contains many large drumlins that would have been islands in Lake Iroquois. Today these former islands look like terraces, formed by historic wave action (Chapman and Putnam 1966).

As described by Singer (1981), the Iroquois Plain can be subdivided into an upper and lower lake plain. The upper lake plain has an irregular, low relief surface and includes the Iroquois shore and near-shore deposits. Sand and gravel bars as well as beach terraces can be observed at surface along the abandoned shoreline. A sandy belt, about 3 km in width, is present south of the abandoned shoreline. The offshore deposits, making up the lower lake plain, are mainly silts and varied clays. The lower lake plain is an area of very low relief interrupted by some drumlins that would have stood as islands of Lake Iroquois. Till is exposed at surface in areas of the Iroquois Plain; strong currents may have prevented deposition of silts and clays in these areas (Singer 1981).

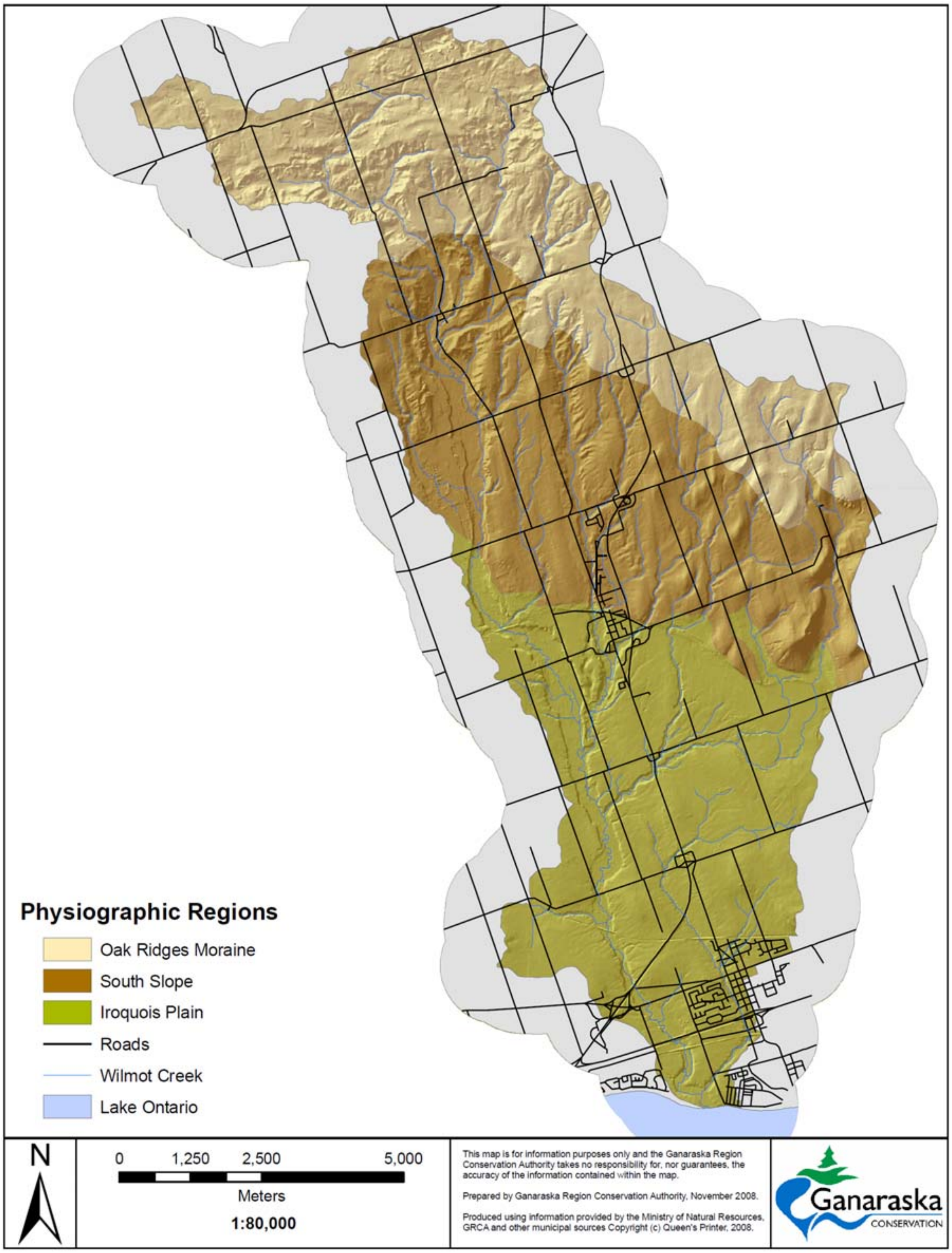


Figure 3.10: Physiographic regions

3.1.5 Surficial Geology

Surficial geology refers to the upper layer or exposed layer of geological deposits. In the Wilmot Creek watershed there are 12 surficial geological units (Table 3.3). The majority of these deposits were created during the Pleistocene epoch when massive ice formations and the resulting meltwaters shaped the surface.

Table 3.3: Surficial Geology of the Wilmot Creek watershed

Surficial Geology Unit	km^2	Percent of watershed
Glacial Lake Deposits: sand and gravel	3.7	3.8
Glacial Lake Deposits: silt and clay	10.4	10.6
Glacial Lake Deposits: silt and sand	15.6	15.9
Glacial River Deposits: sand and gravel	0.6	0.6
Halton Till	15.4	15.8
Moraine Deposits: fine sand to gravel	13.4	13.7
Bowmanville (Newmarket) Till	21.4	21.9
Organic Deposits	0.1	0.1
River Deposits: Early postglacial deposits	3.7	3.8
River Deposits: Late Stage (Modern) Deposits	6.7	6.9
Sand	4.9	5.0
Silt	2.0	2.0

Figure 3.11 depicts the surficial geology of the Wilmot Creek watershed as defined by the Ontario Geological Survey and the Geological Survey of Canada. Bowmanville Till (regionally equivalent to Newmarket Till) forms the dominant uppermost exposed geological layer and acts as an aquitard. As a result many of the tributaries to Wilmot Creek start at the margins of the Bowmanville Till. Glacial lake deposits are found throughout the Wilmot Creek watershed with compositions ranging among silt, sand, gravel and clay. Moraine deposits are located at the northern limit of the Oak Ridges Moraine within the watershed and river deposits are located in the current and postglacial river valleys and beds.

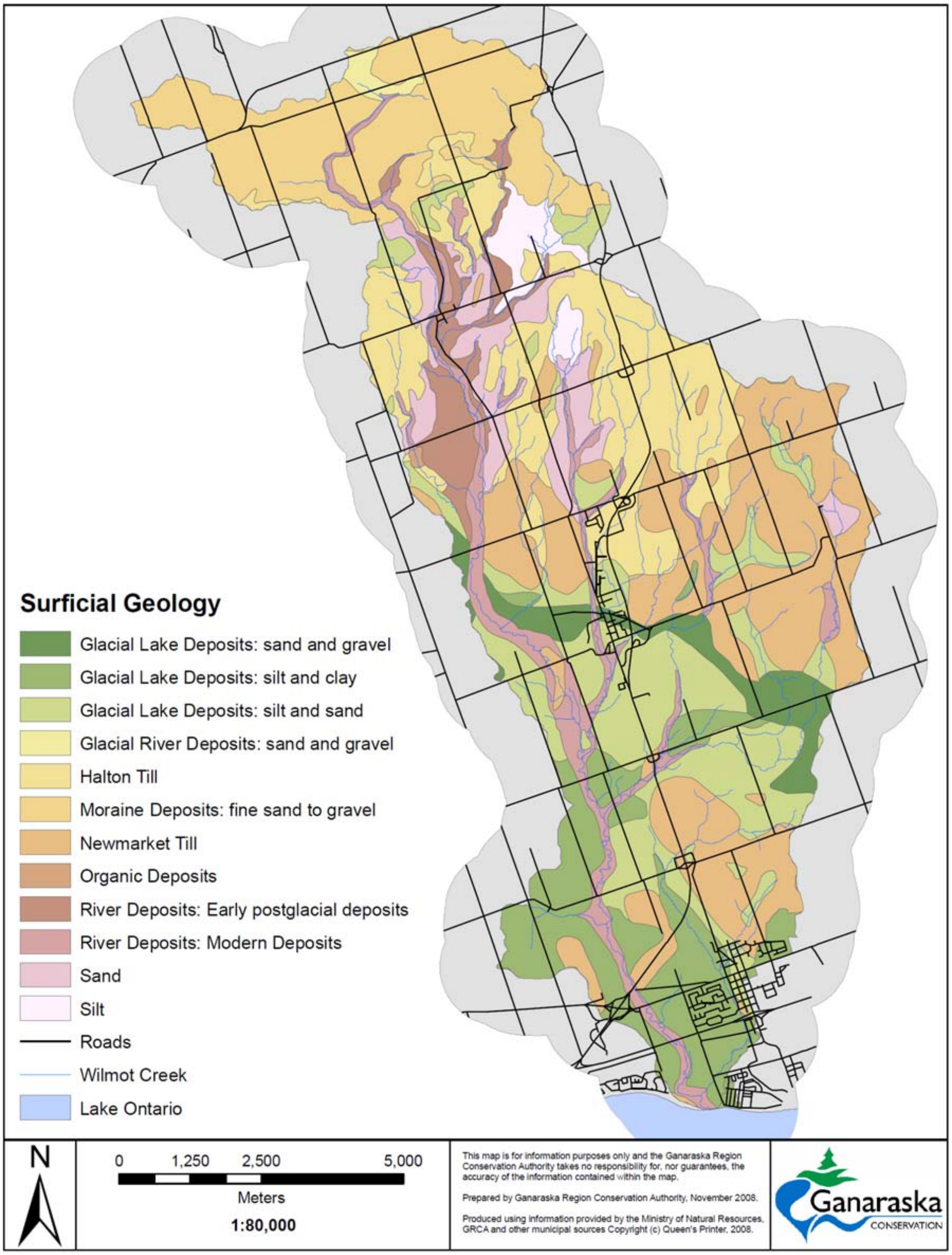


Figure 3.11: Surficial geology

3.1.6 Soils

Soil is defined as the unconsolidated organic material on the immediate surface of the Earth that serves as a natural growing medium for vegetation (Hoffman 1974). Figure 3.12 shows the different soils found in the Wilmot Creek watershed as defined by the Ontario Ministry of Agriculture, Food and Rural Affairs. The till deposits in certain areas of the Oak Ridges Moraine are covered by 3 to 4.6 metres of sand and sandy gravels, and the soils are mainly derived from the sand-gravel strata. The most typical soil of the Oak Ridges Moraine is the Pontypool Series that consists of sand and sandy loams, with the almost-pure sands located on hilltops and the more loamy soils in the drainage channels where they were formed during the period of glacial activity (Chapman and Putnam 1966). Grey-brown podzol, belonging to the Fox soil family, is found in the Oak Ridges Moraine (McGregor 1977). This soil family is characterized by good drainage and susceptibility to erosion (McGregor 1977).

On the South Slope the soils were formed in about half a metre of sand deposits overlying the till plain, and because of this shallower depth, they are not as thoroughly drained as the soils of the Oak Ridges Moraine. Consequently fewer nutrients were drained away leading to the development of typical loam types such as Dundonald sandy loam (Chapman and Putnam 1966). However there are still some patches of completely sandy soil on the higher reaches of the drumlins. These sandy soils can belong to the grey-brown podzol, part of the Bookton soil family, which has good drainage and susceptibility to erosion (McGregor 1977).

Little of the original till material of the Iroquois Plain was left unchanged by the glacial melt water, and soils are therefore different from those in the two northerly sections. The general effect was for sandy loams to be created near the beach line and for clay loams to form farther out in the ancient lake. The beach bars and spits of the ancient lakeshore also left areas of sandy soil.

In hydrologic calculations, soils may be classified into four main groups (A, B, C, D) and three interpolated groups (AB, BC, CD). These classifications depict how soils move water. Table 3.4 describes the features of the hydrologic soils group. Figure 3.13 shows the locations of the hydrologic soil types.

Table 3.4: Hydrologic soils group

Hydrologic Soils Group	Run-off Potential	Infiltration when Wet	Typical Soils
A	Low	High	Excessively drained sands and gravels
B	Moderate	Moderate	Medium textures
C	Medium	Slow	Fine texture or soils with a layer impeding downward drainage
D	High	Very slow	Swelling clays, clay pan soils or shallow soils over impervious layers.

(Hudson 1981)

Soil types and their corresponding characteristics help dictate land uses. In the Oak Ridges Moraine, the dominant soil series is the Pontypool series. This soil series is low in fertility and therefore does not suit agricultural land use. Carman (1940) identified the moraine soils as sand or gravel and sub-marginal for farm use. The recommended use by Richardson (1944) for areas with this soil series is reforestation, which is the predominant land conversion on the Oak Ridges Moraine in the Ganaraska Region Conservation Authority and the Regional Municipality of Durham.

In the South Slope and Iroquois Plain, sandy loam soils are typical. As a result, agricultural practices in these two physiographic regions prevail. Sandy, gravely, stoney and clay loams are found across the South Slope and it is suitable for farming (Carman 1940). The only limiting factors that these soils have for agricultural purposes are imperfect drainage (Tecumseth sandy loam series) and the erosion potential of the Dundonald sandy loam series (Richardson 1944).

Land uses in the Wilmot Creek watershed reflect the predominant soil series found throughout the area. Heavily forested areas in the northern part of the watershed reflect the sandy soils of the Oak Ridges Moraine, and agricultural activities in the South Slope and Iroquois Plain reflect the sandy loam soils found within these regions. Because of the differing soil types and corresponding land use capabilities, the South Slope and Iroquois Plain are favourable for agricultural practices over the Oak Ridges Moraine. Superior soils in the near shore Lake Ontario area have meant that historic urban settlement has occurred in this area. Section 4.1 describes the terrestrial natural heritage of the Wilmot Creek watershed, defined by local soil types and compositions.

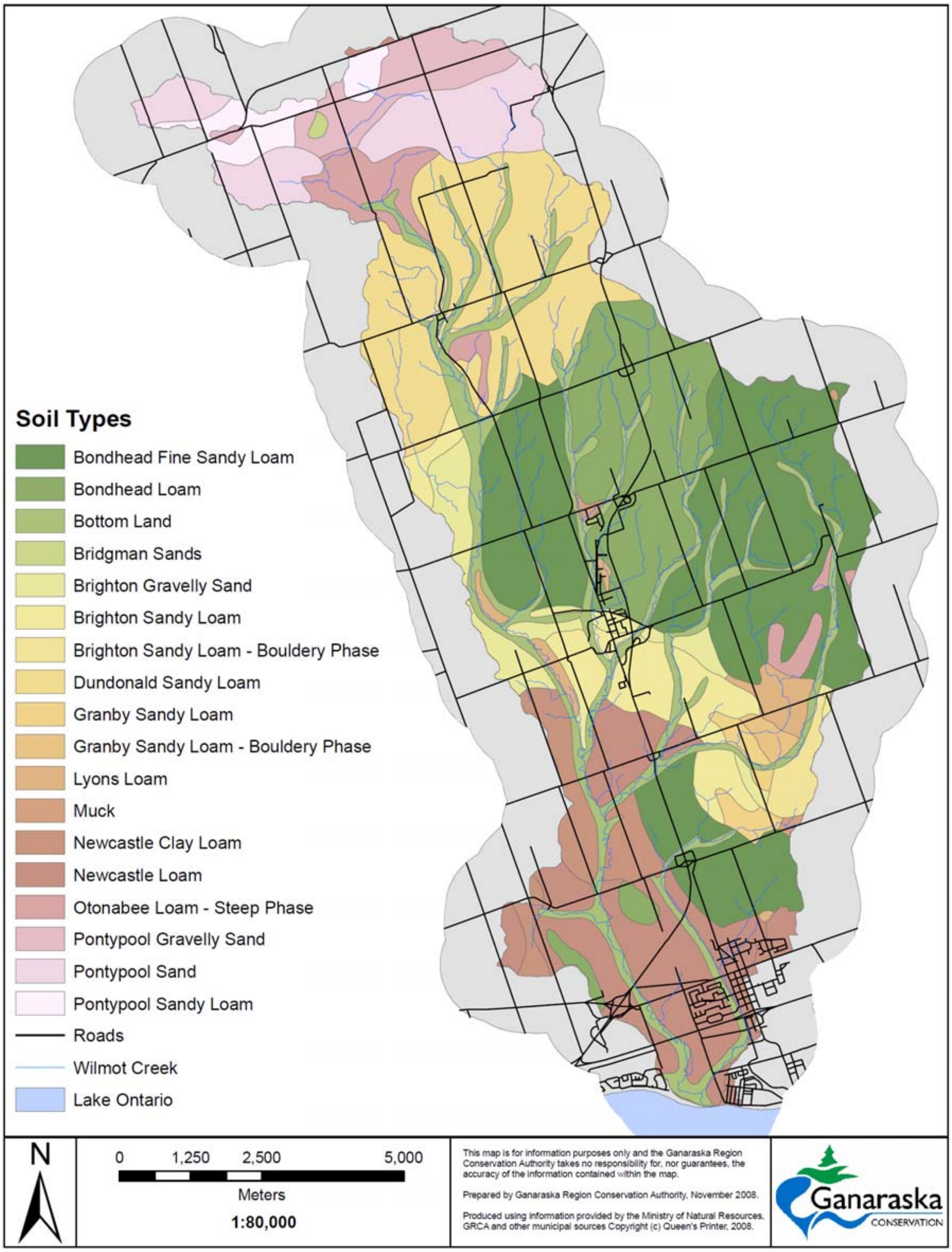


Figure 3.12: Soils

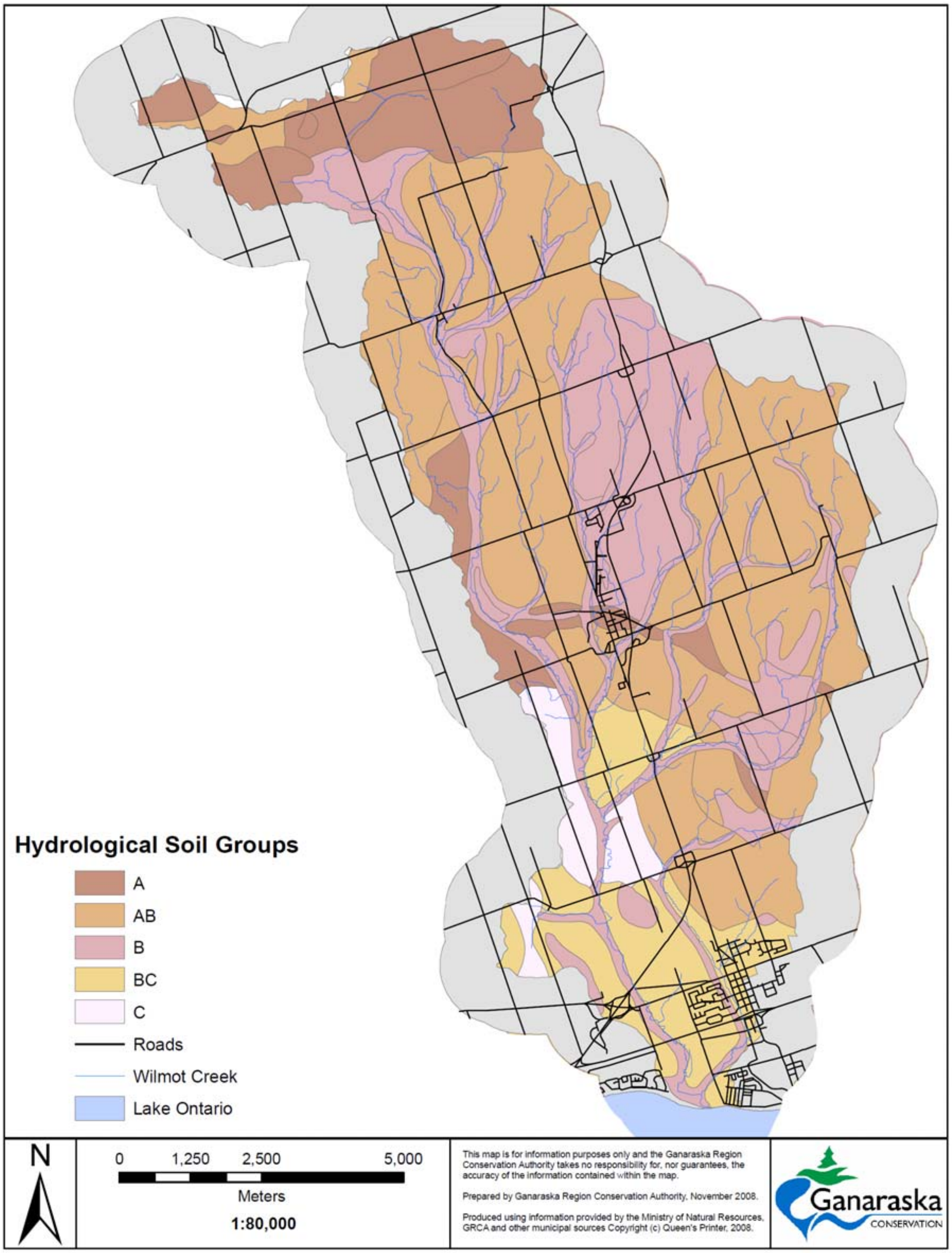


Figure 3.13: Hydrologic soils group

3.2 GROUNDWATER

The movement and location of groundwater in the subsurface are controlled by land cover, sediment types and topography. Porous surficial materials generally comprise groundwater recharge areas. Rainfall and snowmelt percolate through these sediments and replenish the aquifers that form important groundwater supply sources for many watershed residents. In addition these aquifers contribute water to streams of the Wilmot Creek watershed through groundwater discharge. Groundwater discharge contribution during periods of time without precipitation and during critical summer low flow periods is essential in sustaining the ecosystem of the watershed. Areas of the watershed that lack porous surficial materials experience higher surface runoff than groundwater recharge.

3.2.1 Aquifers and Groundwater Flow

Overburden deposits in the Wilmot Creek watershed play an important role in the regional drainage and groundwater recharge patterns. Bedrock valleys and bedrock topography do not control the drainage of Wilmot Creek and groundwater flows in the area. Similar to other watersheds of the area, the thickness of the overburden dictates the distribution of the overburden and bedrock aquifers and the specific importance of each type of deposit as a source of water supply. Higher rates of infiltration generally occur in the more permeable, thick coarse-grained deposits associated with the glacial lake and moraine sediments in the north. The physiographic landforms, and overburden thickness and distribution provide the framework for interpreting the hydrostratigraphic conditions in the Wilmot Creek watershed. The key hydrostratigraphic units observed are:

- Glacial Lake Deposits comprised of sand and gravel that form a discontinuous unconfined shallow aquifer at surface
- Oak Ridges Moraine sediments consisting of ice-contact and outwash deposits that form an aquifer/aquitard complex
- Glacial till aquitards comprised of Halton Till (aquitard) and Bowmanville Till (leaky aquitard)
- Clarke Deposits that are mainly sand and gravel (aquifer)
- Port Hope Till that is mainly a clayey silt till (aquitard)
- Deep coarse sand and gravel aquifer (Equivalent to Scarborough Formation)
- Fractured limestone of the Simcoe Group (in some areas, fractured shale from the Georgian Bay Group) that forms the weathered bedrock aquifer.

The Oak Ridges Moraine acts as a topographic divide and a source of baseflow for the Wilmot Creek and its tributaries. A small number of wells have been drilled in the central parts of the Oak Ridges Moraine and a few of these wells are deep enough to provide a full coverage of the geologic profile therein. The till units (Halton, Bowmanville and Port Hope tills) have relatively low hydraulic conductivity and infiltration characteristics, and generally function as aquitards separating the aquifers.

The Lower Sediment units contain several distinct geologic formations, ranging from sand and gravel to silt and clay textured soils. The Orono municipal wells (MW3 and MW4) are screened in an upper layer of this unit (identified as Clarke Deposits), which is an aquifer comprised of fine to medium sand and gravel (Jagger Hims Limited 2003). Pumping test data from development of the municipal wells indicates that the aquifer has a hydraulic conductivity in the order of 10^{-3} to 10^{-4} m/s (Jagger Hims Limited 2003b).

As determined by the Region of Durham's GUDI Study, the aquifer exhibits a hydraulic connection to Wilmot Creek (Jagger Hims Limited 2003c). This is most likely due to the presence of a relatively thin layer of Bowmanville Till in the vicinity of the wellfield. The deeper part of the Lower Sediment unit in the Orono Municipal Wells Field consists of silt till and clayey silt deposits (Port Hope Till) that are inferred to be part of the Sunnybrook Formation (Jagger Hims Limited 2003). Water well record data for the area indicates that there is a discontinuous water-bearing sand zone above the bedrock interface, which was described in the YPDT-CAMC Regional Groundwater Model report (Earthfx Incorporated 2006) as a thin mixture of both Scarborough Formation and a weathered bedrock unit. As indicated in the water well record data, some of the local domestic water wells are screened within this unit. The bedrock generally yields low quantities of water, based on available Ministry of the Environment water well record data.

The movement of groundwater in the area is a subtle reflection of local topography and drainage as interpreted from Ministry of the Environment water well records. The lateral movement of groundwater in the watershed occurs from topographic highs to lows. The dominant regional groundwater flow direction is southerly, off the Oak Ridges Moraine toward Lake Ontario, with a westerly components in local areas. Figure 3.14 shows the watertable contour elevations. This figure was generated from the regional Oak Ridges Moraine groundwater model (Earthfx Incorporated 2006). The inferred flow lines confirm the regional groundwater flow directions in the watershed as described above.

Cross-sections (Figures 3.7 and 3.8) can provide an indication of bedrock topography and general stratigraphic composition of the area. The cross-sections indicate that the overburden in the north consists of 180 m of mostly sand, silt and gravel materials sloping south. Within these overburden materials there are several sand and gravel zones of considerable thickness, but as outlined above, these cannot be traced as definable units due to the nature of the data sets. For example, cross-section A–A' reveals the presence of a large sand and gravel zone in the north where the cross-section intersects the southern flank of the Oak Ridges Moraine. Most of the private wells intercepted by cross-section A – A' were screened in the Clarke Deposits indicating the importance of this unit as an aquifer. The two deep wells intercepted by cross-section A –A' in the north were drilled in late 1960's for the IHD studies (Funk 1977, and Singer 1981). Figure 3.15 shows the locations of overburden, bedrock and flowing wells.

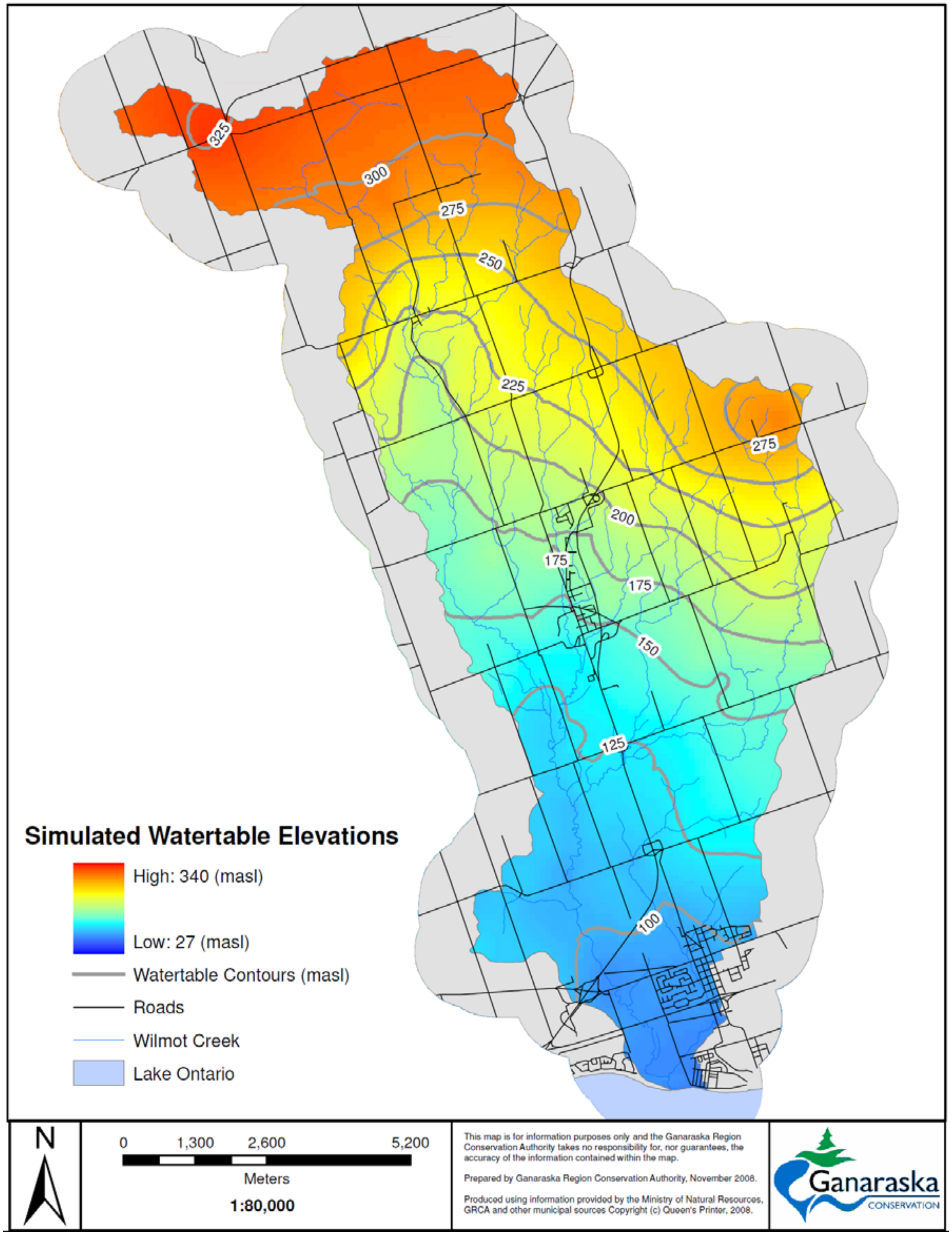


Figure 3.14: Simulated watertable

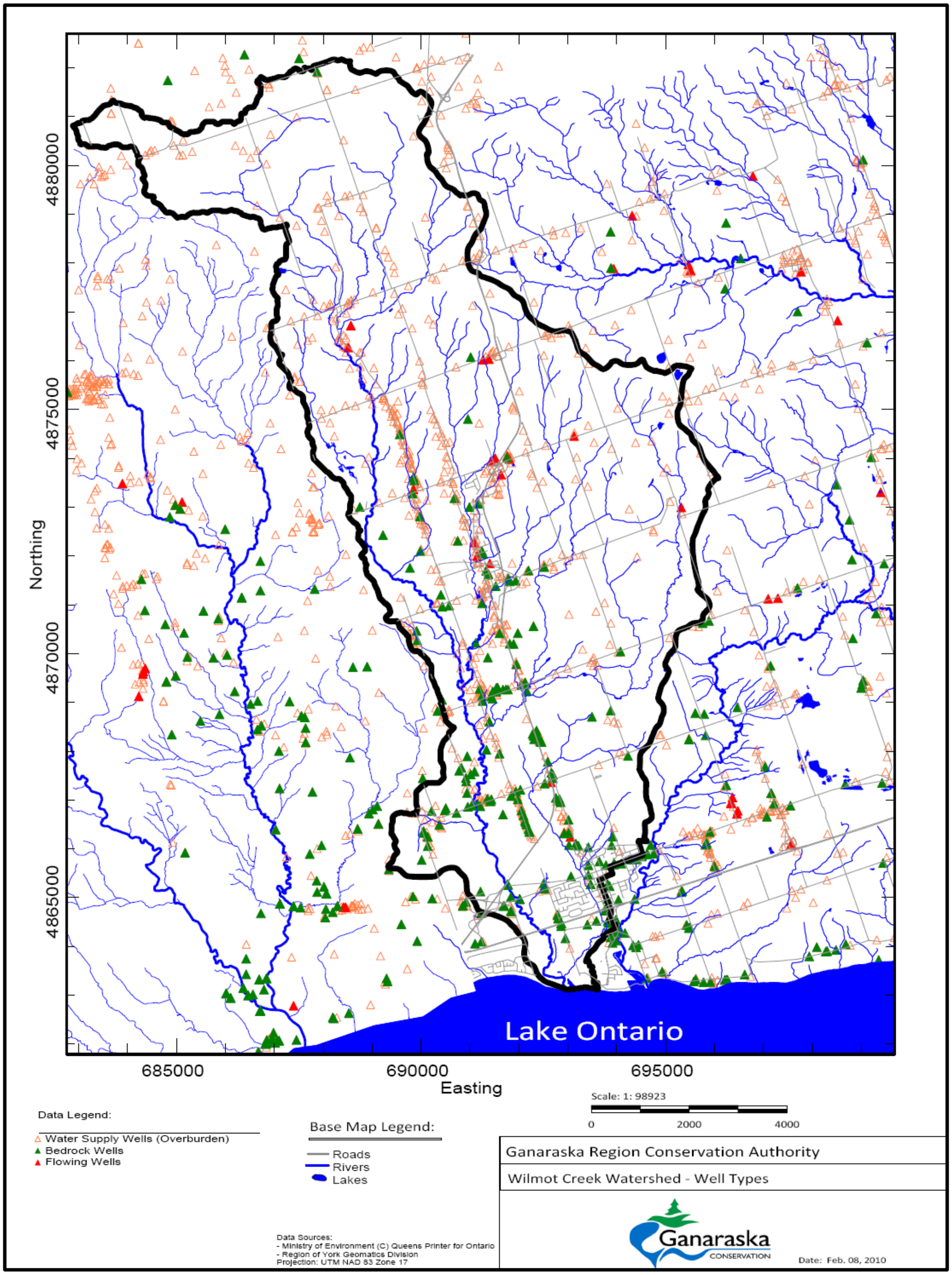


Figure 3.15: Water well types

3.2.2 Groundwater and Surface Water Interactions

Understanding groundwater and surface water interactions at both a regional and watershed scale has recently seen an increase in interest from all areas of watershed science. Gains and losses of water in a stream can be analyzed using stream temperature, baseflow, fish communities, and the presence of stream vegetation and aquatic organisms. However, certain techniques are more appropriate at various spatial scales or in order to answer certain questions.

Groundwater Recharge and Discharge

Recharge is the process by which groundwater is replenished, and it occurs by the vertical seepage of water through soil and unsaturated soils to an area of saturation. Rain and snowmelt are the major sources of recharge, however amounts of recharge and the rate at which it occurs depend on surficial soil composition, land use and topography (Widaatalla and Peacock 2007). Discharge is the opposite of recharge; in this process, groundwater is normally found in an upward gradient leaving the system through porous materials as springs or flow into surface water features such as streams, rivers, lakes and wetlands.

The vertical movement of groundwater in the northern uplands of the Oak Ridges Moraine is normally downward and forms much of the recharge lands in the watershed. There are many factors affecting the distribution recharge rates in the watershed. These include:

- The presence of hummocky topography (Figure 3.16) and thick overburden mainly in the northern part of the watershed
- Distribution of thick overburden mainly in the northern and eastern parts of the watershed also contributes to higher recharge rates (Figure 3.17)
- The presence of the course sand and gravel surficial materials in the north
- The northern part of the watershed has less farmland and many aggregate extraction operations
- The distribution of the silty and clayey till material in the central and southern portions of the watershed.

Most of the primary factors described that influence recharge distribution in the watershed were considered in the construction of the Oak Ridges Moraine Regional Model (Earthfx Incorporated 2006). Recharge rate distribution in the area was provided in the modeling document of the Oak Ridges Moraine (Earthfx Incorporated 2006). The initial estimates of annual average net recharge were supplied as input to the regional MODFLOW model and adjusted during model calibration. The spatial distribution of applied recharge to the regional model in the Wilmot Creek watershed is shown in Figure 3.18.

Recharge rates are highest on the Oak Ridges Moraine due to the sandy soils and hummocky topography (360mm/year) and lowest in areas covered with surficial till deposits (60mm/year). Figure 3.18 shows a location of moderate recharge rate in the central part of the watershed. This is mainly due to the presence of the upper Iroquois Plain in this area. The Iroquois Plain is mainly characterized by presence of sand and gravel bars as well as beach terraces. Other noticeable areas are the low recharge rate zones above and below the upper Iroquois Plain. These areas are associated with the presence of Halton Till in the north and Bowmanville Till and glacial clay in the south, as shown in cross-section A-A' (Figure 3.7).

Potential groundwater discharge areas were mapped from the regional groundwater model (Earthfx Incorporated 2006). Figure 3.19 shows the potential discharge locations in the Wilmot Creek watershed. This figure was produced by comparing the simulated water level elevation of the first aquifer encountered and the ground surface of the watershed. Whenever the elevation of the watertable occurred above the ground surface elevation in any area, that area was mapped as the potential discharge location. The delineation of discharge locations by this method should be treated as preliminary stage investigation and needs to be verified with additional field observations or any other methods. Figure 3.19 can also be used to infer the depth to watertable (shallow versus deep watertable) of the first aquifer encountered at different locations in the watershed. Figure 3.19 indicates that potential groundwater discharge areas are mainly located below the Oak Ridges Moraine and in the central part of the watershed. These discharge areas provide baseflow to Wilmot Creek, which is critical in maintaining stream flows during times when precipitation is minimal or does not occur. Section 3.4 Baseflow describes the baseflow of Wilmot Creek.

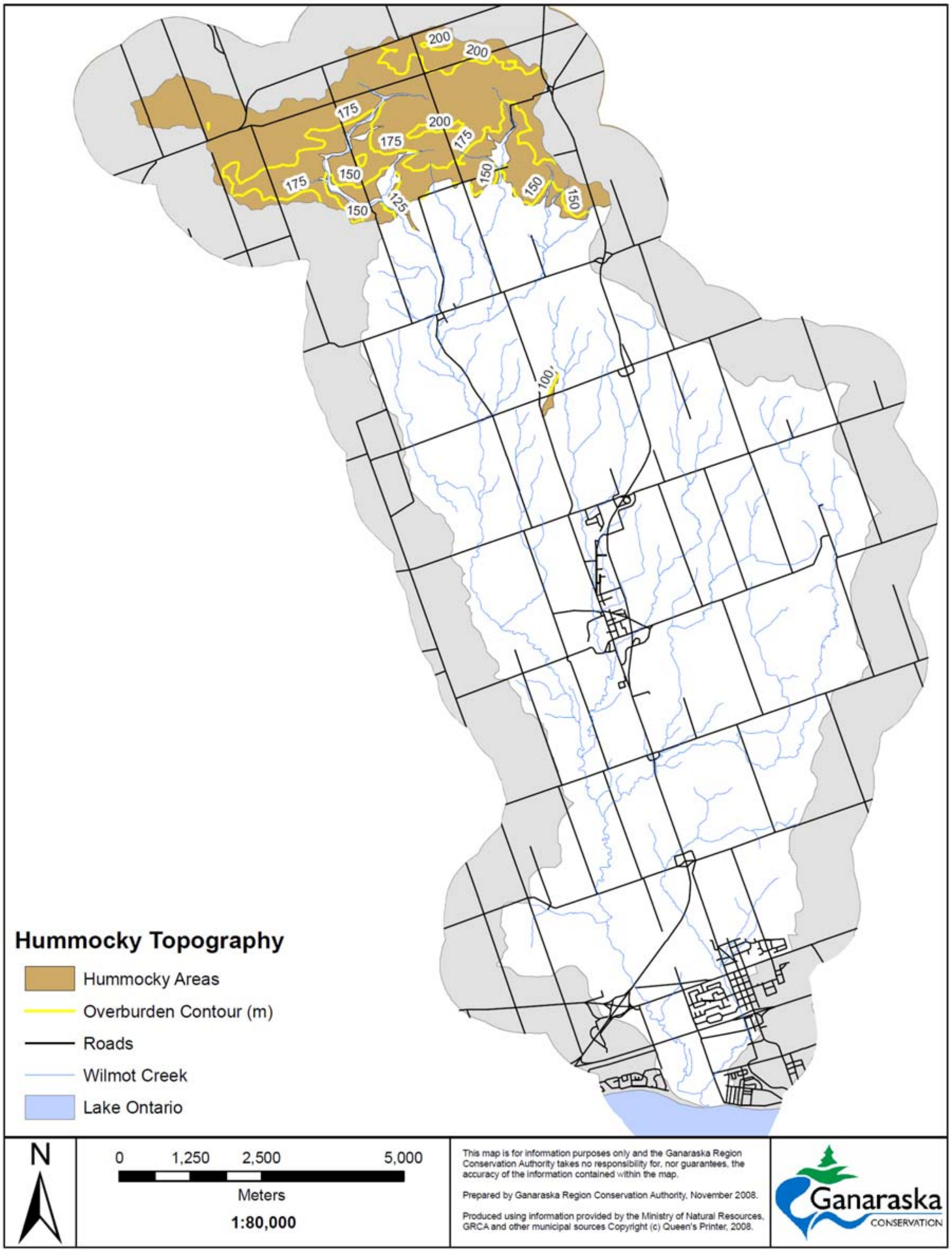


Figure 3.16: Hummocky topography

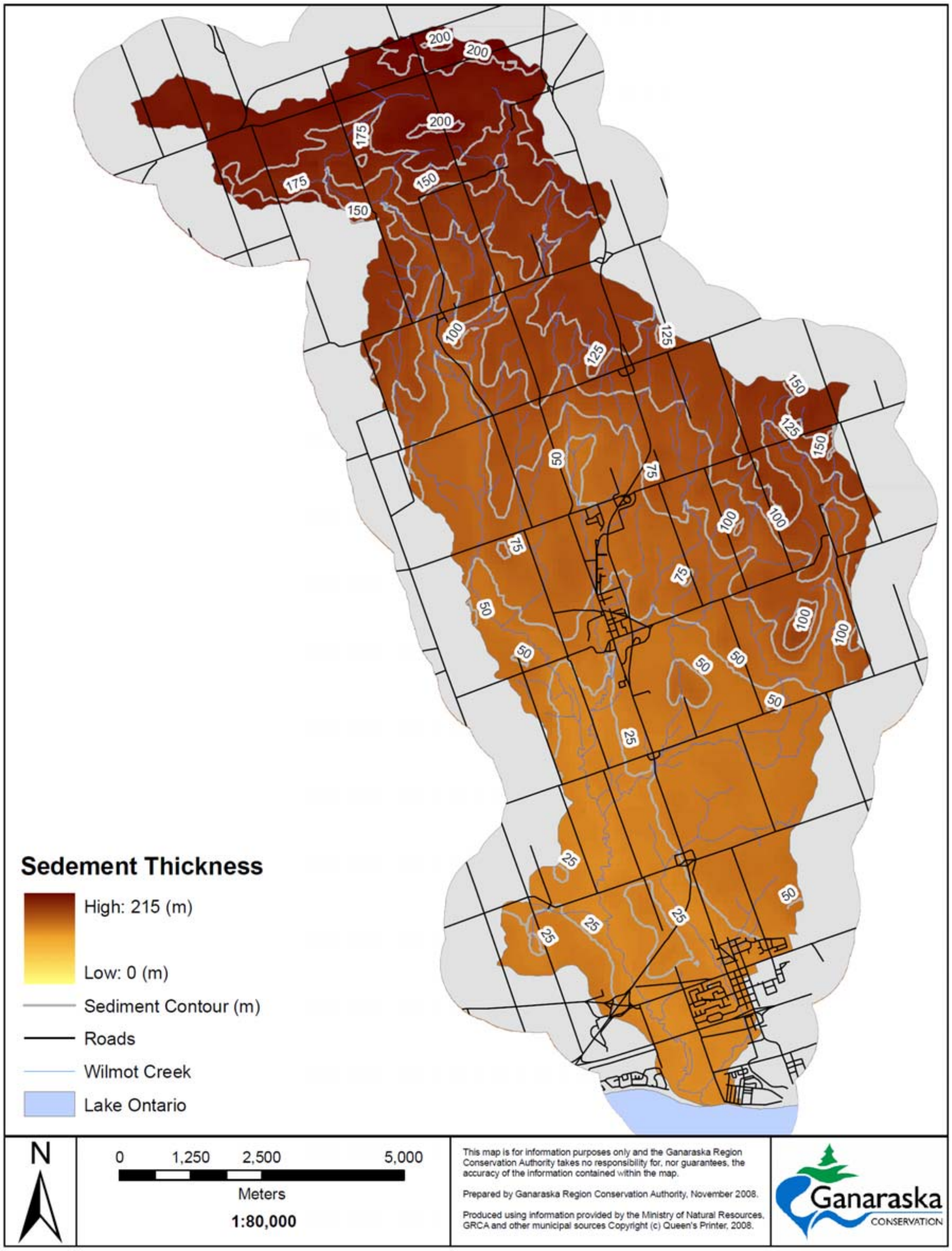


Figure 3.17: Overburden thickness

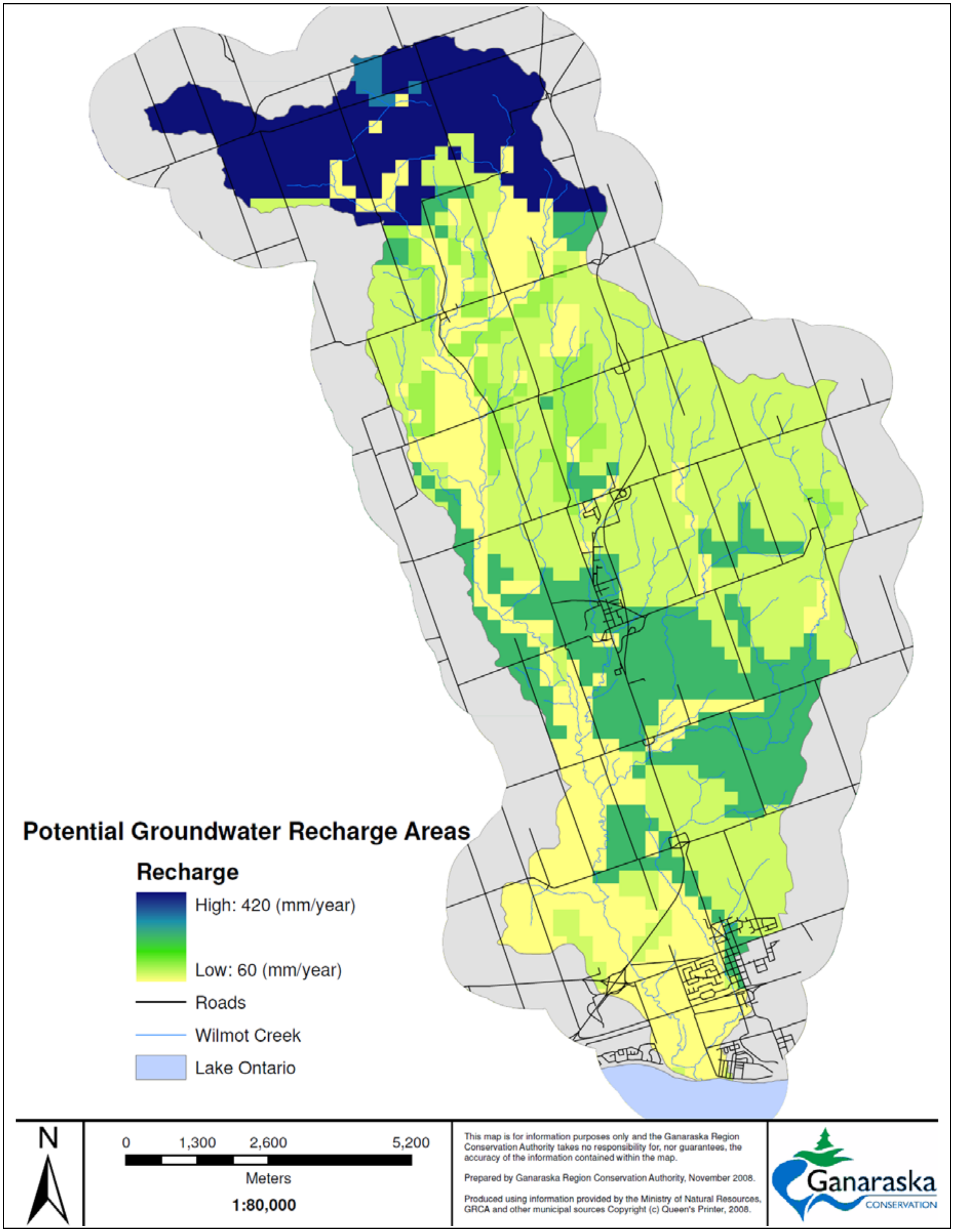


Figure 3.18: Potential groundwater recharge

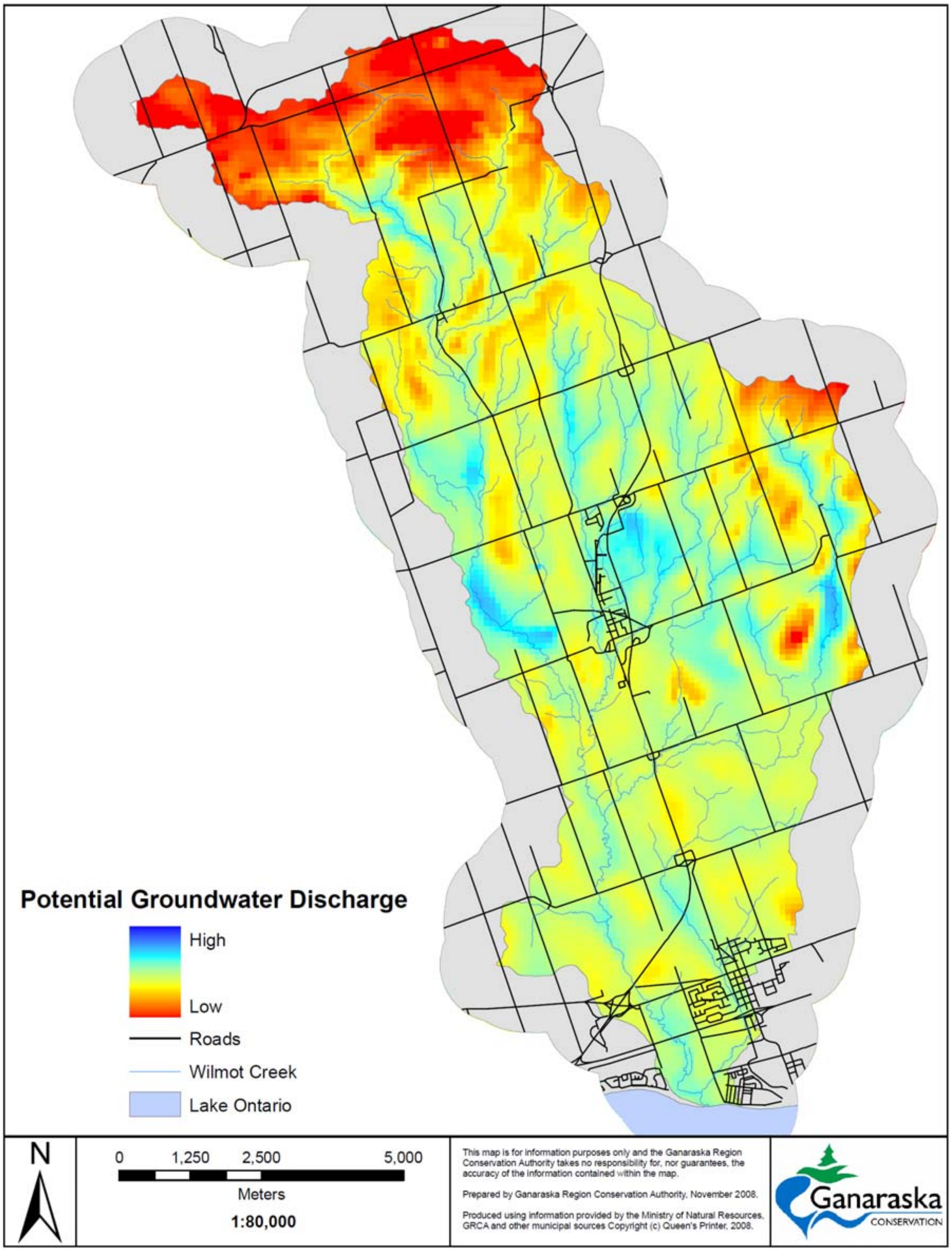


Figure 3.19: Potential groundwater discharge areas

Significant Groundwater Recharge Areas

Potential groundwater recharge and discharge areas have been identified for the Wilmot Creek watershed. However, groundwater recharge areas can be evaluated based on methodologies used to define their significance. In 2009 this evaluation was done under the Drinking Water Source Protection program, directed by the *Clean Water Act, 2006.* The evaluation of significant groundwater recharge areas was done in the Trent Conservation Coalition Source Protection Region, referred to as the study area herein, and is described in a report entitled *Trent Source Water Protection Study Recharge Study* (CAMC-YPDT 2009). Note that the study was completed at a scale larger than the Ganaraska Region Conservation Authority and the Wilmot Creek watershed.

Methodology

The Technical Rules (Ontario Ministry of the Environment 2009) used in the Drinking Water Source Protection program define significant groundwater recharge areas by one of the following two criteria. A significant groundwater recharge area is where:

- The annual recharge rate is at least 1.15 times the annual recharge rate of the area under consideration; or
- The annual recharge volume is at least 55% of the annual water budget surplus (precipitation minus actual evapotranspiration) of the area under consideration.

Significant groundwater recharge areas in the study area were delineated using the second (water budget surplus) method. The delineation process consisted of an analysis of climate, estimation of recharge rates, and calculation of the water budget surplus and the threshold recharge volume.

Climate Analysis

Climate affects groundwater recharge because precipitation and evapotranspiration rates affect the amount of water available to recharge the groundwater system. Data from 71 climate stations across the study area were used to illustrate the interpolated 30-year precipitation and temperature averages. Given the significant variability observed in the precipitation and temperature averages, it was deemed inappropriate to calculate the water budget surplus using a set of climate data from a single station. Thus, taking into account the location of climate stations, the interpolated precipitation and temperature data, general physiography, and the location of watershed boundaries, the study area was divided into northern, central and southern climate zones. The Ganaraska Region Conservation Authority lies within the south climate zone, represented by the Cobourg Sewage Treatment Plant climate station.

Recharge Rates
Recharge rates across most of the Paleozoic Area of the study area were estimated from a three-dimensional regional groundwater flow model developed by the Conservation Authorities Moraine Coalition (Earthfx Incorporated 2006). The model provided estimates of annual recharge rates for most of the quaternary soil types in the study area. These estimates were related to the surficial geology in the study area using surficial geology mapping from the Ontario Geological Survey.

Water Budget Surplus
The water budget surplus is the difference between the precipitation and actual evapotranspiration plus runoff in a given area over a particular time period; this value represents the amount of water that is available to recharge groundwater. The water budget surplus was calculated by subtracting the annual actual evapotranspiration - calculated using Thornthwaite-Mather (1957) and available soil moisture - from the precipitation averages in each of three climate zones in the study area. The water budget surplus for the south climate zone is 353.7 mm/year.

Delineation of Significant Recharge Areas
Significant groundwater recharge areas were delineated by calculating a threshold recharge rate, above which an area would be considered a significant groundwater recharge area. In accordance with the selected approach, this threshold value was calculated as 55% of the water budget surplus for each climate zone. The threshold value for the south climate zone is 194.5 mm/year. Significant groundwater recharge areas in the study area were delineated using the threshold values. However, two further methodologies were considered to refine the delineation of significant groundwater recharge areas, shown in Figure 3.20.

Areas with shallow groundwater, typically found in low-lying valleys, are unlikely to contribute any significant groundwater recharge. Any recharge occurring within these lower-lying areas would move laterally in the shallow groundwater system and discharge in adjacent streams and wetlands. Thus, areas where the water table was less than 2 m below the ground surface were removed from the delineation of significant groundwater recharge areas. After removing areas with shallow groundwater, a number of small areas (less than 0.01 km^2) remained in the delineation. These areas were removed in consideration of the resolution of the input data (i.e., surficial geology mapping and water table mapping) used in the delineation.

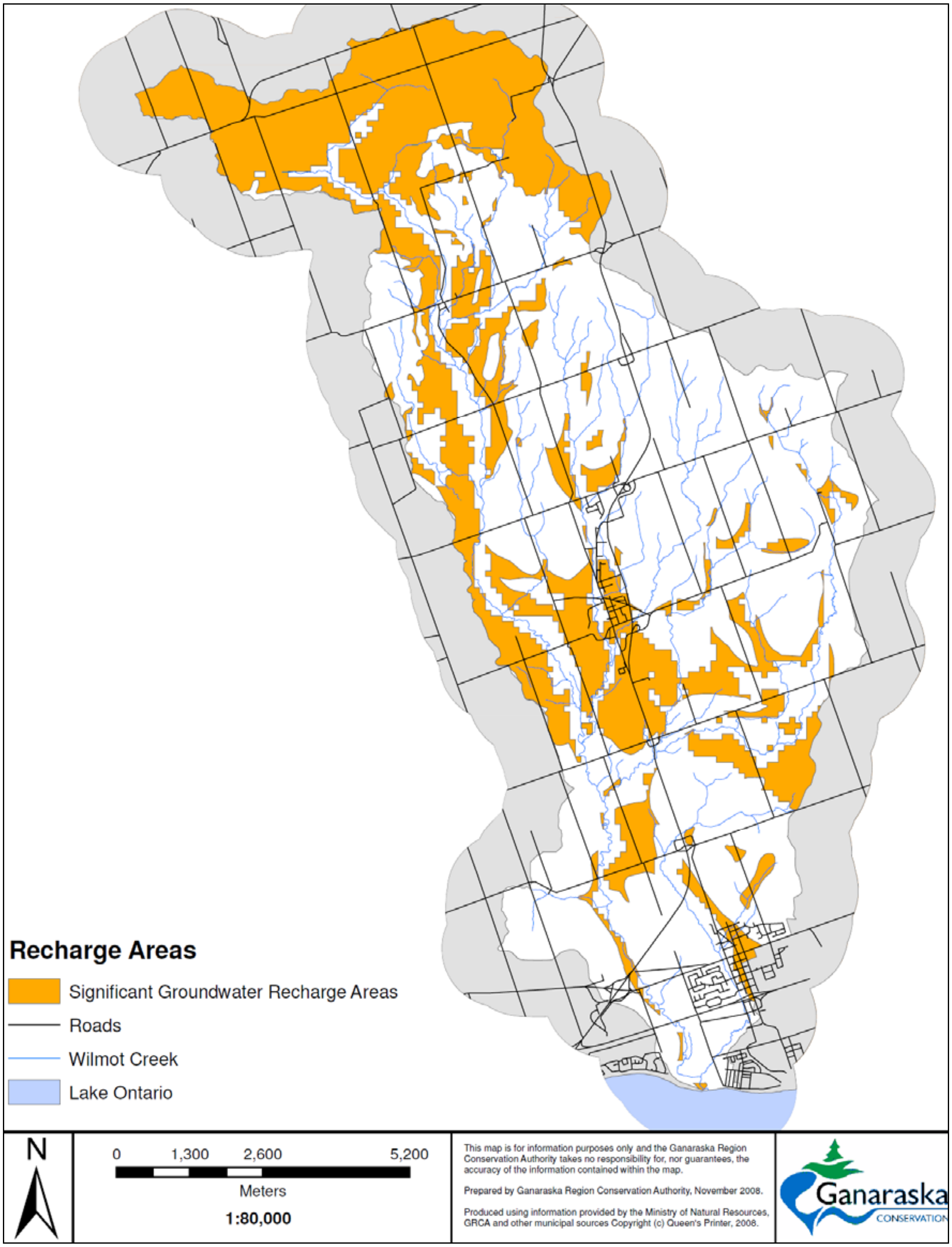


Figure 3.20: Significant groundwater recharge areas

Streambed Piezometers
Although computer-generated models aid in understanding the interactions of groundwater and surface water through the processes of recharge and discharge, field studies with the use of streambed piezometers have been recognized as an efficient tool to quantify these interactions. Widaatalla and Peacock (2007) reported on these interactions using streambed piezometers located across the Ganaraska Region Conservation Authority. Two piezometer monitoring locations are in the Wilmot Creek watershed (Figure 3.22), however when analyzing the western portion of the Ganaraska Region Conservation Authority, the Best Road station was used (the east site in Figure 3.22)

In western watersheds, the Best Road station was the most responsive as it exhibited a reverse pattern to the precipitation data in 2005 and 2006 (Figure 3.21). The lack of water takings in this area of the watershed could explain this pattern. Consequently, this could lead to an assumption that most of the groundwater discharge at the Best Road site is affected by gradual changes in storage capacity of the shallow aquifer and not necessary by the immediate recharge in the catchment. The western sites mirrored the rainfall data during both years. In addition, almost all of the western sites reflected the decrease in rainfall during August 2006.

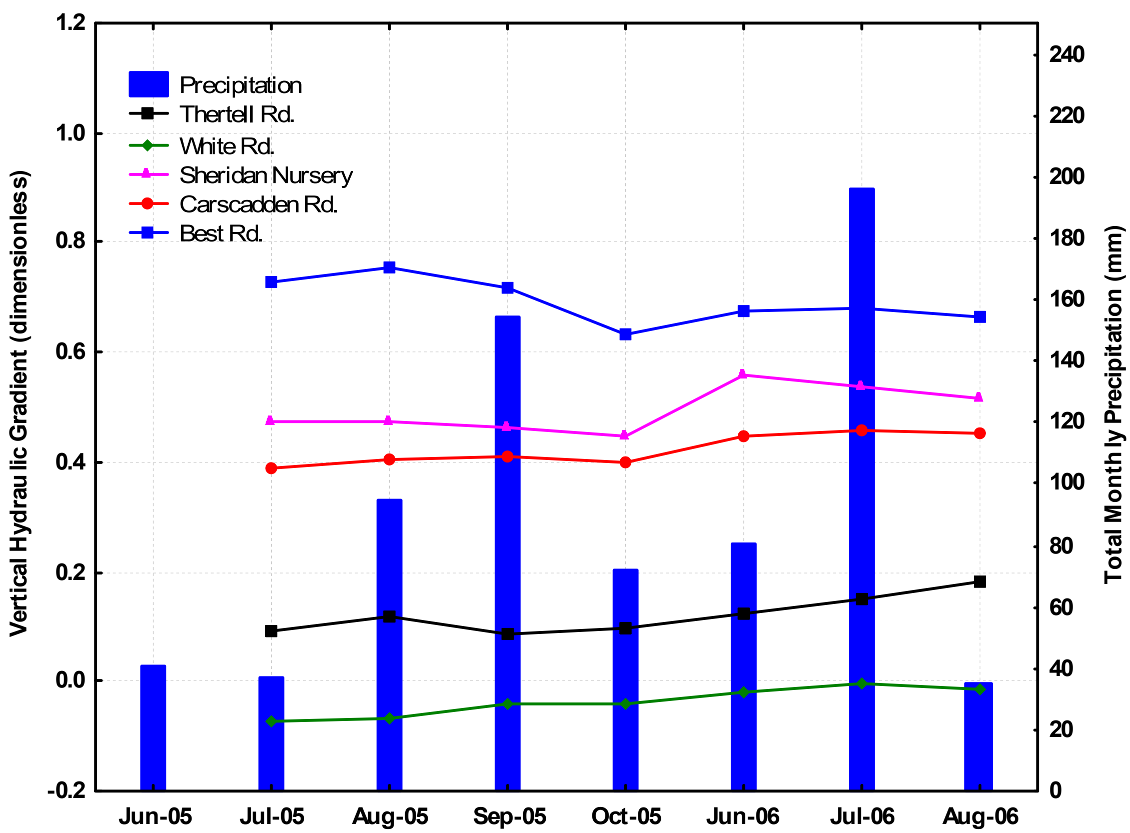


Figure 3.21: Monthly hydraulic gradients in relation to precipitation

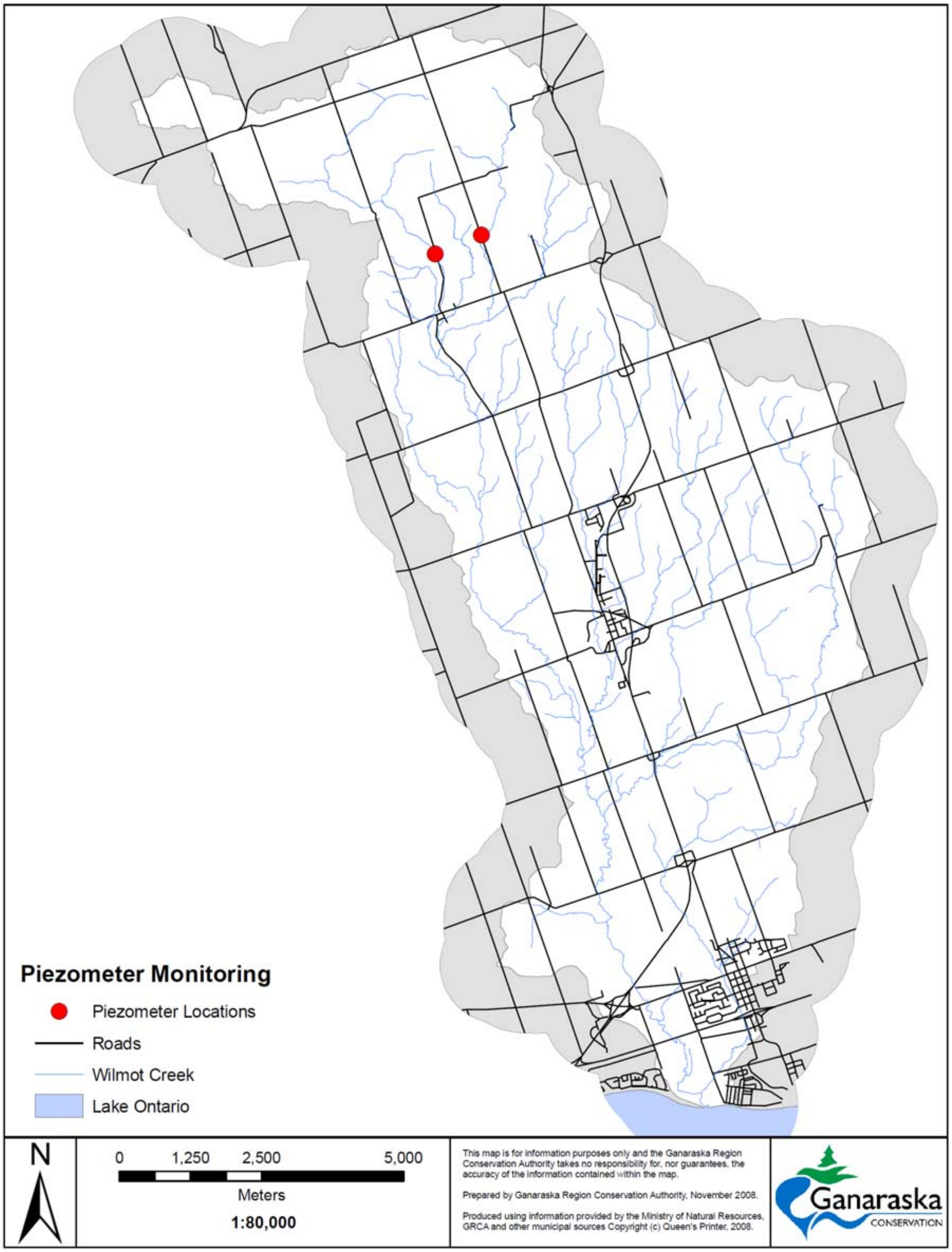


Figure 3.22: Piezometer locations

GRCA Baseflow Analysis

The study and understanding of baseflow in a watershed is important in watershed management since water demand during these low flow periods can cause stress on aquatic ecology. Baseflow for the purpose of this document, is defined as stream discharge during periods when storm flow has ceased and stream flow consists entirely of delayed sources of flow. However, depending on the purpose of the study, baseflow or low flow can also be interpreted more narrowly as the flow during a defined period of prolonged dry weather (Hinton 2005).

Baseflow is a result of groundwater discharge to a stream, and it is controlled by topography and the geological and hydrogeological characteristics of the watershed. Baseflow provides the majority of the flow to streams during dry periods and therefore has a significant effect on the quantity and quality of surface waters. In the Ganaraska Region Conservation Authority, streams are under baseflow conditions approximately 70% of the time. Areas where groundwater discharges to streams (upwelling areas) provide cooler water temperatures, which create attractive refuges and suitable habitats for aquatic species.

During baseflow conditions in the Wilmot Creek watershed, surface water quantity is entirely generated by groundwater discharge due to minimal influence or absence of delayed flows from ponds or stormwater outfalls. Surface water quality is also affected by the quantity and quality of groundwater entering the system as baseflow.

Baseflow Survey Methods

From August 26 to 28, 2008, baseflow was surveyed at 85 locations in the Wilmot Creek watershed. Pygmy flow meters were used with the Area-Velocity method, while volumetric gauging was used at perched culverts as defined by Hinton (2005). A nested sampling approach was taken to standardize the baseflow dataset to one measurement day. Five reference sites were selected to represent 5 groups of baseflow sampling sites. Reference sites were selected based on their suitability for accurate flow measurements and their location within sub-catchments. The five reference sites were sampled on 3 days; the first and last day of the study, and the day the represented group of sites was sampled. The variations in flow that occurred over the sampling period were identified by determining the variance in flow at the reference site between the day of sampling and the standardization day for each represented group. The variation observed was then used as a factor to calculate the standardized flow for each site.

Standardized baseflow discharge from each sample site was used to determine the gain or loss observed between sites by subtracting the discharge observed between a site and its next upstream site. This data was then used to show gains and losses per unit area of sub-catchments and per unit length of flowing channels within subcatchments.

Subcatchment areas were delineated using the Ministry of Natural Resources version one flow direction grid in combination with the geo-referenced locations of baseflow sampling sites. The lengths of all channel segments with observable flow were measured from sample site to sample site immediately upstream by adding the attribute lengths of stream segments. If there was no site upstream of a site, it was recorded as a headwater site and the stream channel was measured to the end of the known or estimated source of flow. Decisions were made based on known geological and hydrogeological characteristics of the watershed to determine the exact locations of sources and changes in baseflow contributions.

Baseflow Survey Results

Analysis of field sampling indicates that the majority of the baseflow in Wilmot Creek is gained or lost from specific locations, attributable to geological and hydrogeological features. The Oak Ridges Moraine and Iroquois Plain physiographic features have a dramatic effect on baseflow occurrences and distribution due to their coarse surficial sediments and dramatic elevation changes. Underlying geologic features control both the rate and direction of groundwater flow as it moves toward stream channels. The most important geologic features are the Bowmanville Till (equivalent to Newmarket Till), which acts as an aquitard that slows groundwater flow downward, and the sandy aquifers that allow water to move upward, downward and laterally toward surface water at lower elevations.

The topography and coarse surficial sediments associated with Moraine deposits in the northern part of the watershed generally have high infiltration capacities, which allow for significant groundwater recharge during wet periods. In the summer, as evapotranspiration rates increase due to temperature and vegetative activity, the watertable drops and the first order streams in the upper Moraine sediments tend to become dry (Figure 3.23).

At the lowest elevations of the Moraine where coarse sediments are thin, there is significant groundwater discharge from the upper aquifer. Underlying geology at the margins of the Moraine is of a finer material such as ancient glacial lake deposits of silty sand, the Bowmanville Till or the Halton Till. This is especially evident in the upper reaches of Wilmot Creek north of the 8th Concession of Clarington (formerly Clarke Township) where four small tributaries collect groundwater discharge and join to form the main branch of the creek. This area contributes over 286 liters per second (L/s) or 37% of the total baseflow observed in Wilmot Creek (Figure 3.24).

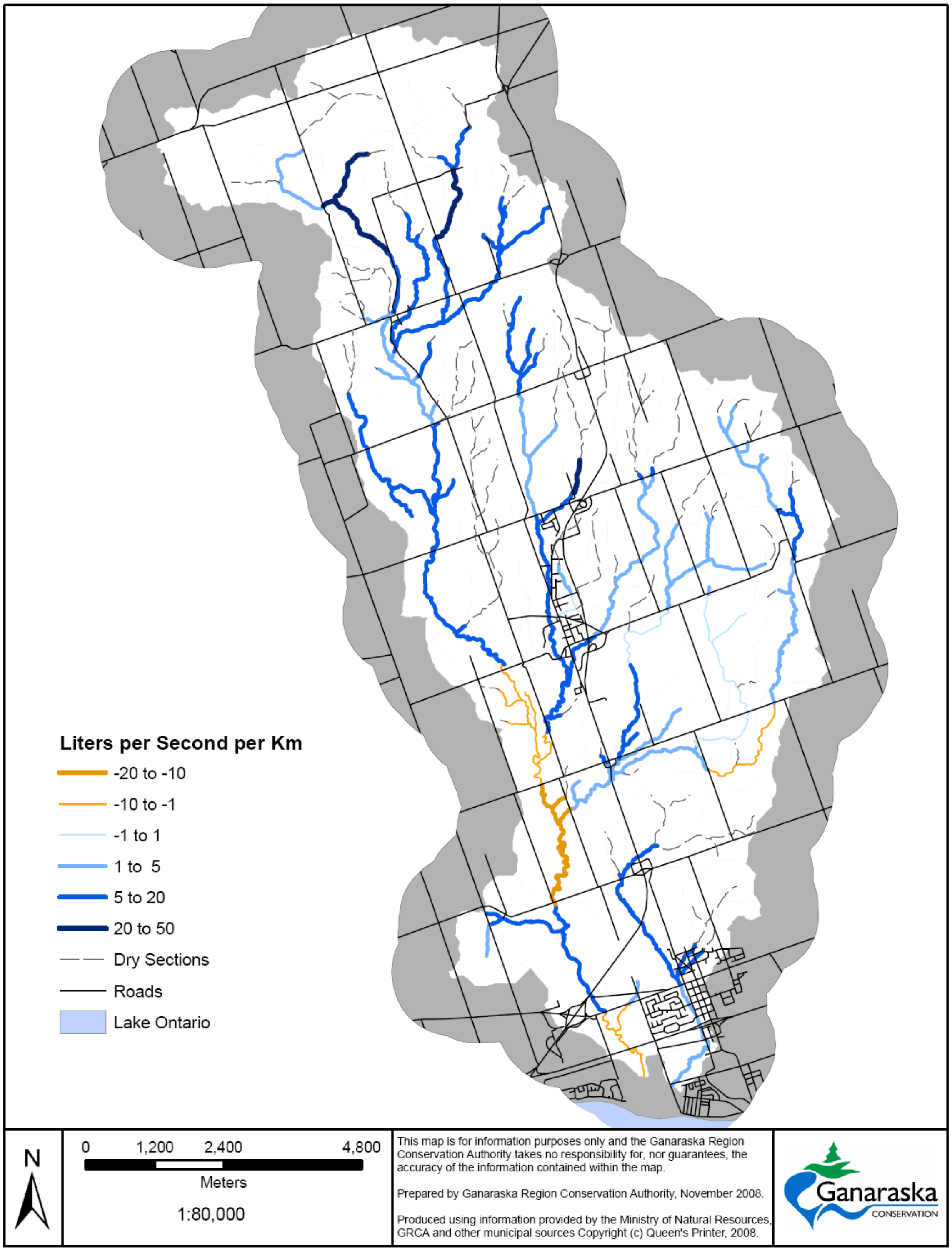


Figure 3.23: Baseflow per unit length

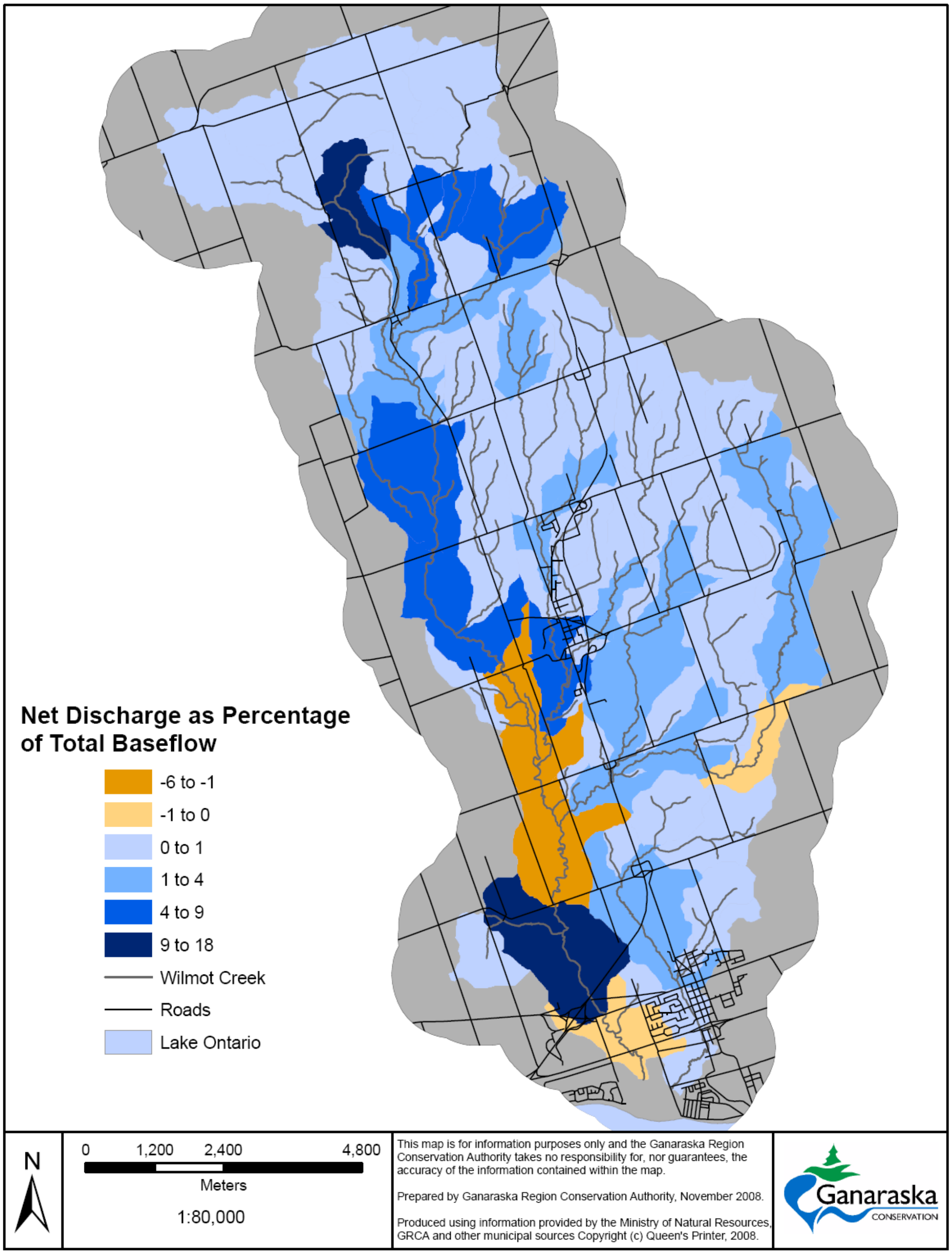


Figure 3.24: Net flow as percentage of total baseflow

There are a number of areas of local groundwater recharge and subsequent discharge on the South Slope, contributing further baseflow to Wilmot Creek. Patchy areas of sandy geology deposited by glacial melt water on the South Slope cause locally high infiltration. As water moves vertically through the surficial deposits, it eventually encounters a lower aquitard layer, such as the Bowmanville Till, and is forced to flow more laterally toward valleys due to the low permeability of the till layer. As the sandy layers become thin and the aquitard becomes more exposed, the groundwater reaches the surface at a discharge point and runs into stream channels. Over thousands of years many channels have cut down through the sandy layers to expose more of the aquitard, moving the discharge locations further upstream.

Some of the surficial sandy deposits extend below the Halton Till (upper aquitard) and can carry water some distance from the recharge areas of the Moraine. One such area is north of Concession 7 between Best Road and Highway 115/35, where one of the tributaries of Orono Creek begins. In this area a large silty deposit of Halton Till lies over a sandy aquifer confining it and allowing recharged groundwater from the porous layers of the Moraine to travel laterally southward to be discharged downstream in Orono Creek. The above noted area is an important baseflow contributing area for Orono Creek and also lies in the path of the future development of Highway 407. When dealing with confined or deep aquifers, it is important to note that their groundwater maybe recharged at locations outside of the surface defined watershed; for example in the western headwaters of the Ganaraska River.

As water flows downstream in the Wilmot Creek watershed it encounters the Iroquois Plain that consists of coarser sediments than the underlying till layers. In a number of area watersheds. losses of stream flow at the upper shoreline are observed due to the coarse sediments and less topography that can allow the surface water to percolate into the ground more easily. In the Wilmot Creek watershed, the shoreline sediments appear to be thinner and less influential in the channel areas resulting in little observation of losses at the Lake Iroquois interface. The substantial contributions from lower aquifers due to a higher groundwater table in 2008, lack of intensive monitoring, and measurement uncertainty could all play a role in disguising the expected losses at the upper part of the glacial Iroquois Plain. On the downstream side of the shoreline, many of the tributaries show generous increases in baseflow. As the shoreline feature becomes thin further downstream, groundwater again appears as springs or seeps as the surface as lower till sediments are exposed. It is also possible that deeper aquifers are becoming exposed due to the major drop in elevation below the shoreline, therefore contributing further baseflow to Wilmot Creek.

Below the Iroquois Plain the topography is much flatter with stream reaches in the main channel flowing within a broad valley between the 5th and 3rd Concessions. Losses in baseflow were observed in these areas which may be caused by a number of factors. In these broad valleys Wilmot Creek flows through surficial deposits of the Clarke Formation (silt and sand) and recent river deposits. These deposits appear to absorb water from the channel and surrounding floodplain. These deposits appear to absorb water from the cannel and surrounding floodplain. The infiltrated water then moves laterally until the watertable again reaches the surface as finer sediments of the Bowmanville Till become more exposed.

South of Concession 3, baseflow increases again as the floodplain narrows and the sand surface deposits thin out. The finer aquitard layers are more exposed and the channels may also cut down into the lower aquifers allowing more groundwater to reach the surface. Where lower confined aquifers are exposed, groundwater is forced upward under pressure forming springs. These areas are especially sensitive because the deep groundwater is likely to be very clean and cold when compared to surface water, creating a high quality coldwater refuge area for fish.

Downstream of Highway 401, Wilmot Creek encounters another broad flat floodplain of fine glacial lake deposits. Minor losses were observed in this area due to a number of possible natural and anthropogenic influences that may be affecting baseflow quantities. These losses could be explained by anthropogenic water takings that were not observed within the baseflow survey. Likewise the development in Newcastle has the ability to hide further contributions to baseflow as was observed in the Foster Creek tributary. In urban areas the drainage of shallow groundwater is more efficient due to the use of foundation drains, stormwater systems and other drainage infrastructure.

This baseflow analysis reveals the important and significant functions associated with topography, hydrostratigraphy, and the contribution of groundwater to the Wilmot Creek watershed. The deposits associated with the Oak Ridges Moraine are shown to contribute significant baseflow downstream through groundwater discharge between the divide of the Moraine and the South Slope feature. Furthermore, the underlying geologic layers in the South Slope have lower hydraulic conductivity and therefore cause groundwater to discharge to streams rather than seeping downward. Localized areas of coarse surficial deposits around the south slope and shoreline features allow groundwater recharge to shallow unconfined aquifers resulting in discharges downstream that form the source of many tributaries of Wilmot Creek. Some streams cut through the till layers into lower aquifer units resulting in discharge of coldwater that likely originated in the Oak Ridges Moraine to the north.

Future baseflow monitoring initiatives in Wilmot Creek should focus on determining variations due to precipitation inputs from year to year and identifying any changes in baseflow due to land use changes and development such as the extension of Highway 407 through the watershed. It may also be useful to monitor some locations to minimize measurement uncertainties.

Geological Survey of Canada Baseflow Analysis

In 1995 the Geological Survey of Canada (Hinton 2005) conducted a baseflow survey examining the spatial patterns of groundwater discharge in the Wilmot Creek watershed. The Ganaraska Region Conservation Authority adapted the methods used by Hinton in further baseflow studies, such as the one described above.

Hinton (2005) analyzed the portions of net discharge contributed by various subcatchments of the watershed (Figure 3.25). The area of highest groundwater discharge (more than 50% of the net discharge) occurs in the headwater streams of the watershed. Groundwater discharge is high to very high in the headwater tributaries and likely occurs both as flow through the sand and gravel streambeds and as discharge from groundwater seeps adjacent to the streams (Hinton 2005). The high groundwater discharge in these streams is explained by high recharge in the coarse moraine and river sediments in the upslope areas and the drop in elevation along the south slope of the Oak Ridges Moraine that provides a natural drainage point for discharge.

Hinton (2005) described the second most important area of groundwater discharge (26%) occurs along the watershed's main valley below the former Iroquois Plain (Figure 3.25). The survey results indicated that large increases in baseflow exist between Concessions 5 and 3 along Wilmot Creek, and Orono and Stalker Creeks near their confluences (Hinton 2005). The drop in elevation from the till plain and the lower elevations of the valley compared to the adjacent lake sediments make the valley the preferred location of groundwater discharge. Although it is likely that some of the discharge originates from the surrounding area (particularly the sandy sediments from upper Iroquois Plain), it is possible that some of the groundwater discharged in this area originates as recharge in the Oak Ridges Moraine and reaches the lower watershed as deeper groundwater flow. This is confirmed by the presence of Bowmanville Till in the surrounding area as an obstacle limiting local recharge. Clarke deposits found beneath the Bowmanville Till are also a possible contributing aquifer to the discharge in the creek below the Iroquois Plain. Figure 3.25 also shows the low recharge rates in the adjacent area.

The large decrease (-5%) in baseflow along the main branch of Wilmot Creek in the central part (below Taunton Road) was a dilemma for author of the survey report. The fact that this area is located between the two highest baseflow contribution areas makes any further interpretations a difficult and complicated task. Further analysis of the baseflow survey results was also done by investigation of low-flow discharge per unit length of stream reaches (Hinton 2005). Figure 3.26 shows the high discharge areas in the north and south as well as the losing stretch of the main branch in the central part of the watershed. The losing areas identified by the survey and shown in Figures 3.25 and 3.26 are contrary to modeled geology (Section 3.1.2), which show the same areas as being potential discharge location predicted by the regional groundwater model

(Earthfx Incorporated 2006). This is mainly due to the method used in generating modeled geological cross-sections. It is believed that the losses shown it this reach represent leakage to lower aquifer units, The aquitard units may be eroded in the stream valley thereby partially exposing the aquifers allowing recharge.

The high discharge and losing catchments of the watershed were later confirmed by the Ganaraska Region Conservation Authority baseflow monitoring and data analysis in 2002 (Peacock 2004). Figure 3.27 shows the Ganaraska Region Conservation Authority results that confirm those of the Geological Survey of Canada. The only difference between the two results is the minor shift of the central losing stretch to the north in the Ganaraska Region Conservation Authority analysis. Further confirmation of the northern discharge areas were based on the results of potential discharge and spring areas in the Oak Ridges Moraine as investigated by Dyke et al. in 1997.

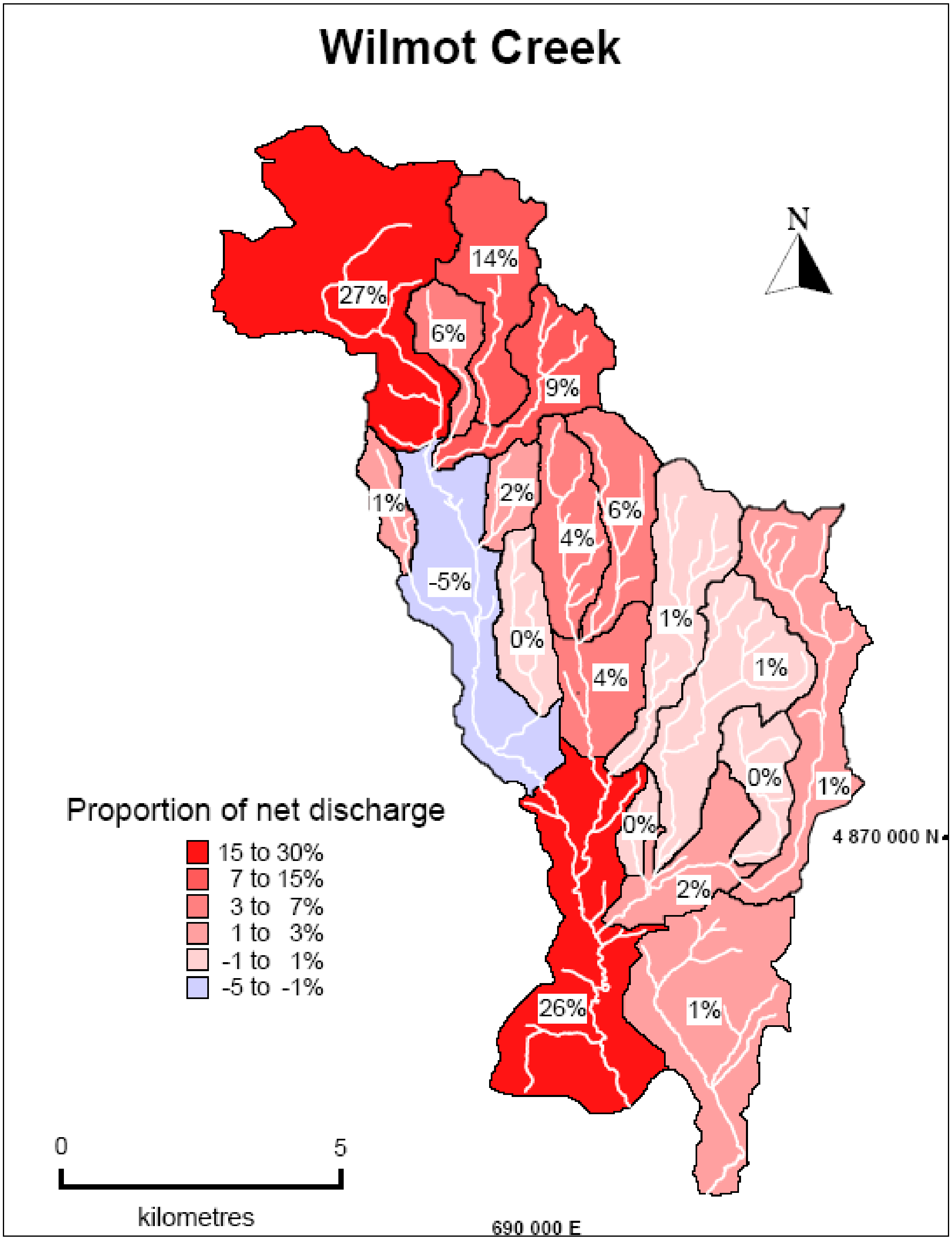


Figure 3.25: Hinton's proportions of net low-flow discharge (Hinton 2005)

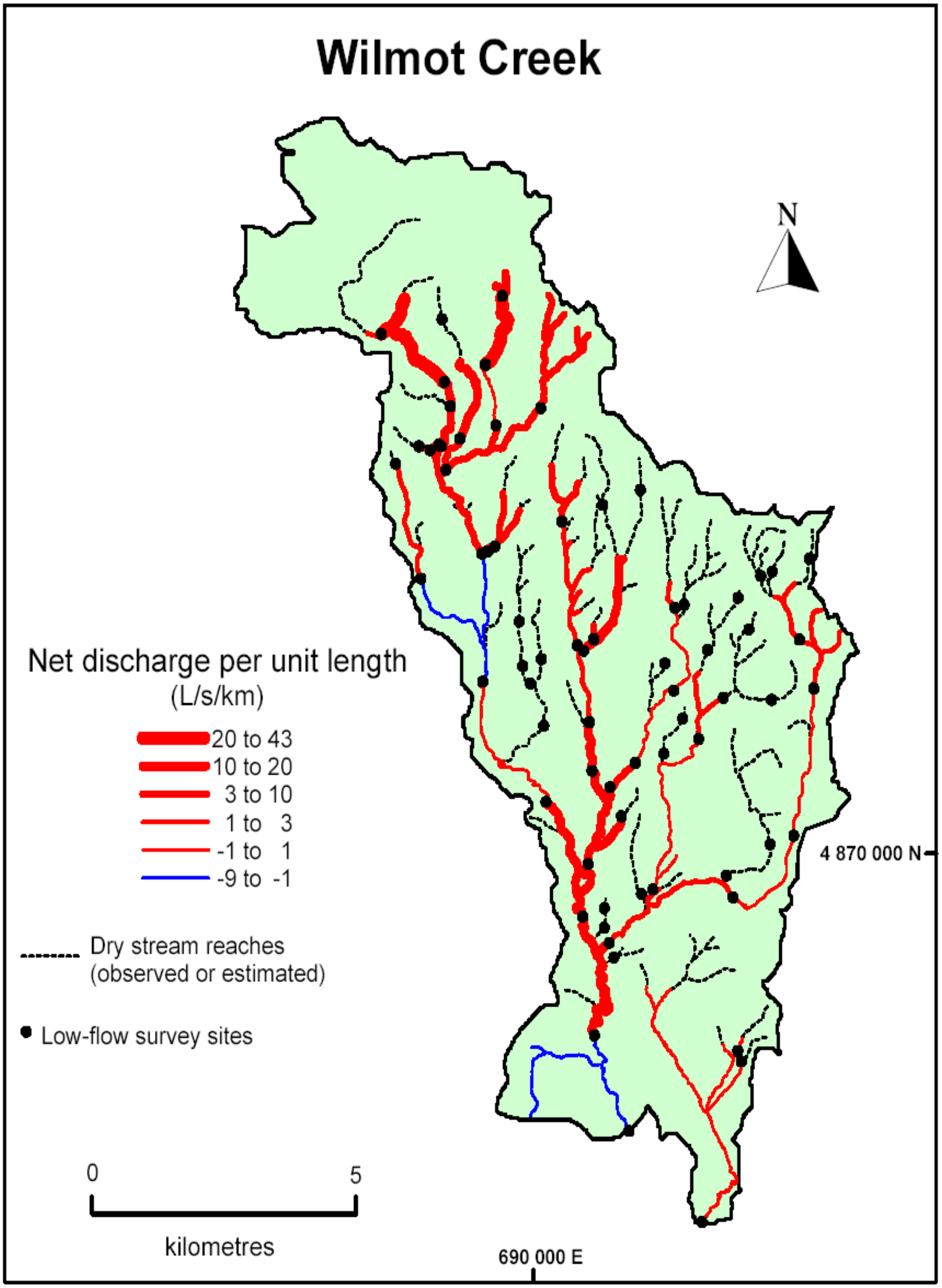


Figure 3.26: Hinton's net flow discharge per unit length (Hinton 2005)

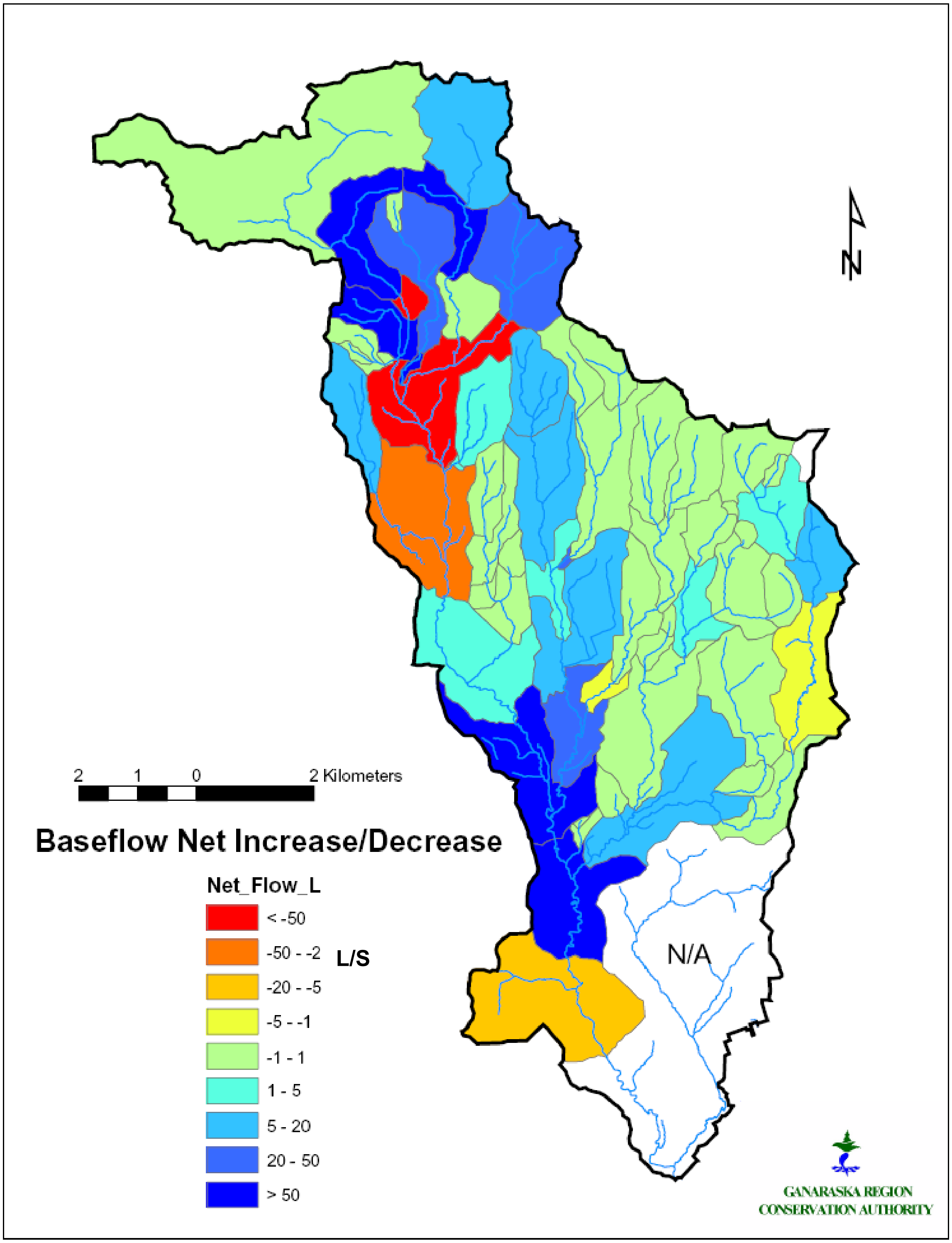


Figure 3.27: GRCA analysis of baseflow net increase / decrease (Peacock 2004)

The Community of Orono Well Supply and its Relationship to Streamflow

The Ganaraska Region Conservation Authority, Regional Municipality of Durham and Jagger Hims Limited investigated the decrease in baseflow in the central part of the watershed. The Community of Orono municipal wellfield as well as a number of permits to take water are within this area, as well as the capture zone to the Orono municipal wellfield (Figure 3.28; Jagger Hims 2003c). Several studies and groundwater models completed by Jagger Hims Limited (2003 and 2003b) defined the status of the Orono municipal wells as GUDI (Groundwater under the Direct Influence of Surface Water) with insitu filtration and hydrologic link to the creek. Recent studies have confirmed that the Orono municipal wellfield is <u>not</u> GUDI.

Figure 3.29 shows a north south cross-section in the wellfield area. This cross-section is comparable to the watershed wide cross-section A-A' (Section 3.1.2) as both cross-sections shows the presence of Bowmanville till (Newmarket till) in the area and illustrates the importance of the lower sediments as a major aquifer in the watershed. Figure 3.30 shows the location of the wellfield cross-section A-A' and the simulated watertable contours of the area. Further investigation of the hydrologic system occurred evaluating fish community surveys in the watershed. Figure 3.31 illustrates a noticeable shift in fish communities in the losing stretch (Desjardins and Stanfield 2005).

A plan for further study in the area was completed by Ganaraska Region Conservation Authority staff through a focused monitoring program (Peacock 2004). During the summers of 2004 and 2005, the GRCA as part of the Regional Municipality of Durham watershed monitoring project, operated a surface water monitoring network in the Orono Crown Lands (Figure 3.32). The monitoring program was developed to quantify the effects that water takings were having on the surface water flow in Wilmot Creek and to satisfy the MOE PTTW requirement for the municipal wellfield[1].

Joint analysis of the Ganaraska Region Conservation Authority data (Peacock et al. 2006) and Jagger Hims Limited (2006) data revealed that the surface water flow in the central section of Wilmot Creek experienced a perched condition during certain time of the year. The analysis also showed that the creek retained its gaining status further down stream below the Iroquois Plain. Figure 3.33 shows one of many identical hydrographs of the monitoring stations. Figure 3.34 shows the differences in flow between monitoring stations compared to the pumping data of the Orono Municipal wells. The loss and gains can be seen to be part of a larger natural system as they cannot be attributed to the pumping of the municipal wells.

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[1] A separate report produced by Jagger Hims Limited (2006) was written to fulfill other MOE requirements for the Community of Orono PTTW and provides additional analysis on groundwater and aquatic habitats in Wilmot Creek.

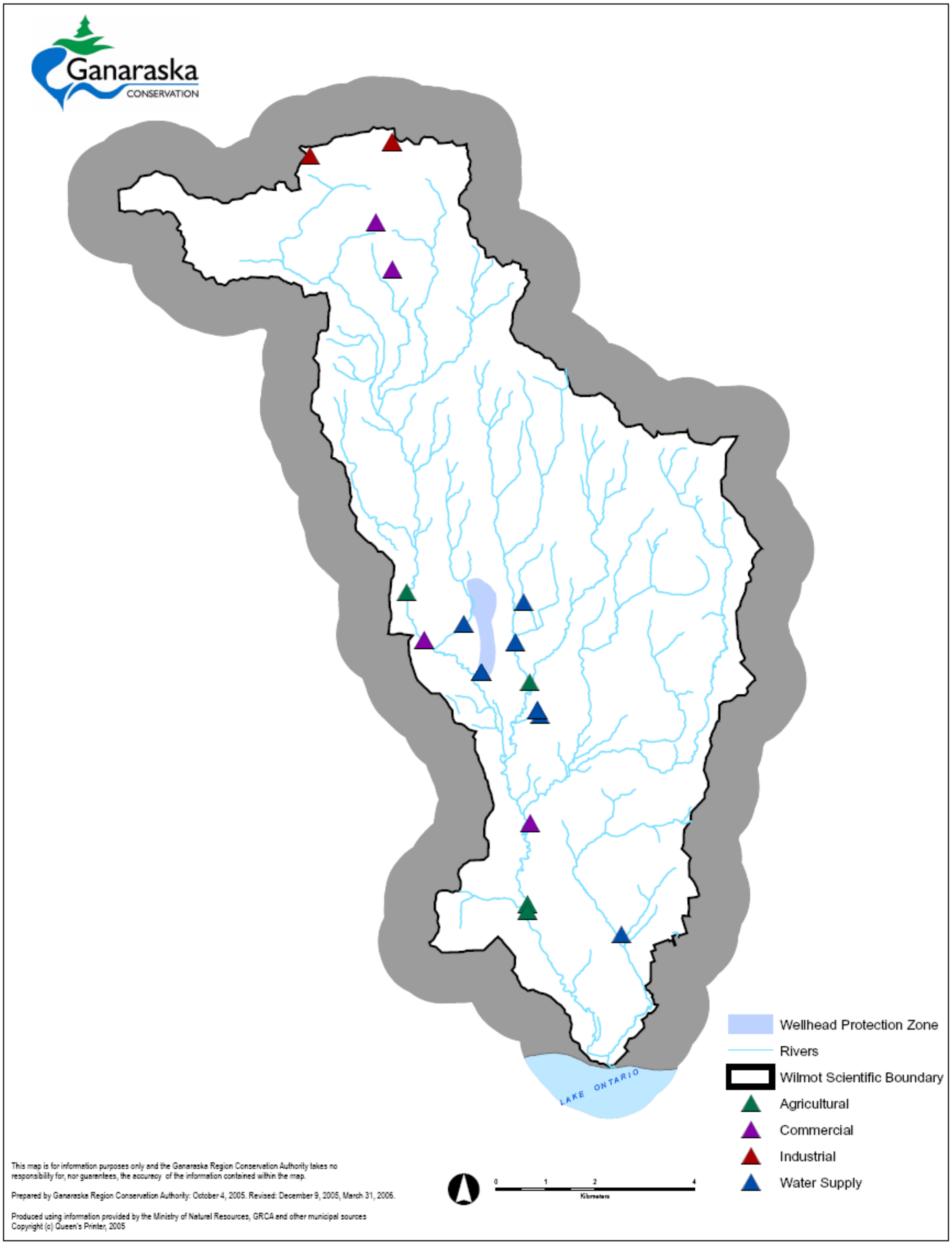


Figure 3.28: Active and inactive PTTW locations

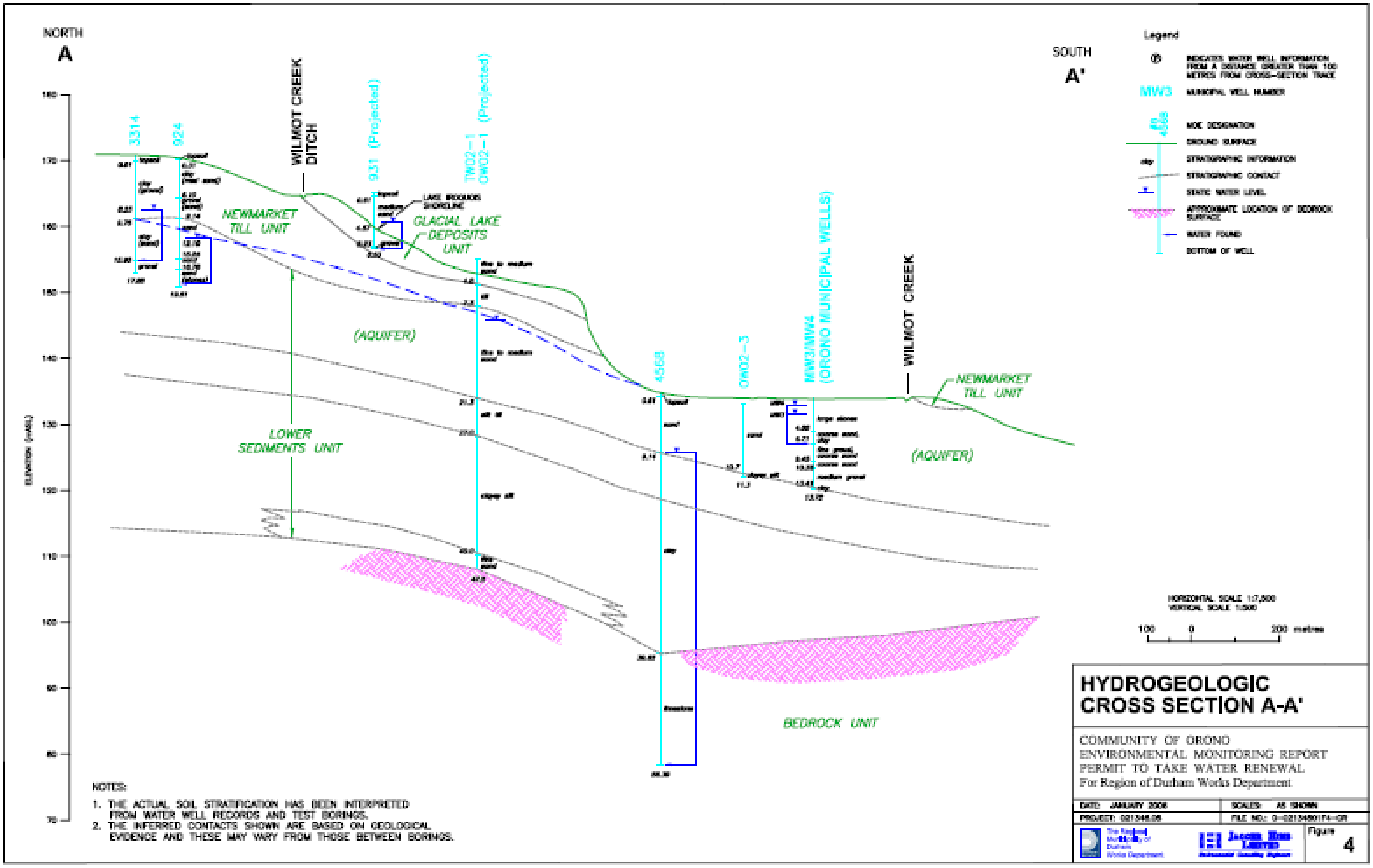


Figure 3.29: North – South cross-section in the wellfield area (Jagger Hims Limited 2003)

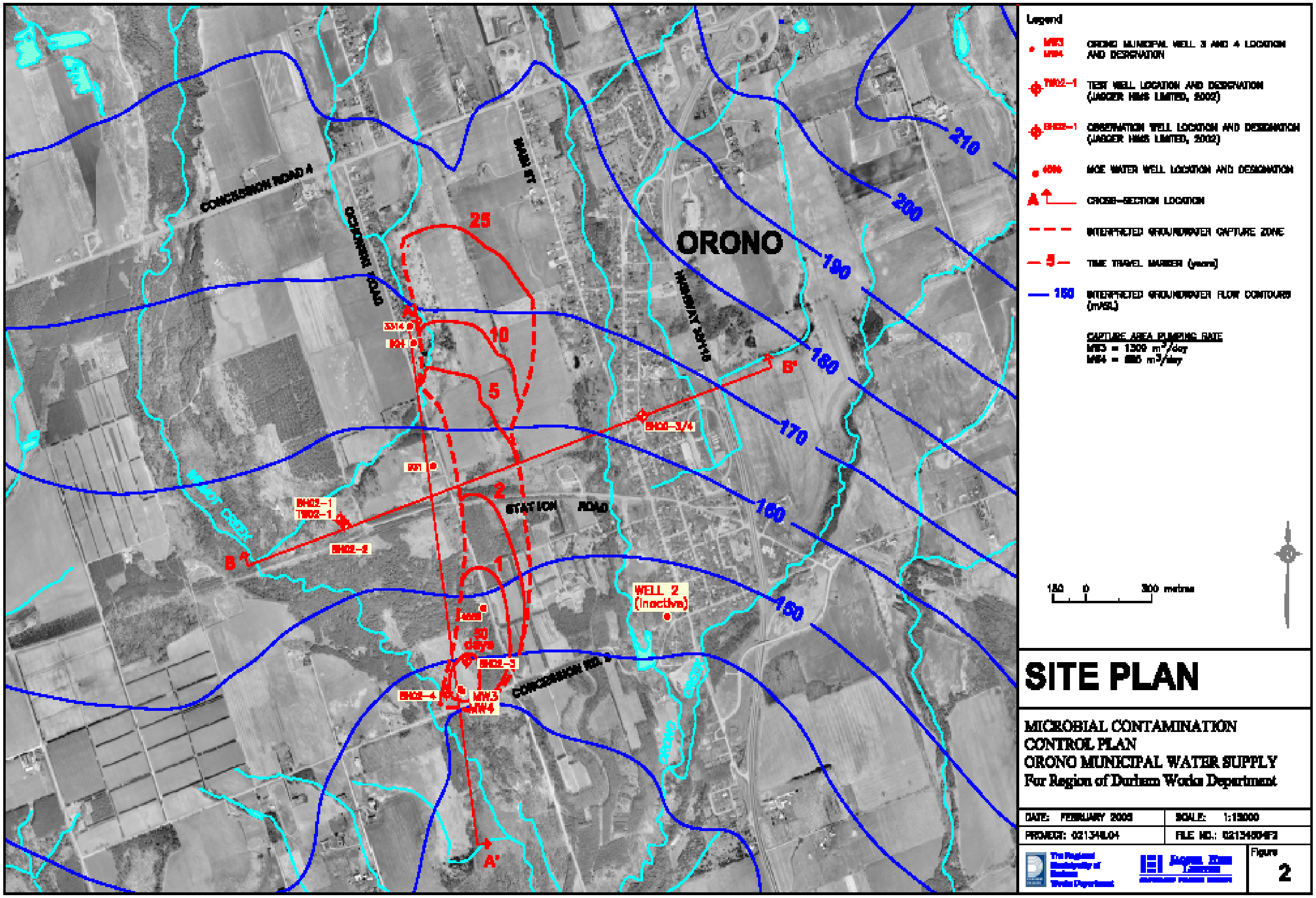


Figure 3.30: Orono municipal well, locations of cross-section A-A’ and groundwater monitoring stations

(Jagger Hims Limited 2003)

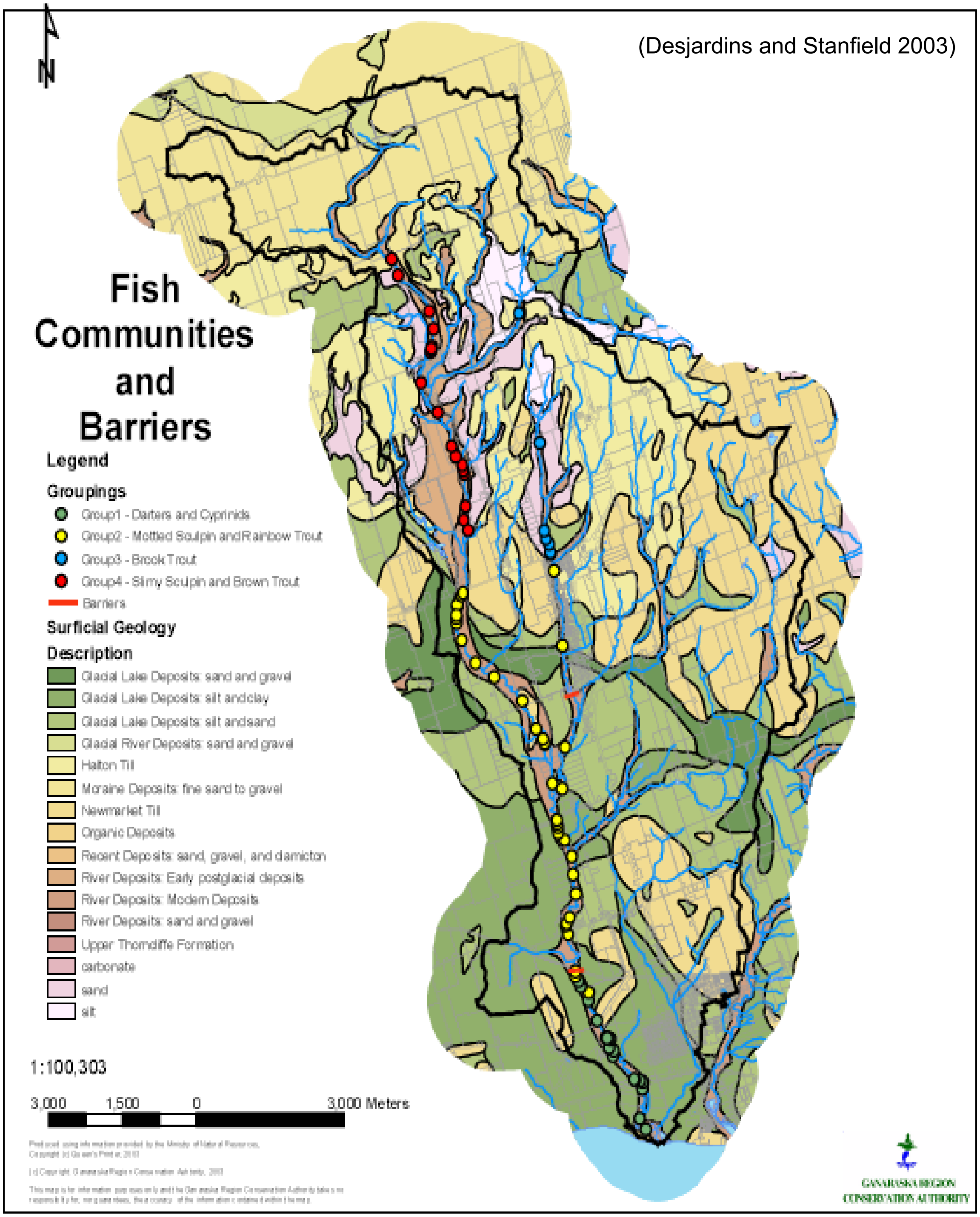


Figure 3.31: Survey of fish species in the Wilmot Creek watershed

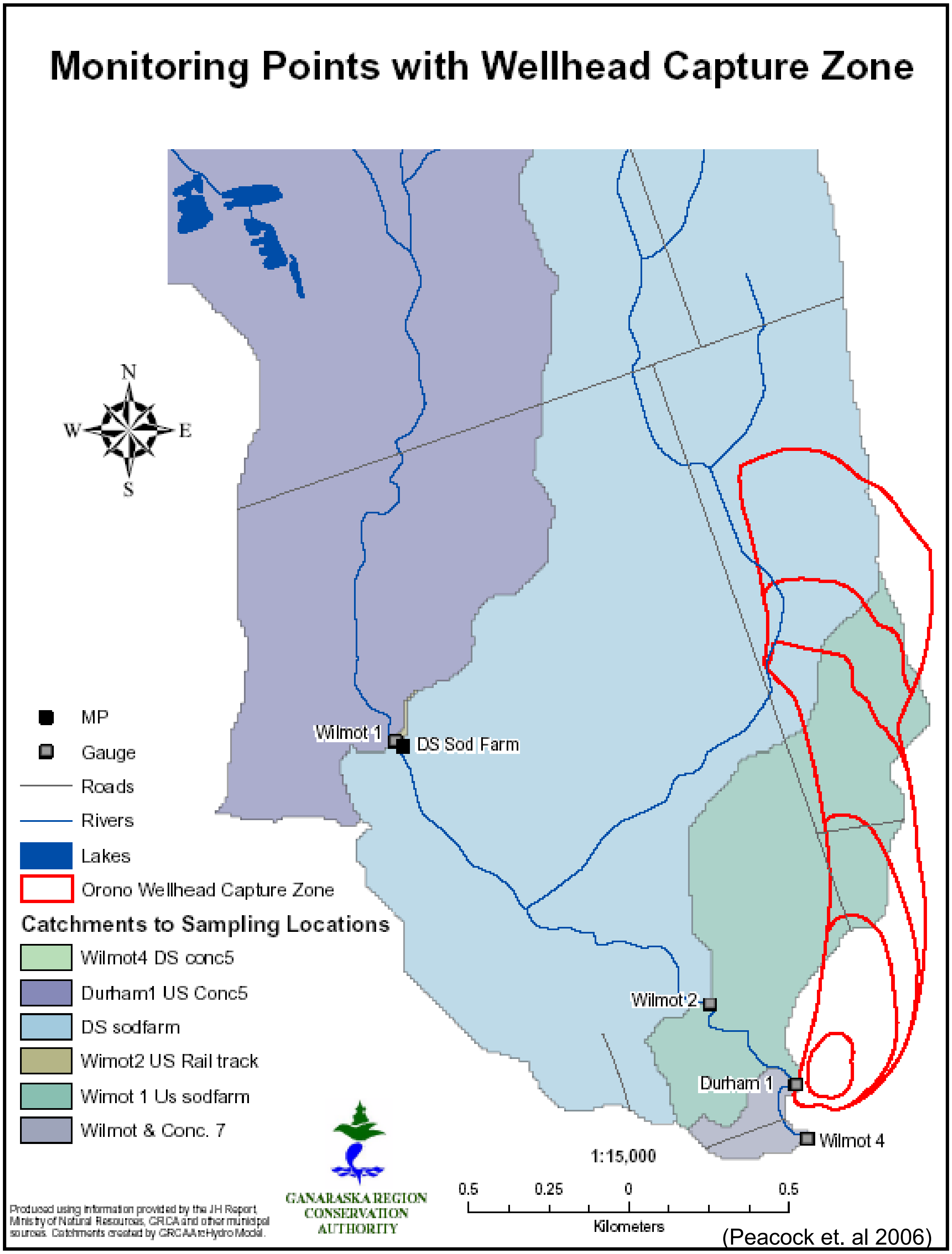


Figure 3.32: Gauge locations and Orono Wells capture zone

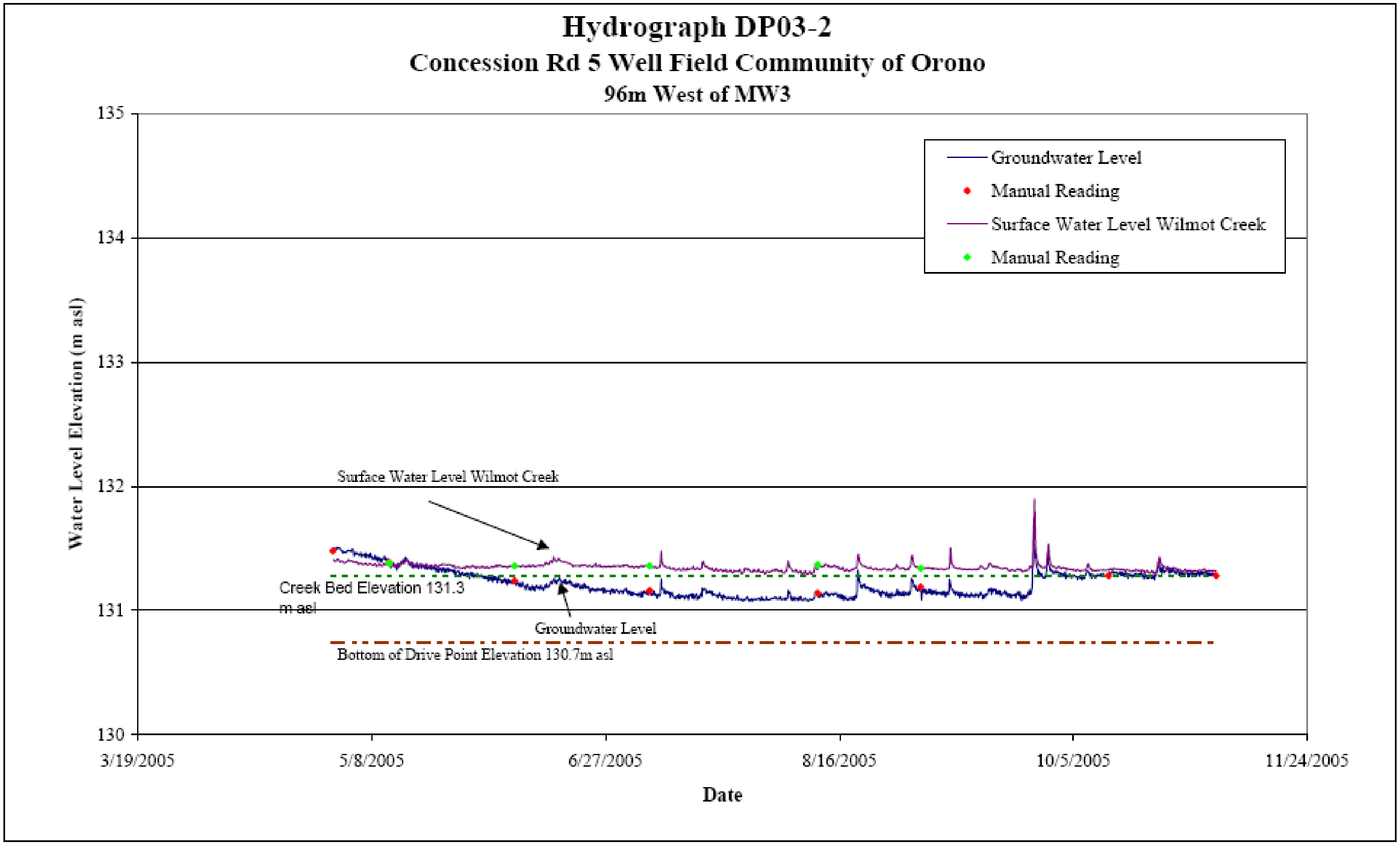
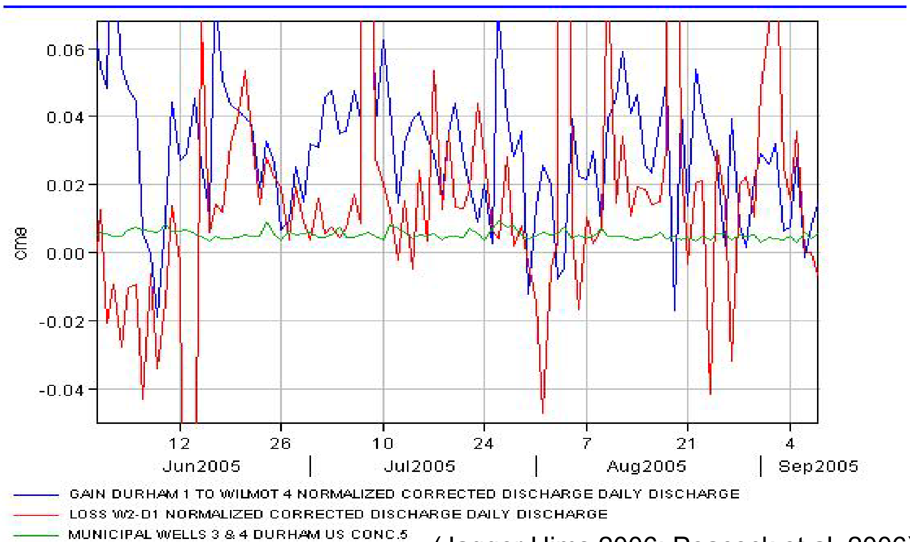


Figure 3.33: Example hydrograph of joint surface water and groundwater monitoring

(Jagger Hims Limited 2006; Peacock et al. 2006)



(Jagger Hims 2006; Peacock et al. 2006)

Figure 3.34: Orono Wells (MW3 & MW4) pumping data versus loss from W2 to D1 and gain from D1 to W4

3.3 GROUNDWATER ANALYSIS

Groundwater analysis allows watershed managers to understand groundwater systems and where and how it contributes to surface water systems. In addition, by understanding the groundwater system, drinking water sources and non-potable water uses can be maintained in a manner that protects the natural environment and the groundwater resource.

3.3.1 Groundwater Modeling and Wellhead Protection Area

The source of drinking water for the Community of Orono originates from two drilled water wells located approximately 1.5km west of Highway 35/115, adjacent to Wilmot Creek on Concession 5. The two wells, designated MW3 and MW4 are completed in an overburden aquifer (top portion of the lower sediments package). These wells have provided the community of Orono with safe drinking water since they were drilled and developed in 1986.

Groundwater management and wellhead protection is an initiative that the Regional Municipality of Durham Works Department began several years ago to safeguard the groundwater resources surrounding its municipal wells. A three-dimensional numerical groundwater flow model (MODFLOW) was developed to identify the capture areas that contribute groundwater to the municipal wellfield in Orono (Figure 3.35 and 3.36; Jagger Hims Limited 2003c). This study has identified the land area surrounding the municipal wells in need of groundwater management and protection strategies. The study also included an inventory of the potential sources of contamination. Further studies are occurring through drinking water source protection to further the understanding and protection of this municipal drinking water source.

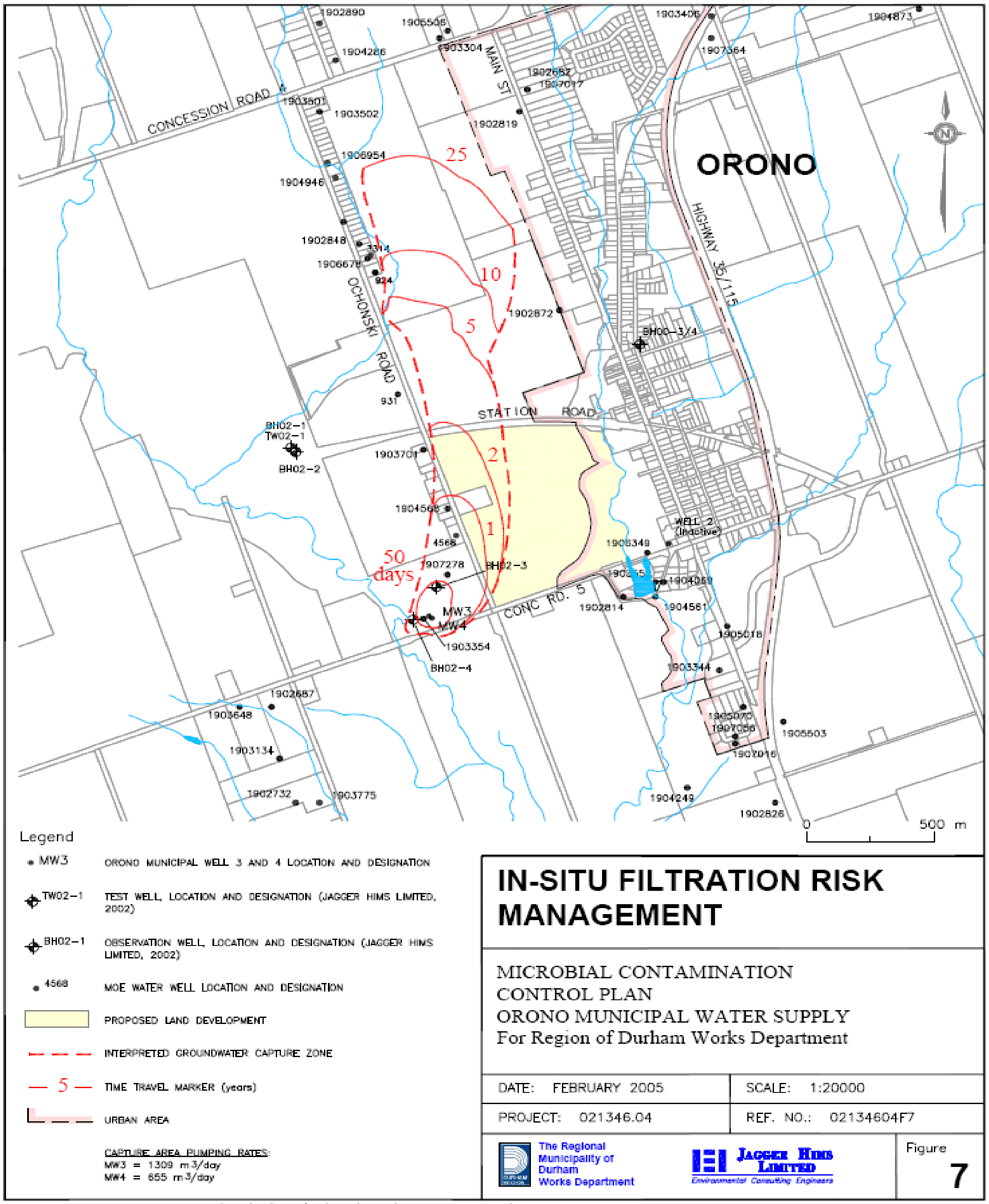


Figure 3.35: In-situ Infiltration - Orono Municipal WHPA

(Jagger Hims Limited 2006)

Figure 3.36: Community of Orono Municipal wells capture zone (Provided by the Region of Durham)

3.3.2 Aquifer Vulnerability

Groundwater vulnerability has been evaluated for the Wilmot Creek watershed through the Drinking Water Source Protection program, directed by the *Clean Water Act, 2006.* The evaluation of groundwater vulnerability was carried out in the Trent Conservation Coalition Source Protection Region and is described in a report entitled *Groundwater Vulnerability Assessment - TCC Source Protection Region* (AECOM 2009). Note that the study was completed at a scale larger than the Ganaraska Region Conservation Authority and the Wilmot Creek watershed.

The objective of identifying groundwater vulnerability is to address groundwater source protection. Delineations are also intended to recognize different uses of water in a regional setting, including shallow and deep private wells, ecological resources and recharge/discharge areas. Such delineations also serve as the basis for protection efforts for these water resources. Preliminary aquifer vulnerability areas in the Ganaraska Region Conservation Authority have been delineated through earlier municipal groundwater studies (Morrison Environmental Limited 2004).

Methods
The Technical Rules (Ontario Ministry of the Environment 2009) used in the Drinking Water Source Protection program list four acceptable methods to be used for the assessment of groundwater vulnerability. Two of the four acceptable methods were selected for use and these have been used in previous studies throughout the Ganaraska Region Conservation Authority.

- Intrinsic Susceptibility Index (ISI) – A score or index value is given to each well (e.g., Ministry of the Environment Water Well Record Database). This index or score at each well is then interpolated between wells to produce a vulnerability map. This method takes into account the soil type and thickness above the aquifer, and the static water level in the well.

- Aquifer Vulnerability Index (AVI) – A score or index value is assigned based on mapping products (e.g., depth to aquifer, soil type and thickness) that reflects the relative amount of protection provided by physical features that overlie the aquifer. This method, unlike the ISI, does not take into account water table or water level information.

Scoring of groundwater vulnerability is as follows:

	ISI or AVI Range
High Vulnerability	0 to < 30
Medium Vulnerability	30 to < 80
Low Vulnerability	> 80

Results for the Paleozoic Study Area

Using the ISI method, shallow aquifers in areas north of the Oak Ridges Moraine are generally of high or medium vulnerability. Shallow aquifers in the centre of the Oak Ridges Moraine and the Iroquois shoreline appear to be slightly more vulnerable than in the north and south flanks of the Oak Ridges Moraine. This is expected since the deposits are largely unconfined coarse-textured material. However, the AVI method produced more conservative results along the centre of the Oak Ridges Moraine, whereas the ISI method produced results more conservative in the rest of the Palaeozoic Study Area.

In general, the AVI method produced more conservative results in the Oak Ridges Moraine since the method is based on geological characteristics, whereas the ISI method created results less conservative given there are fewer wells, which are needed for analysis, within the area of study on the Oak Ridges Moraine. As a result, and after Ontario Ministry of the Environment approval (for the purpose of the Drinking Water Source Protection program), the resulting ISI and AVI maps were merged to create a conservative groundwater vulnerability map for the Ganaraska Region Conservation Authority that can be used to determine groundwater vulnerability for the Wilmot Creek watershed (Figure 3.37).

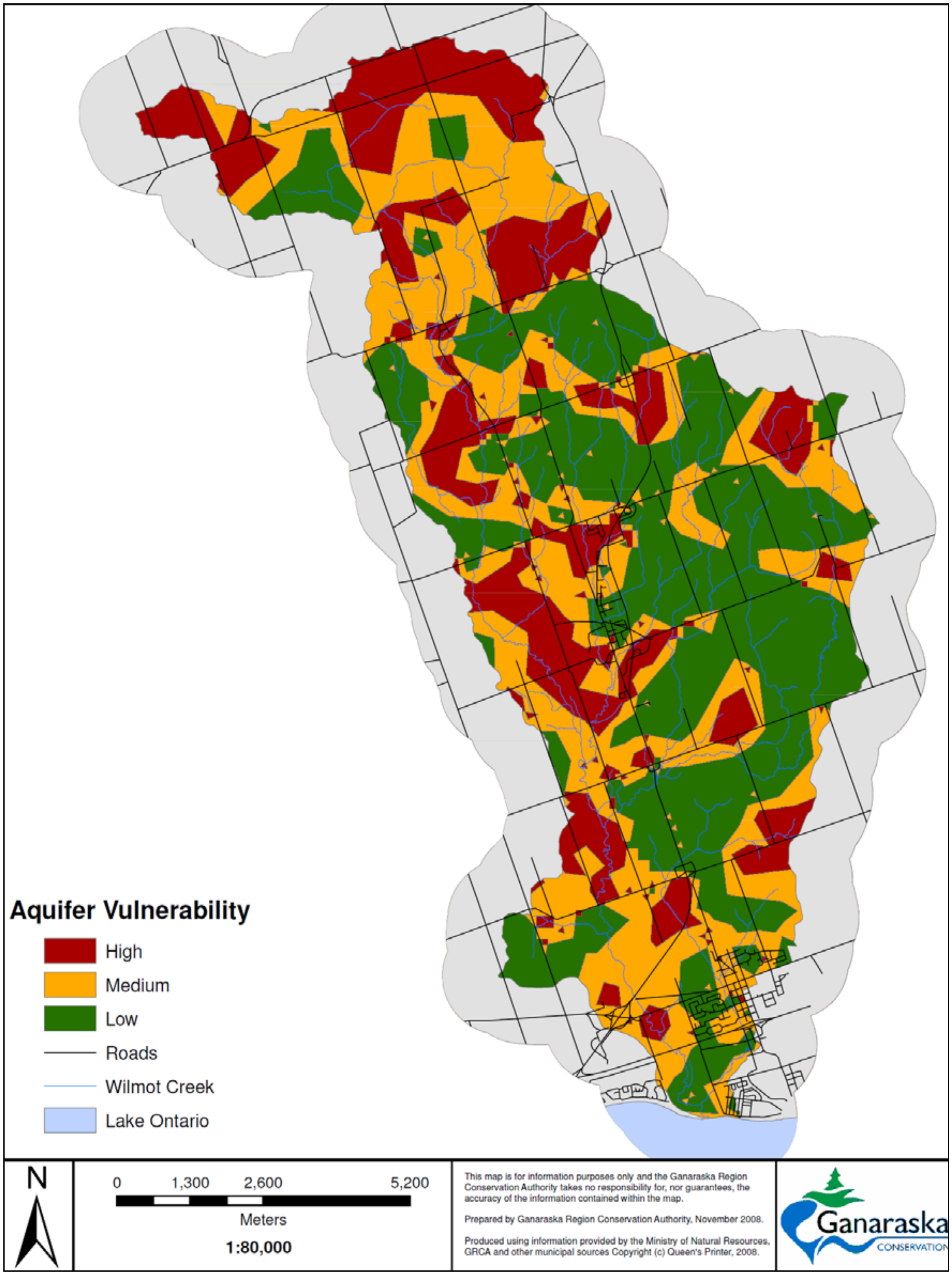


Figure 3.37: Groundwater vulnerability

3.4 SURFACE WATER

Surface water flows and occurs on the surface of the ground. Water enters the surface via precipitation and groundwater discharge and it moves through water flow, groundwater recharge or transpiration. The following section describes surface water characteristics, surface water flows and water quantity.

3.4.1 Drainage Basin Characteristics

The Wilmot Creek watershed is the third largest drainage basin in the Ganaraska Region Conservation Authority jurisdiction. Originating in the Oak Ridges Moraine at an elevation of approximately 331 masl, Wilmot Creek drains a land base of 97.7 km^2. It flows southeast for about 21.2 km at an average slope of about 12 m/km and discharges to Lake Ontario (Singer 1981; Figure 3.38). Wilmot Creek tributaries include Orono, Hunter, Stalker and Foster Creeks. The drainage areas of these tributaries are listed in Table 3.5. Figure 3.39 shows the Wilmot Creek main branch and its tributaries.

A watershed such as Wilmot Creek is drained by tributary streams that combine into a main channel. Several methods have been used for ordering the tributary streams in a drainage network; however the Horton-Strahler method is widely used (Wetzel 2001). The smallest permanent stream is designated as the first order, and the confluence of two first-order streams create a second order stream. This increase by confluence occurs until the system outlets, to a specified point, which in this case is Lake Ontario. Wilmot Creek, as defined by the Horton-Strahler method, consists of five stream orders that in total travel a distance of 172.7 km. Stream order lengths are as follows: first order 73.4 km, second order 50.3 km, third order 28.4 km, fourth order 11.9 km, and fifth order 8.6 km (Figure 3.40). First order streams are the dominate stream order in the Wilmot Creek watershed. In addition to these stream orders, many intermittent and ephemeral streams contribute to the flows and habitat of Wilmot Creek during differing times of the year.

Table 3.5: Drainage areas of the major tributaries in Wilmot Creek

Stream/Tributary	Drainage Area (km^2)
Main Branch	51
Foster Creek	9.6
Hunter Creek	8.1
Orono Creek	18.0
Stalker Creek	11.5

As Wilmot Creek flows through the landscape, the local watershed characteristics change as a result of human influences. Imperviousness is one such landscape characteristic that alters the drainage response of a watershed. Impervious areas are hardened through paving (e.g., parking lots and roads) and development (e.g., buildings and infrastructure). These land cover types prevent water from infiltrating through the ground, increase surface runoff rates, and alter pathways of surface water (e.g., drainage through storm sewers to a stream). Areas of high imperviousness are located primarily south of Highway 401 in Newcastle and the central part of the watershed in Orono and Leskard. These impervious areas cause a noticeable response in a stream even during small rainfall events since water must run off of any hardened surface. In natural areas, or areas with limited imperviousness, many summer rainfall events create no runoff and little stream response, as more rainfall is infiltrated into the soil.

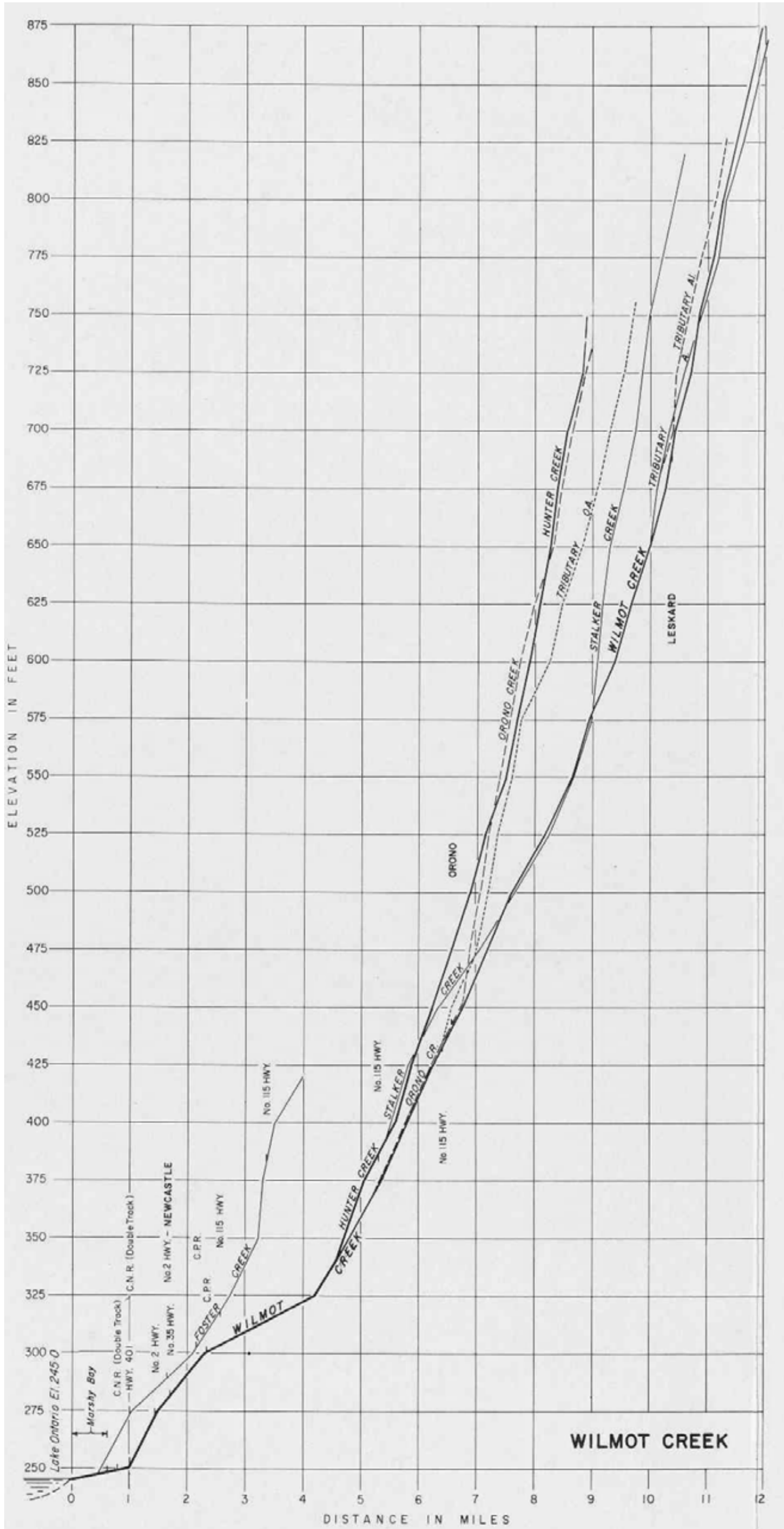


Figure 3.38: Historical cross-section of Wilmot Creek

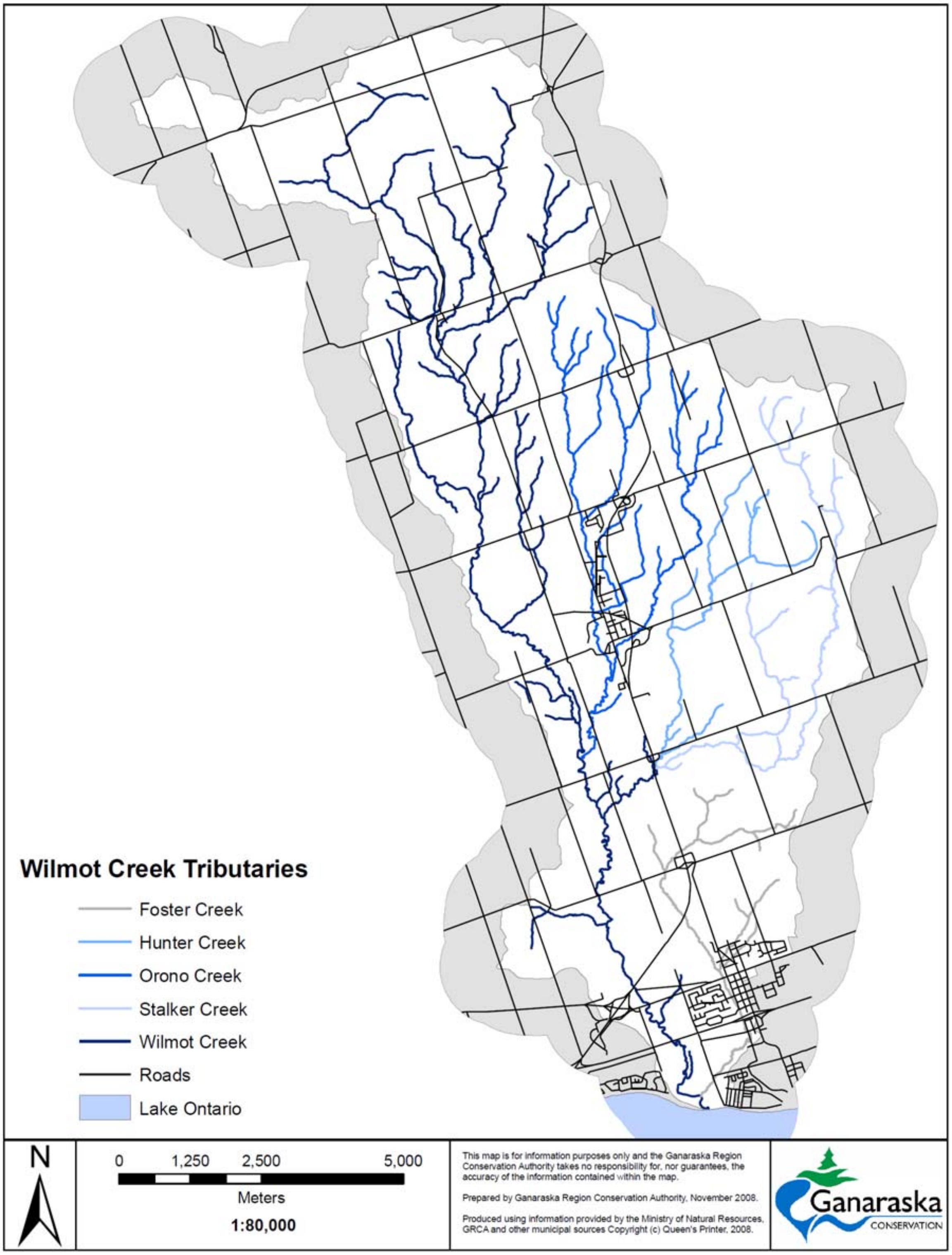


Figure 3.39: Wilmot Creek tributaries

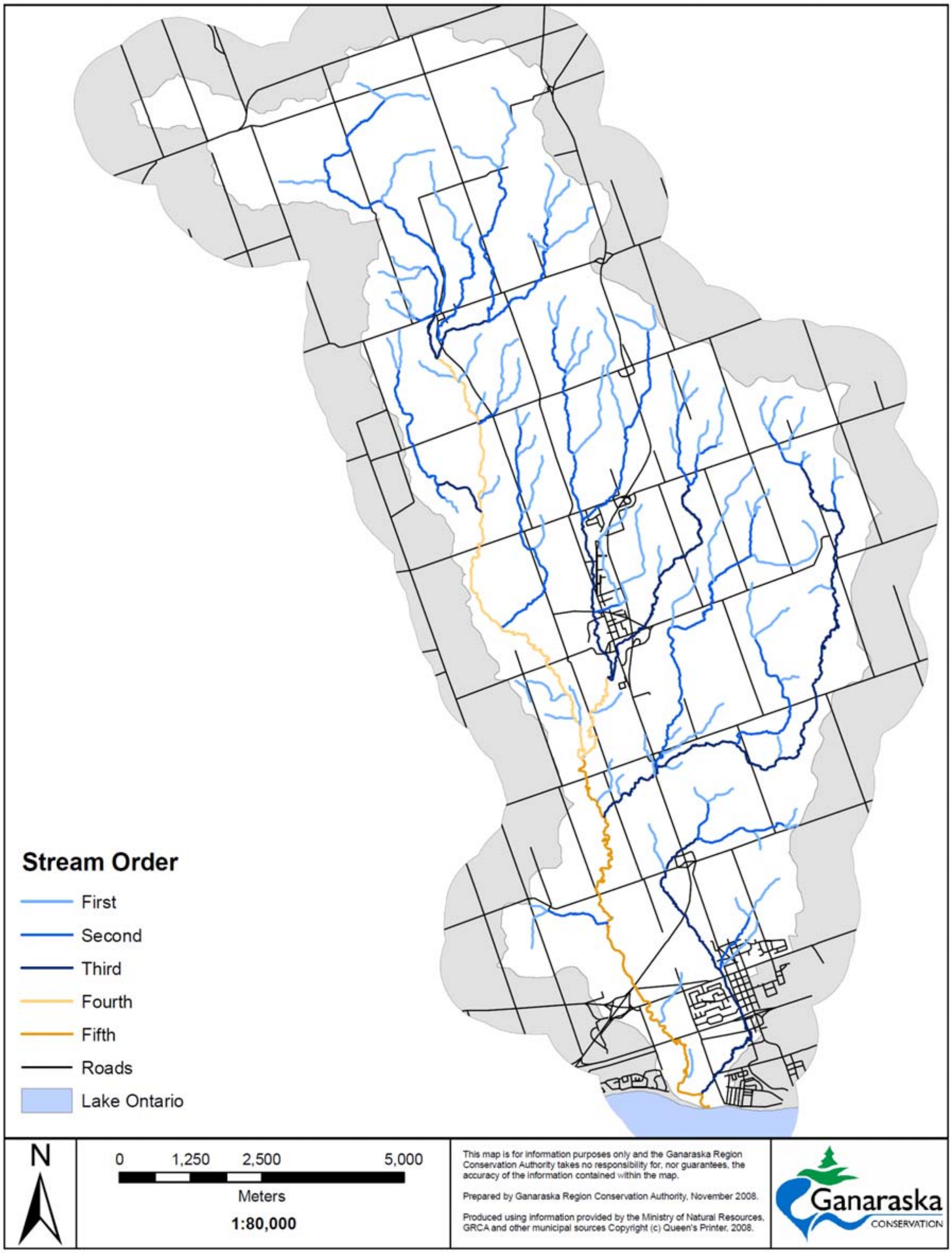


Figure 3.40: Stream order

3.4.2 Dams and Instream Barriers

Instream barriers can include natural barriers, and manmade water control structures including culverts, weirs and dams that are obstructions to fish migration. These obstructions can sometimes separate upstream fish communities from those downstream, in some cases providing protection from competition. In addition to obstructing fish, these barriers impede the natural passage of wood and sediment, and they can have an impact on water quality and fish habitat.

There are relatively few remaining human-built barriers in the Wilmot Creek watershed. At this time there are three known barriers (Figure 3.41). These include the Orono Mill Pond Dam in Orono Creek, which is a barrier to all fish, and partial barriers (perched culverts, barriers to non-jumping fish) at the CPR crossing on the mainstem of Wilmot Creek below Concession 3 and at the Highway 35/115 crossing on the east branch of Orono Creek.

The largest dam and pond in Wilmot Creek is the Orono Mill Pond Dam. Historically the mill pond and dam were used to run a grist mil and later the pond served as an irrigation reservoir for the Provincial tree nursery (Garner Lee Limited 2001). Today, the pond provides recreational benefits and a glimpse into the past. The Orono Mill Pond Dam consists of an earthen embankment and a concrete control structure. Stop logs regulate the flow of water through the dam.

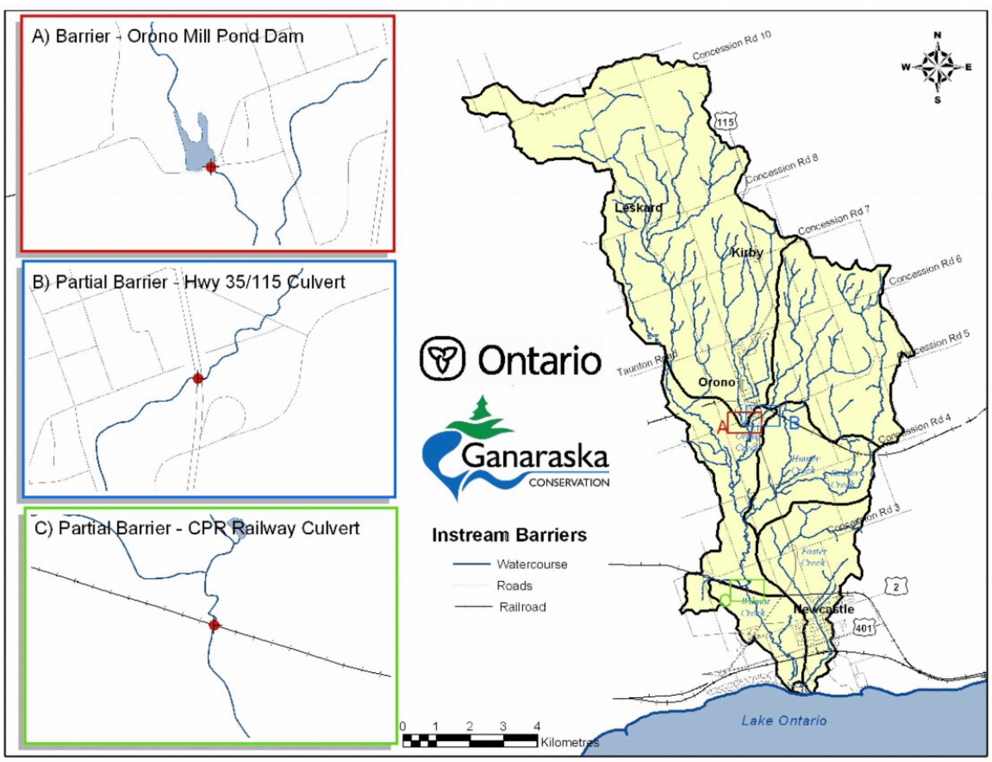


Figure 3.41: Dams and instream barriers

3.4.3 Stream Gauge Stations

Since 1965 flow data has been collected in the Wilmot Creek watershed. Table 3.6 describes the historic and current gauge stations. There are two operational gauge stations, located on the main branch of Wilmot Creek at Concession Road 3 (02HD009) and Concession Road 7 (02HD021) (Figure 3.42).

There are four seasonal gauging stations in Wilmot Creek. Flow data from these gauges has been collected since 2004 and analyzed to fulfill the surface water monitoring component specified in the Regional Municipality of Durham's Permit to Take Water for the Community of Orono municipal wells. Table 3.7 provides information about these gauging stations. The catchment and study area for these gauges is located between Taunton Road and Concession Road 5, west of Orono.

Table 3.6: Gauge stations in the Wilmot Creek watershed

Station	Location	Record Year	Status
02HD009	Concession Road 3	1965 to present	In Operation
02HD021	Concession Road 7	August 2005 to present	In Operation
GRCA Gauge	Foster Creek (Telephone Rd)	2000 to 2004	Discontinued

Table 3.7: Active seasonal stream gauging stations

Watershed	Gauging Station	Location
Wilmot Creek	Wilmot 1	Downstream of Taunton Road upstream of the Vissers Sod Farm water taking.
Wilmot Creek	Wilmot 2	Upstream of the wellfields zone of influence and downstream of the Rail Track that extends west of Station Street.
Wilmot Creek	Durham 1	Within the wellfields zone of influence upstream of Concession 5.
Wilmot Creek	Wilmot 4	Outside the wellfields zone of influence, downstream of Concession 5

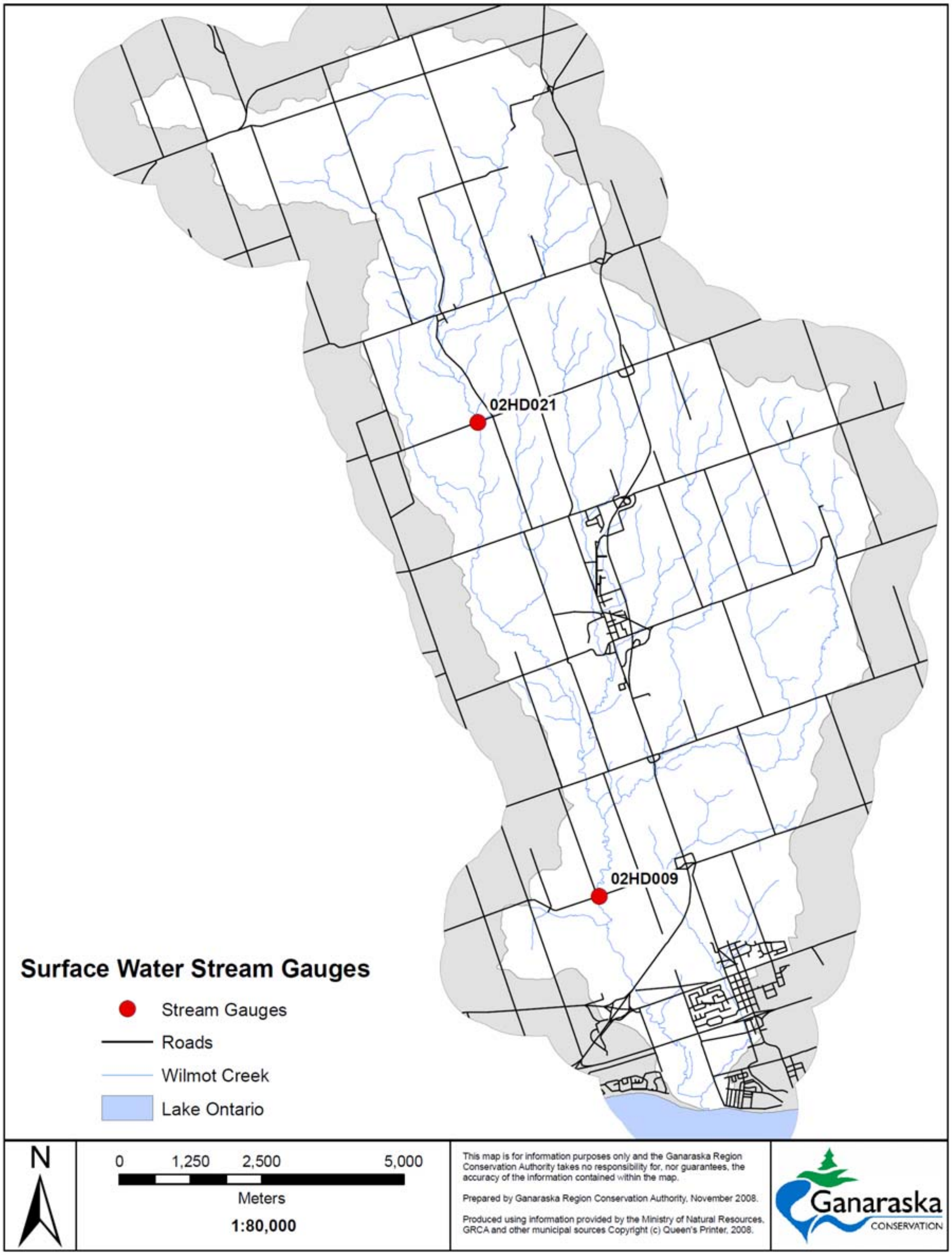


Figure 3.42: Stream gauges

Station 02HD009 at Concession Road 3 can provide a glimpse at water flows in Wilmot Creek. It should be noted that gauge data presented has not undergone quality control and quality assessment by Environment Canada. Therefore, the data does contain inaccurate flow measurements that may relate to ice build-up or other flow-controlling factors.

Figure 3.43 shows that monthly flows in Wilmot Creek are highest in March and lowest in August. This reflects the increased flows associated with snowmelt runoff in the spring and baseflow conditions in the summer. Mean monthly flows indicate the normal expected flow in Wilmot Creek for each month, as measured at the Concession Road 3 gauge station. The mean values can be used to judge the differences in monthly flows between years. The maximum and minimum flows represent the possible range of monthly flows within Wilmot Creek.

Differences between years can also be observed at the Concession Road 3 gauge station. In 2007 higher flows in Wilmot Creek were observed in the winter compared to the mean monthly flows, with a summer flow below normal levels (Figure 3.43). The increase in winter flows can be attributed to increased surface runoff during winter thaws and below normal flows can be attributed to a very dry summer.

Flows in Wilmot Creek in 2008 were lower in the winter with higher flows in the summer and fall (Figure 3.43). This difference in monthly flows in Wilmot Creek can be attributed to a significant amount of precipitation in the summer. The difference in flow between 2007 and 2008 can also be seen through the annual mean flow. In 2007 the mean annual flow was 1.03 cubic metres per second (m^3/s) compared to 1.36 m^3/s in 2008.

Flow data is also available from the Concession Road 7 gauge station that can be used in comparing flows at different locations in the watershed. Limited data exists at this site to analyze mean monthly flows between years. Figure 3.44 indicates that mean monthly flows are lower at Concession Road 7 than Concession Road 3, which is a result of a smaller drainage area contributing to flows at the Concession Road 7.

The gauge stations in Wilmot Creek primarily assist in flood forecasting and warning for residents of the Wilmot Creek watershed. However, these stations can aid in the understanding of flows as they relate to other watershed functions (e.g., baseflow and surface runoff contributions).

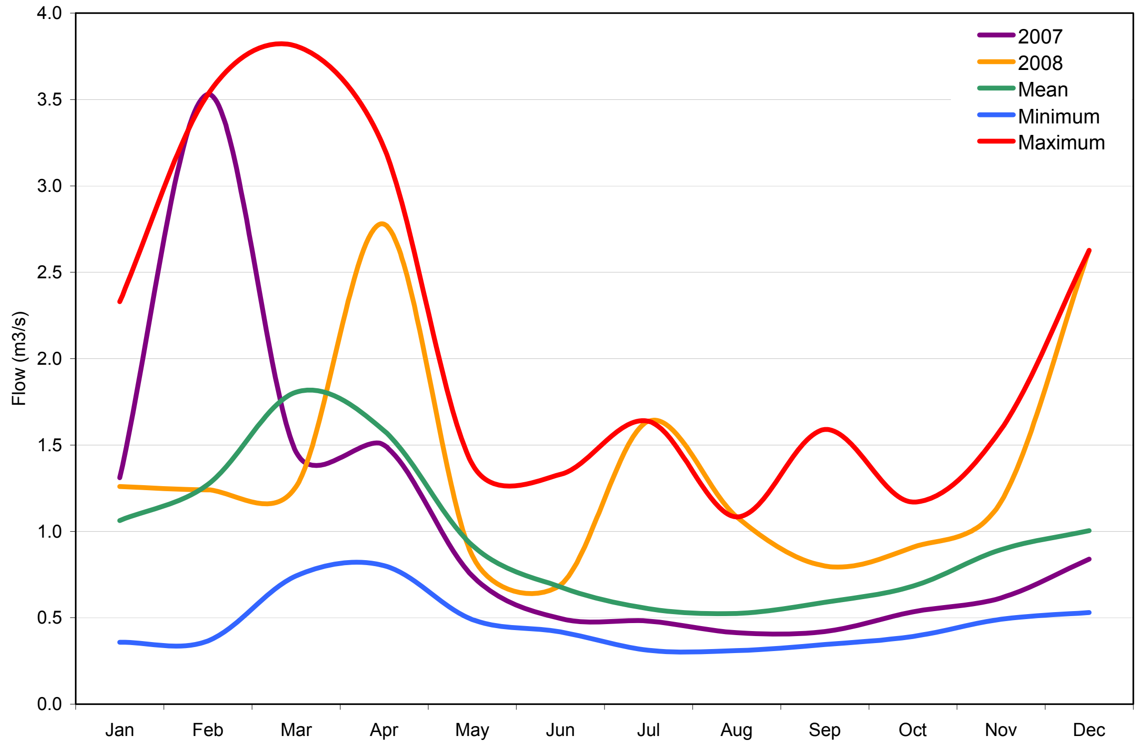


Figure 3.43: Wilmot Creek flows at the Concession Road 3 gauge station

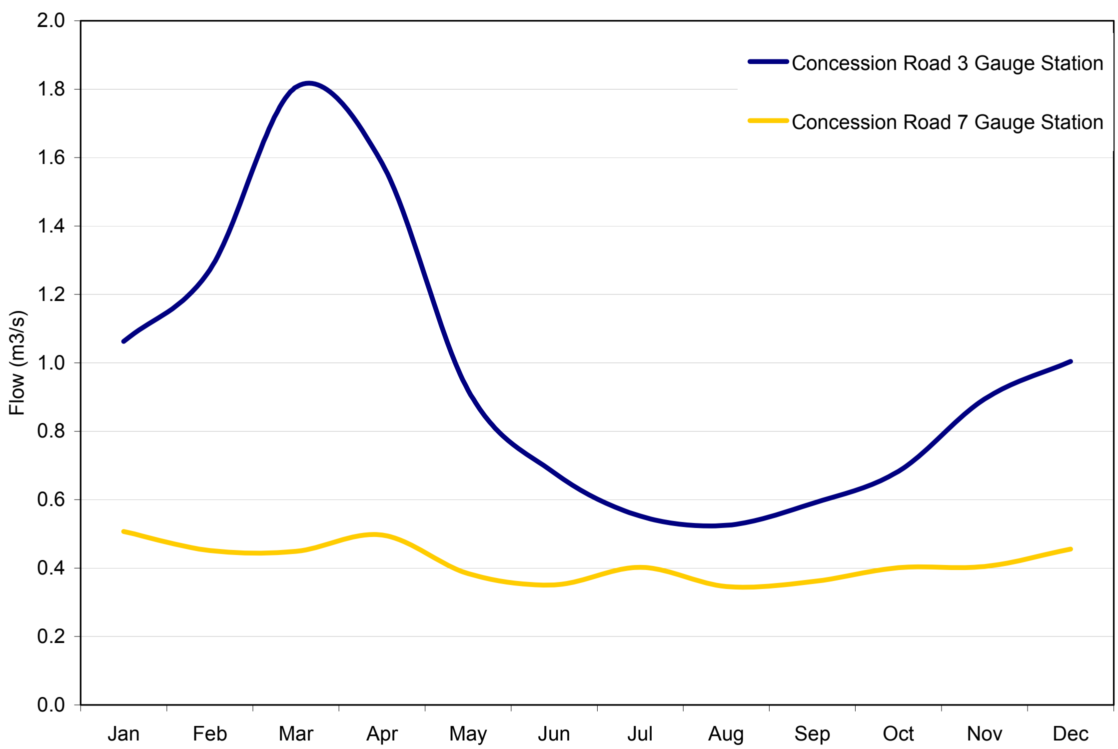


Figure 3.44: Mean monthly flows at Wilmot Creek gauge stations

3.4.4 Ontario Low Water Response

The Ontario Low Water Response (formerly Ontario Water Response) program was developed in 1999/2000 to prepare and coordinate a provincial response plan in the event of a drought. The program recognizes that water management must be approached at both the provincial and local levels. The provincial role is to provide overall direction through policies and guidelines, central information storage and analysis, and emergency support (Ganaraska Region Conservation Authority 2007b). At the local level, monitoring of water levels, information collection and program delivery can be accomplished.

As part of this program, and in response to low water conditions, a Ganaraska Region Water Response Team has been established to assist with implementing the response. Members include local municipalities, the Ontario Ministry of Natural Resources, the Ontario Ministry of the Environment, the Ontario Ministry of Agriculture, Food and Rural Affairs, and the Department of Fisheries and Oceans.

The indicators to the Ontario Low Water Response program are the amount of precipitation and streamflow conditions. Different threshold levels for precipitation and streamflow are used to categorize the level of low water conditions (Table 3.8). Methods used to determine threshold levels are defined in Ganaraska Region Conservation Authority (2007b).

Table 3.8: Summary of threshold levels for low water response

Condition	Precipitation		Stream Flow
Level 1	3 or 18 month Precipitation < 80%	or	Spring: - < 100% of lowest monthly average flows Other months: - < 70% lowest monthly average flows
Level 2	1,3, or 18 month Precipitation < 60% or 3 weeks of < 7.6 mm per week	or	Spring: - < 70% of lowest monthly average flows Other months: - < 50% lowest monthly average flows
Level 3	1,3 or 18 month precipitation < 40%	or	Spring: - < 50% of lowest monthly average flows Other months: - < 30% lowest monthly average flows

(Ganaraska Region Conservation Authority 2007b)

Once a low water condition has been identified, an appropriate response is carried out. The following, as defined in Ganaraska Region Conservation Authority (2007b), are the responses that will take place in relation to each condition.

- Level 1 Response: Communication will occur between the Water Response Team and the Ministry of Natural Resources. Each Water Response Team member is responsible for communicating water conservation messages within their sector. The message will consist of a media release, which will focus on current watershed conditions and promote a 10% voluntary water use reduction.

- Level 2 Response: When a watershed moves from Level 1 to Level 2 conditions, notification is given to members of the Water Response Team and the Ministry of Natural Resources. Each member is responsible for communicating water conservation messages within their sector with the target of a further 10% water use reduction. Municipalities may consider restrictions on non-essential use as appropriate. The provincial agencies on the Water Response Team will contact the Ontario Water Directors' Committee Low Water Committee Coordinator. The Coordinator will activate the Low Water Committee to reinforce cross-ministry program support. The Coordinator will also notify the Provincial Emergency Response Coordinator and request regular briefings with Emergency Measures Ontario.

- Level 3 Response: When a watershed moves from Level 2 to Level 3 conditions, notification is given to members of the Water Response Team and the Ministry of Natural Resources. The Ontario Water Directors' Committee Low Water Committee is responsible for declaring a Level 3 condition. At the Level 3 condition water restrictions may be necessary and will be implemented through the appropriate government agency.

Since the Ontario Low Water Response program was initiated in 2000, the Wilmot Creek watershed has experienced a Level 1 low water condition in 2005 and 2007. Therefore, a voluntary reduction in water use by 10% was encouraged.

3.5 Surface Water Analysis

Analyzing surface water can be done from a flow and a use perspective. Understanding the quantity and flow characteristics allows for protection of surface water, people and property. The following sections discuss hydrology, hydraulics, floodplains and water budgeting in the Wilmot Creek watershed.

3.5.1 Wilmot Creek Hydrology

Hydrology determines the amount of flow generated by a particular storm. The storm examined is defined in terms of the worst event that would statistically happen in a certain number of years. Computer models are used to determine flows and do so by examining rainfall, land area and cover, infiltration, and evaporation to determine the runoff associated with a rainfall.

3.5.2 Hydraulics Analysis

Hydraulics models take runoff results from the hydrology models and convey them down the river system estimating the extent of the area flooded by (or needed to carry) the flow. Simply put, hydrology calculates how much of the water will become runoff, and hydraulics calculates how high the river will rise.

In the Wilmot Creek watershed many settlement areas were built around water courses that provided power and transportation. Analysis is required to scientifically define floodplains for both the protection of existing land uses and the prevention of introducing new uses into hazardous areas.

Flood Flows

As stated in the *Technical Guide - River and Stream Systems: Flooding Hazard Limit* (Ontario Ministry of Natural Resources 2002), "*The group of flood standards referred to in the Natural Hazard Policy is the basis by which floodplains are delineated. It is designed to accomplish the main objectives of floodplain management: to prevent loss of life and to minimize property damage and social disruption*." There are three types of flood events used in defining the flood standard in Ontario: synthetic storms developed from the two large historical events (Hurricane Hazel and the Timmins storm), observed and documented historical events (if larger than the 100-year event), and statistically derived 100-year events. The magnitude of the flood which defines the floodplain limits in a particular area of the province is largely dependent upon the susceptibility of that area to tropical or thunderstorms, rainfall, snowfall or a combination of these meteorological events (Ontario Ministry of Natural Resources 2002).

The Wilmot Creek watershed lies within Zone 1, as defined in technical guidelines, and as such the Regulatory Flood is defined by the greater of:

- The flood level corresponding to the peak flow generated by the Regional Storm (Hurricane Hazel)
- An observed and well-documented flood level
- The 100-year flood level.

All watersheds in the Ganaraska Region Conservation Authority have their Regulatory Flood defined using a Hurricane Hazel-based event.

Wilmot Creek Hydrologic Model

This section has been summarized from Ganaraska Region Conservation Authority (2008b).

The Ganaraska Region Conservation Authority updated hydrologic model was developed based on Greenland International Consulting Limited (2003) using available GIS data and modeling programs. The model was calibrated using five summer events and verified by two other events from the period of 2000 to 2008. Four types of design storms (AES 12 hr, SCS 12 hr, SCS 24 hr and Chicago 12 hr) were applied on the calibrated model for the existing land use scenario. The Chicago storm was found to be the critical storm event that caused the highest runoff.

The simulated results were compared with previous studies (M.M. Dillon Limited 1977 and Greenland International Consulting Limited 2003). The Ganaraska Region Conservation Authority results were significantly higher (7 to 106%) than Greenland International Consulting Limited (2003). Compared to M.M. Dillon Limited (1977), the simulated regional flows (Hurricane Hazel) are about 20% lower before the Foster Creek confluence and 10% higher at the outlet. All the discrepancies from previous studies can be explained. Frequency analyses on the maximum instantaneous flows and maximum daily flows at Wilmot Creek Concession Road 3 gauge station (02HD009) and regional analyses (index flood method) were conducted as secondary checks. The 15% higher flows were estimated from frequency analyses, compared to the Ganaraska Region Conservation Authority model. This difference is reasonable because the annual maximum daily/instantaneous flows may be caused by snowmelt event over frozen ground in spring in some years whereas the OTTHYMO model considers peak flows resulting from rainfall events only.

Peak flows for future land use scenarios were further estimated by applying the calibrated model on the future land use which was extracted from the Municipality of Clarington Official Plan. The storm water management pond “H” currently under construction in a Foster Creek subdivision was considered in the model of 2 to 100 year return period future scenario. The simulated flow rates for both 2 to 100 year return period flows increase slightly, while the regional flow decrease slightly at the outlet for future land use situation. The peak flows for different return periods and regional flows at the key nodes (Figure 3.45) of interest for both existing scenario and future land use scenario are summarized in Tables 3.9 and 3.10.

The results of the new hydrologic model for Wilmot Creek are the best estimate of flow and therefore should be input into a hydraulic model to establish new regulatory floodlines for the Municipality of Clarington. It is recommended that the calibrated peak flow rates for the 100-year Chicago 12 hour storm, as well as the calibrated peak flow rates from Hurricane Hazel, be used as input the Wilmot Creek floodplain mapping. It is also recommended that the existing development scenario be used as input to the hydraulic model as this model produces greater regional peaks than the peak flows.

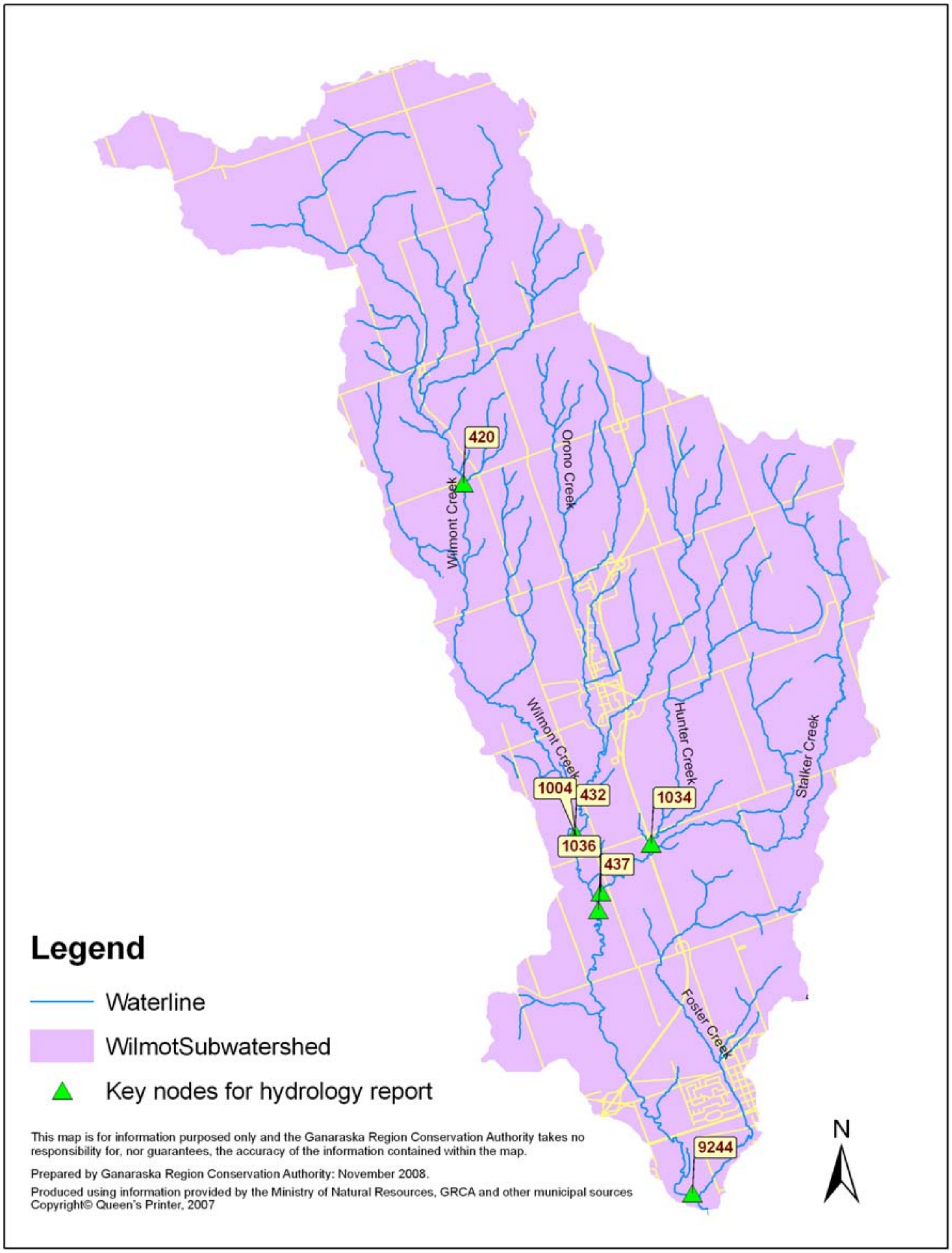


Figure 3.45: Wilmot Creek watershed hydrologic model key nodes

Table 3.9: Peak flows at key nodes modeled using existing land use

Key Nodes	NHYD in VO2 Model	Drainage Area (km^2)	Peak flows for return period 2 to 100 year (m^3/s) by Chicago 12hr						Regional Flows (m^3/s)
			2	5	10	25	50	100	
Wilmot Creek upper reach	420	26.8	3.1	5.8	7.7	10.8	13.2	15.9	116.5
Orono Creek	1004	18.0	6.5	11.5	15.0	20.5	24.6	29.2	125.0
Orono Creek confluence	432	57.2	9.4	16.7	21.8	29.9	36.0	42.8	241.0
Hunter Creek	1034	7.1	1.6	3.0	4.1	5.7	6.9	8.3	44.6
Stalker Creek confluence	1036	20.7	3.9	7.1	9.4	13.2	16.0	19.2	108.4
Wilmot Creek main branch and Stalker confluence	437	78.8	13.3	23.9	31.3	43.4	52.4	62.6	351.0
Upstream of Foster Creek confluence	9244	88	11.4	20.6	27.3	39.3	49.7	61.9	358.8
Outlet	9298	97.9	12.1	21.7	28.8	41.8	52.9	66.0	386.7

Table 3.10: Peak flows at key nodes modeled using future land use

	NHYD in VO2 Model	Drainage Area (km^2)	Peak flows for return period 2 to 100yr (m^3/s) by Chicago 12hr						Regional Flows (m^3/s)
			2	5	10	25	50	100	
Wilmot Creek upper reach	420	26.8	3.2	5.8	7.7	10.8	13.2	15.9	116.5
Orono Creek	1004	18.0	6.6	11.7	15.2	20.8	25.0	29.7	125.3
Orono Creek confluence	432	57.2	9.5	16.9	22.0	30.2	36.3	43.0	241.2
Hunter Creek	1034	7.1	1.6	3.0	4.1	5.7	6.9	8.3	44.6
Stalker Creek confluence	1036	20.7	3.9	7.1	9.4	13.2	16.0	19.2	108.4
Wilmot Creek main branch and Stalker confluence	437	78.8	13.5	24.0	31.5	43.6	52.7	63.0	351.2
Upstream of Foster Creek confluence	9244	87.91	11.2	20.2	26.7	38.6	48.8	60.7	350.5
Outlet	9298	97.9	12.1	21.9	29.0	42.1	53.2	66.2	372.7

3.5.3 Natural Hazards

Natural Hazard Limits are boundary lines that delineate areas where there is a concern for public health and safety associated with natural hazards. Generally these hazards are a result of flooding, erosion or instable organic soils. The Province of Ontario has developed criteria for defining these Natural Hazard Limits (Ontario Ministry of Natural Resources 2002), which are implemented both through the *Provincial Policy Statement* (2005) and *Ontario Regulation 97/04*. Criteria are also outlined in the *Development, Interference with Wetlands, and Alterations to Shorelines and Watercourses Regulation*, implemented by Conservation Authorities throughout the province. These regulations are empowered by Section 28 of the *Conservation Authorities Act*, and the Ganaraska Region Conservation Authority administers *Ontario Regulation 168/06*, in the Wilmot Creek watershed.

The Ganaraska Region Conservation Authority has developed hazard limits for the riverine, coastal and wetland systems (organic soils), for the purpose of provincial policy and regulations implementation. These limits have been used to create a single mapping product for all hazard areas in the watershed (Figure 3.46). Lake Ontario hazards, which are also delineated, are not being addressed in this background report.

General Objectives of Hazard Lines

The general objective of hazard mapping is to develop background information that will satisfy data requirements of the municipal zoning by-laws and the natural hazards component of the *Provincial Policy Statement*. The Ganaraska Region Conservation Authority has established objectives which form the basis of the decision-making process associated with regulation implementation. These objectives include an Authority program designed to "*prevent loss of life and/or property damage resulting from flooding and/or erosion on lands subject to the Regulation by minimizing hazardous and unnecessary development of lands within Regulatory floodplains*" (Ganaraska Region Conservation Authority 2005). Other objectives include the following.

- To promote the conservation and wise use of watercourses and their associated valleylands
- To require mitigating measures to be undertaken for work within regulated areas, which singly or cumulatively may cause an increase in flooding or erosion, or a decrease in the environmental quality of the stream and its associated valleylands
- To reduce the necessity for public and private expenditures for emergency operations, evacuation and restoration of properties subject to flooding
- To regulate uses of floodplains and any development within them that in future years may require emergency operations and expensive protective measures
- To regulate development on or adjacent to potential dangerous slopes
- To reduce soil erosion from valley slopes

- To regulate the draining or filling of wetlands which may reduce natural water storage capacity and protect provincially and/or locally significant wetlands
- To minimize water pollution associated with filling and construction activities. The Ganaraska Region Conservation Authority will liaise with other agencies regarding pollution matters and promote wise use of water resources to help improve water quality throughout the watershed
- To make information available regarding erosion prone areas to interested parties.

Provincial Policy Statement

The *Provincial Policy Statement, 2005* (PPS) defines development as *"new lot creation, a change in land use or construction which requires approval under the Planning Act"*" (Ontario Ministry of Municipal Affairs and Housing 2005). The PPS protects public health and safety through the land use planning process by directing development away from these hazardous areas, and only permitting development where hazards can be safely addressed. Section 3.0 of the PPS contains the natural hazard policies that form the basis for comments the Ganaraska Region Conservation Authority provides to municipalities on applications circulated in the Wilmot Creek watershed.

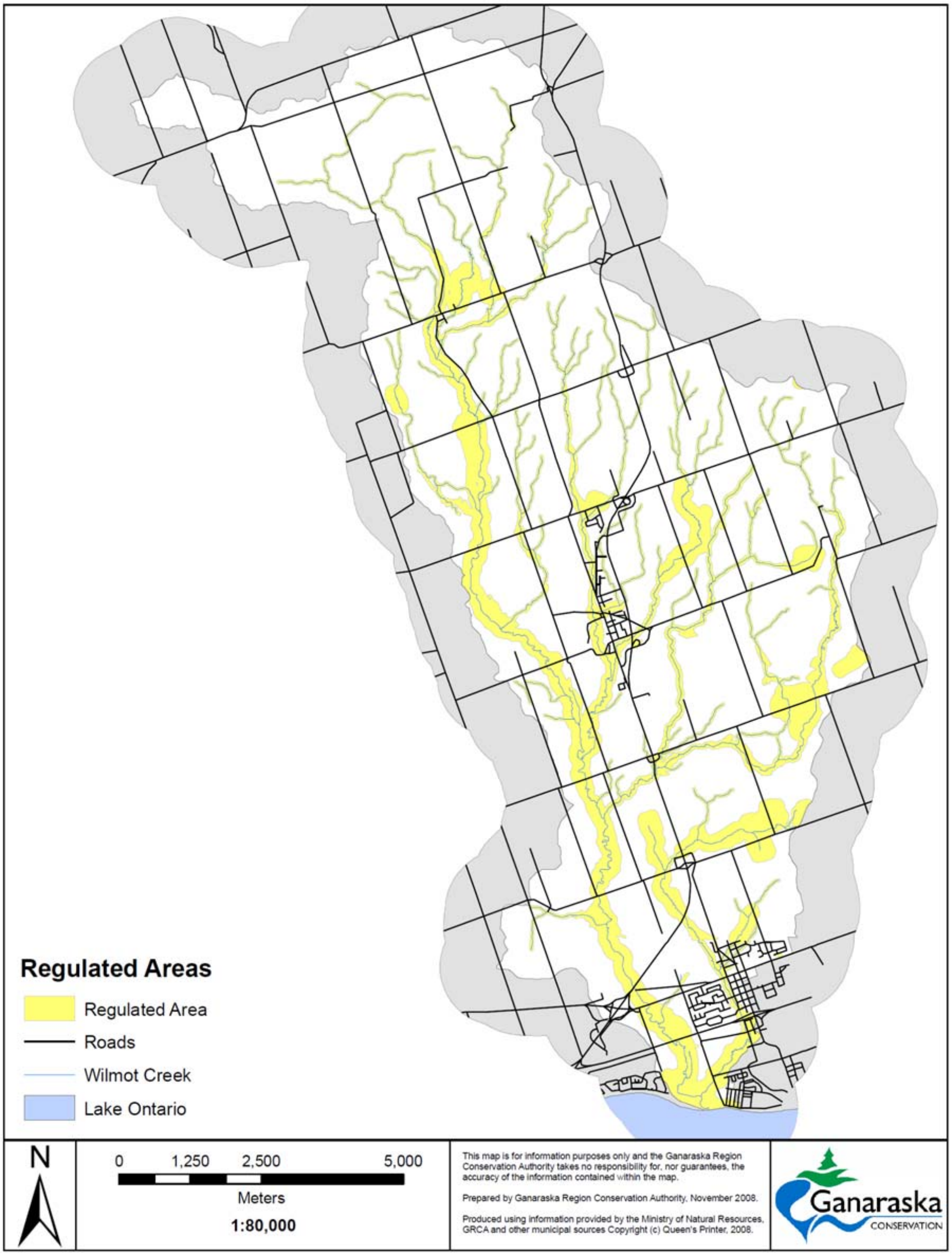


Figure 3.46: Regulated areas

Hazard Types and Limits

Riverine Hazards

Riverine hazards result from the proximity of a structure to a river, creek or stream. Natural hazards relating to riverine systems may include flooding, stream erosion, slope instability, and the shifting tendencies of meandering riverine systems. Riverine hazard limits address these hazards. To account for the variation present in the shape of riverine systems, two basic categories have been developed to facilitate the determination of the erosion-related components of the natural hazard limit: confined and unconfined riverine systems. The following sections outline the methods that have been developed to set the boundaries within which development is susceptible to hazards.

Flooding Hazard Limit

The Flooding Hazard Limit, or Regulatory Floodline, is generally based on the greater of the Hurricane Hazel storm event (the Regional Storm) or the 100-year return period storm. Floodlines for the Regional Storm are calculated using precipitation data from Hurricane Hazel, which occurred in 1954, while the 100-year floodlines are based on a storm that statistically occurs once every one hundred years.

The Regulatory Floodline is determined through a computer simulation of the specified storm centred over the watershed in question. There are two types of computer models involved: (1) the hydrology model calculates how much water will flow into the river and (2) the hydraulic model calculates how high the water will rise in the river. These models take into account watershed features including soils (type and degree of saturation), vegetation, grades, and existing land uses, and defines the water surface elevations that will be produced by the storm. Figures 3.47 and 3.48 display the application of this model in delineating the Regulatory Floodline.

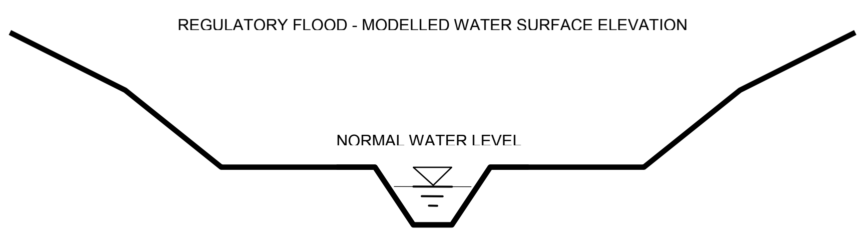


Figure 3.47: Watercourse cross-section with a Regulatory Floodline

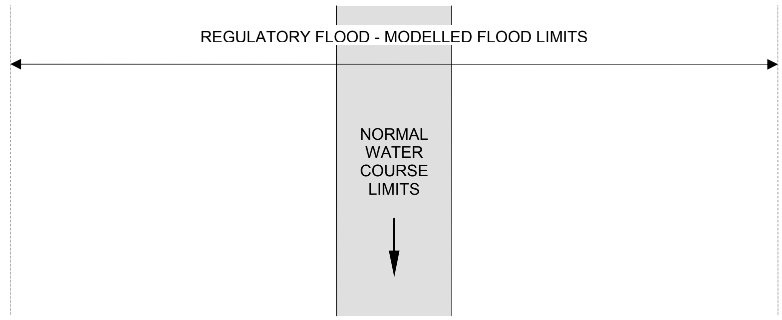


Figure 3.48: Plan view of a watercourse with a Regulatory Floodline

Erosion Hazard Limit - Confined Systems

The Erosion Hazard Limit for a confined system consists of the Toe Erosion Allowance, the Stable Slope Allowance, and the Erosion Access Allowance. A confined system, for this purpose, is defined as a watercourse within a clearly visible valley that is impacting on the valley walls, and is shown in Figure 3.49.

Stream Erosion

Stream bank erosion is an important cause of valley slope instability, and is ultimately responsible for the presence of valleys. Stream erosion directly at the toe of a valley slope can steepen and undercut the slope, leading to the eventual failure of the bank. The Toe Erosion Allowance has been implemented to buffer development from the hazardous effects of toe erosion, and also to buffer the natural river processes from the influences of development. This allowance is based on a minimum distance of 15 metres between the edge of a river system and the toe of its confining valley wall. Figures 3.49 and 3.50 show the application of the Toe Erosion Allowance. On a reach to reach basis, a determination is made as to whether the stream impacts on the valley wall at any location. If so, the Toe Erosion Allowance is expanded to include all lands between the top of bank and the toe of slope (valley floor).

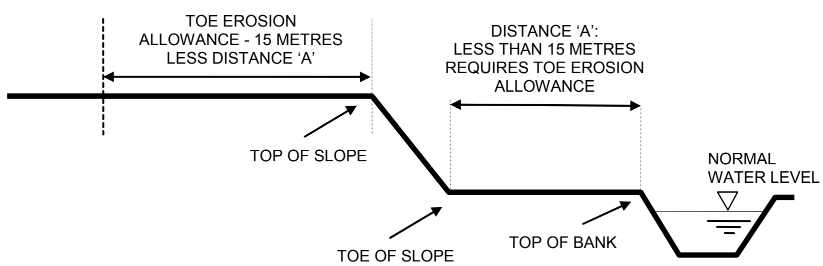


Figure 3.49: Watercourse cross-section with Toe Erosion Allowance

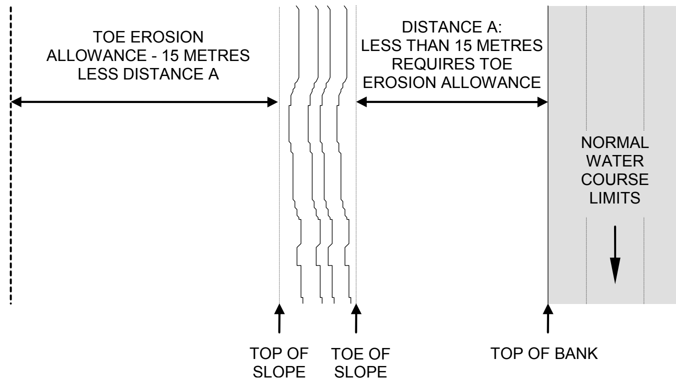


Figure 3.50: Plan view of watercourse with Toe Erosion Allowance

Slope Stability Allowance

Slopes are also naturally subjected to movement and failure. The Stable Slope Allowance has been implemented to buffer development from the hazards of slope instability, and also to prevent the influence of development on the rate of slope movement. This allowance is based on an assumed stable slope gradient of 3 horizontal units to 1 vertical unit (3:1). For slopes at steeper gradients, the allowance is equal to the distance between the actual valley top of slope and the point at which a slope at a 3:1 gradient, rising from the same toe position, would intersect the ground surface. Figure 3.51 shows the application of the Stable Slope Allowance.

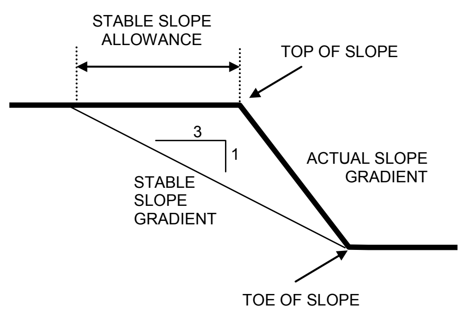


Figure 3.51: Stable Slope Allowance

Access Allowance

In addition to the above-mentioned Toe Erosion and Stable Slope Allowances, a minimum 5-metre Erosion Access Allowance is also applied to maintain sufficient access for emergencies, maintenance and construction activities. This allowance is analogous to a factor of safety, providing protection against unforeseen conditions that may adversely affect the natural processes of an erosion-prone area. Figure 3.52 shows a typical application of the Erosion Access Allowance in conjunction with the Toe Erosion and Stable Slope Allowances. The Erosion Hazard Limit for a confined system is comprised of these three allowances (Erosion Access, Toe Erosion and Stable Slope).

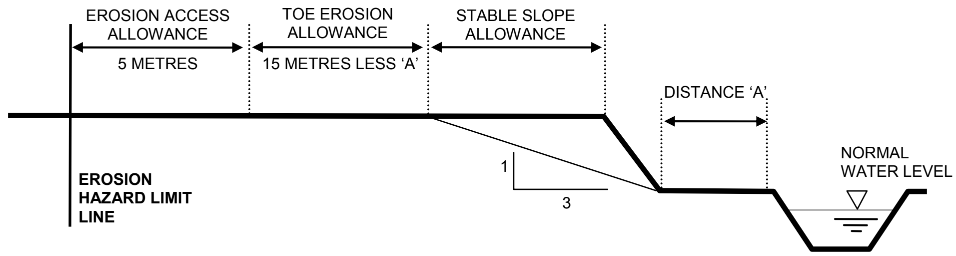


Figure 3.52: Erosion Hazard Limit (for a confined system)

Erosion Hazard Limit - Unconfined Systems

The Erosion Hazard Limit for unconfined systems consists of the Meander Belt Allowance and the Erosion Access Allowance. Unconfined systems occur where a watercourse is not contained within a clearly visible valley section. If the stream sits in a large valley section but does not impact on the valley wall, the stream is considered unconfined.

Meander Belt

In unconfined systems, the watercourse is not contained within a visible valley, rather the flow of water is free to shift across the land. As a result, the watercourse of an unconfined system does not impact on the valley walls. Meandering tendencies of the watercourse, areas of confluence and areas of geographical change must be thoroughly examined to accurately designate representative reaches along the watercourse. For this purpose, a reach is defined as areas of similar topography along the watercourse, and regions between confluences.

The Meander Belt Allowance provides a limit to development in the areas where the river system is likely to shift. This allowance is based on 20 times the bankfull channel width, where the bankfull channel width is measured at the widest riffle section of the reach. A riffle is a section of shallow rapids where the water surface is broken by small waves. Measurements of the bankfull width have been determined for each reach, or groups of reaches, by observing existing aerial photographs, maps and field data. Where on-line ponds are located in unconfined systems, the meander belt width is increased by the width of the open water in the pond.

Erosion Hazard

The Erosion Hazard Limit for an unconfined system is comprised of the Meander Belt Allowance and the 6-metre Erosion Access Allowance. Figure 3.53 shows a typical application of the Meander Belt Allowance and the Erosion Access Allowance to define the Erosion Hazard Limit.

Access Allowance

As with confined systems, the 5-metre Erosion Access Allowance is also applied in unconfined systems to maintain sufficient access for emergencies, maintenance and construction activities. This allowance is shown in conjunction with the Meander Belt Allowance in Figure 3.53.

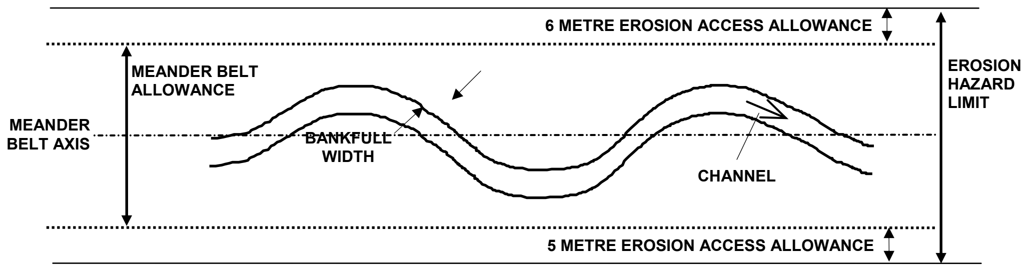


Figure 3.53: Erosion Hazard Limit (for an unconfined system)

Natural Hazard Limit - Riverine Hazards

The Toe Erosion Allowance, Stable Slope Allowance, Erosion Access Allowance and Meander Belt Allowance (where applicable) are applied in combination to every riverine system in the Wilmot Creek watershed. The result of these allowances is the final Erosion Hazard Limit. The Flooding and Erosion Hazard Limits are drawn out for each riverine system, and the furthest landward limit of these two lines is taken to be the Natural Hazard Limit.

Wetland Natural Hazards

Wetlands are defined in the *Provincial Policy Statement* as follows.

> *Lands that are seasonally or permanently flooded by shallow water, as well as lands where the watertable is close to or at the surface. In either case the presence of abundant water has caused the formation of hydric soils and has favoured the dominance of either hydrophytic plants or water tolerant plants. The four major types of wetlands are swamps, marshes, bogs, and fens.* (Ontario Ministry of Municipal Affairs and Housing 2005).

Section 28 under the *Conservation Authorities Act* acknowledges the same wetland definition as the *Provincial Policy Statement*.

Wetlands are included as a natural hazard because they exhibit two hazards: flooding and instability due to organic soils. To satisfy requirements of both the Natural Hazard Policy and the Generic Regulation, provincially significant wetlands and unevaluated wetlands (identified through the Ecological Land Classification) are defined as part of the wetland natural hazards.

In order to map wetlands for natural hazard purposes, provincially significant wetlands, wetland complexes, and locally significant wetlands were mapped.

Once the wetland boundary was determined, the wetland was classified as either provincially significant or locally significant. For provincially significant wetlands a buffer of 120 m was added to the wetland to define the Natural Hazard Limit. Locally or regionally significant wetlands were mapped and a 30 m buffer was added to define the Natural Hazard Limit.

3.5.4 Water Budget and Stress Assessment

The following section was modified from the Tier 1 water budget process, prepared for the Drinking Water Source Protection program. Please refer to (Ganaraska Region Conservation Authority (2008) for further detail.

A water budget is a scientific, computer-based tool used to define a watershed's hydrologic system. Results of a water budget provide understanding of how water flows onto and on the surface, and through and below the ground. Water budgets will expand beyond the quantification of components in the water balance equation (precipitation, evapotranspiration, groundwater and surface water flow) to include water use. Water budget analyses are undertaken in a watershed to quantify water entering and leaving the watershed, and to characterize the contribution of each component to the overall hydrologic system.

Stress analysis identifies the functional relationships among water budget components and produces a foundation that can be used to evaluate future watershed stresses. Stresses (e.g., development activities, water taking or climate change) in a watershed can modify the relative contribution and characteristics of the components of the hydrologic system, and alter the overall water budget. This may threaten the health of ecosystems that have become established under the current hydrologic cycle. Stresses that result in increased peak flows or significant reduction in groundwater discharge that sustains a river baseflow, are examples of how an altered hydrologic cycle can threaten the health of ecosystems. A water budget analysis can be carried out to predict the effect of newly induced stresses on components of the hydrologic cycle such as peak flows, and groundwater recharge and discharge.

Water Budget Equations and Components

A water budget is an estimation or account of the various hydrologic cycle processes for a given study area and it consists of inputs, outputs and changes in storage. The inputs are precipitation, groundwater or surface water inflows, and anthropogenic inputs such as waste effluent. Outputs are evapotranspiration, water supply removals or abstractions, surface or groundwater outflows, as well as any changes in storage in the area of interest. The inputs must equal the outputs if the system is to remain in equilibrium. The individual inputs and outputs of a water budget can be expressed as follows.

Equation 1

$$P + SW_{in} + GW_{in} + ANTH_{in} = ET + SW_{out} + GW_{Out} + ANTH_{out} + \Delta S$$

Where:

P = precipitation
SWin = surface water flow in
GWin = groundwater flow in
ANTHin = anthropogenic or human inputs such as waste discharges
ET = evaporation and transpiration
SWout = surface water flow out
GWout = groundwater flow out
ANTHout = anthropogenic or human removals or abstractions
ΔS = change in storage (surface water, soil moisture, groundwater)

(Ontario Ministry of the Environment 2007)

For this study, the recent version of the model CANWET 3 was used to run the water budget. The current version gives an opportunity to use monthly curve numbers, evapotranspiration coefficient, recession coefficient and seepage coefficient. The seepage coefficient facilitates the discharge to and recharge from neighbouring watersheds. In addition, Geographic Information System (GIS) layers were used in the model (Table 3.11), and stream gauge 02HD009 within Wilmot Creek were used to calibrate the model.

Table 3.11: GIS layer sources used for surface water budget

Data Layer and Summary of Preparation
Physiographic Regions (MNR and YPDT-CAMC 2006) recession constant is 0.06, which was calculated from recession segments of hydrographs at gauge stations.
Soils (OMAFRA 2004) defined textures guided by Soils Layer Development for CANWET (Greenland, 2006). Assigned values of unsaturated water capacity according to CANWET User’s Guide.
Basins (Delineated by ArcHydro (V. 1.2) on the basis of DEM, V2 from MNR)
County (MNR 2002)
Streams (MNR 2002)
Weather (Environment Canada Website) selection of two stations on the basis of locations, correlation, data quality and fitness with corresponding stream flow data.
Elevation (MNR, Version 2)
Land use (GRCA ELC 2006) re-classified according to CANWET User’s Guide (Version 1.0). Revised to future land use layer based on *Municipality of Clarington Official Plan* (2007)
Tile Drainage analyzed and determined that recorded tiles are not significant in modeled watersheds.
Point source discharge to Lake Ontario, not necessary to be modeled.
Permit to Take Water (PTTW) (MOE 2007) consider consumptive factor (Aqua Resource Inc. 2004). Remove the permits of takings from Lake Ontario temporary extractions and permits expired before 2003.

Stress Assessment Methodology

A stress assessment looks at the amount of water in a watershed in relation to water uses. Through drinking water source protection, the province has developed stress rankings to determine if a watershed is stressed based on water supplies and water uses. In the Wilmot Creek watershed, the water supply estimation constitutes two components, surface water supply, which is the water available as stream flow, and groundwater supply which is the water available in the aquifers.

Surface Water Supply Study Approach

Five methods have been suggested through drinking water source protection (Ontario Ministry of the Environment 2007) to calculate monthly surface water supply.

1. Calibrated continuous surface model results: Q_{p50} (monthly median)
2. Stream flow monitoring from Hydroclimatological Data Retrieval Program (HYDAT): Q_{p50} (monthly median)
3. Stream flow monitoring (manual): monthly/bi-monthly measurements of baseflow
4. Prorated stream flow monitoring: prorated stream flow dataset from nearby gauge stations with similar physiographic and land use setting
5. Ontario Flow Assessment Technique (OFAT) 30_{Q2} estimated average annual baseflow.

This study follows approaches 1 and 2 to estimate the surface water supply for the Wilmot Creek watershed. Since Wilmot Creek is gauged, the CANWET model was calibrated at the Concession Road 3 gauge station. The Q_{p50} of the simulated stream flow is used to estimate surface water supply. Three scenarios were then run to estimate surface water supplies. These include the current (existing) scenario, the future scenario and a future scenario under climate change.

Current Scenario

The current scenario implies estimating surface water supply for the existing climate and the current land use scenario. The CANWET model was run using long-term climate data from 1976 to 1995 and the existing land use features. The simulated stream flow data for the 20-year period was then used to estimate Q_{p50} to determine the monthly surface water supply.

Future Scenario

The future scenario implies estimating surface water supply for the existing climate and the future land use scenario. The CANWET model was run using climate data from 1976 to 1995 and the land use scenario expected after 25 years. The 25-year future scenario assumes full build out of the Municipality of Clarington official plan designated lands (Figure 3.54). The Q_{p50} was then estimated from the 20-year simulated stream flow to predict the future monthly water supply.

Future Scenario with Climate Change

Climate is expected to change in the future with the increasing levels of greenhouse gases in the atmosphere. A number of groups around the world have been involved in predicting how much the change might be. To depict the climate change scenario, Global Climate Models (GCM) have been developed at different geographical locations. The Canadian Centre for Climate Modeling and Analysis under the umbrella of Environment Canada has also come up with a series of Canadian Global Climate Models (CGCM) for climate prediction, study of climate change and variability, and to better understand the various processes that govern our climate system.

The CGCM divides the globe into 3.75^{o} x 3.75^{o} grids and models climate data for each of these grids at a varied time series. For this study, CGCM2 IPCC SRES "A2" GHG was used and future climate data was generated for the years 2021 to 2040. The CANWET model was then run using future climate data and future land use features to simulate stream flow under this changed climate scenario.

The future climate generated by CGCM seemed to overpredict precipitation. The average annual precipitation for 20 years was 1276 mm, about 42% more than the average annual precipitation observed between 1976 and 1995. Therefore the CGCM model simulations need further investigation. However, for the present study the CGCM simulations were used to estimate water supply.

Further, the simplistic modeling approach used for water budget and stress assessment has been found limiting for handling groundwater flows under changed climatic conditions. This is due to some inherited limitations in the SCS-CN approach and single tank sub-surface structure of the CANWET model.

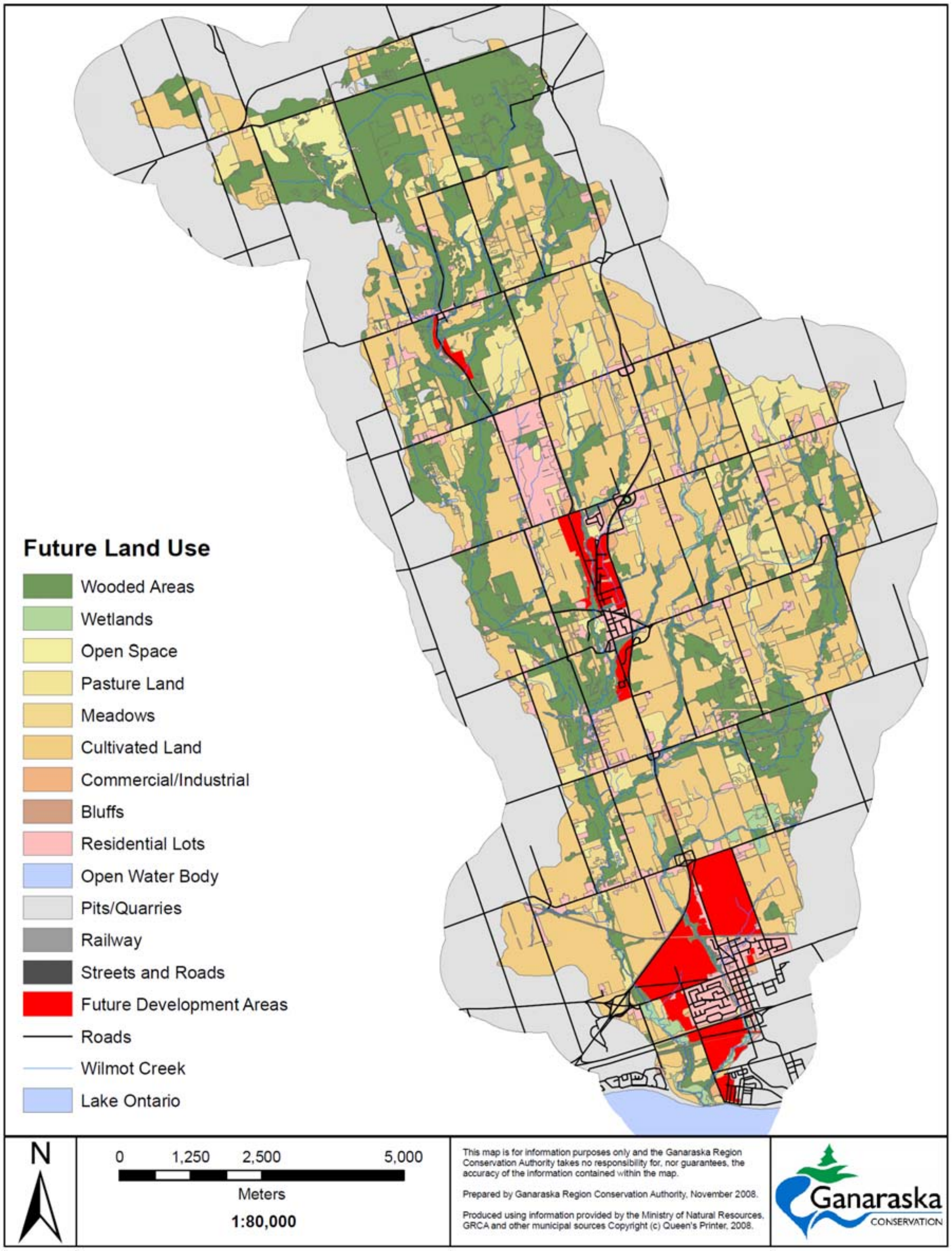


Figure 3.54: Future land use

Groundwater Supply Study Approach

As indicated through drinking water source protection guidance documents (Ontario Ministry of the Environment 2007), in the "analysis of groundwater supplies, aquifer storage is not considered and the watershed water supply terms are therefore assumed to be constant on an average annual basis. As such, recharge estimation methods applied should determine recharge estimates as the average annual rates."

Ontario Ministry of the Environment (2007) lists the following methods for estimating groundwater recharge.

- Baseflow separation/water balance
- Calibrated continuous surface water model or groundwater model
- Calibrated soil moisture balance
- Experience.

In this study, calibrated surface water model CANWET was used to estimate annual average groundwater recharge. The calibrated models were run for the 20-year simulation period (1976-1995) and estimated annual groundwater recharge was then averaged to predict groundwater supply.

The observed stream flow was also partitioned into baseflow and surface flow using two approaches: digital filter strip and base sliding interval. The base sliding interval technique was found more appropriate for the Wilmot Creek watershed. The baseflow separation results were compared with the model simulated results. The modeled groundwater recharge was slightly higher than estimated values using the baseflow separation technique, however it realistically represented the characteristics of the watershed under study and therefore was used. Three scenarios were then run to estimate groundwater supplies: the current (existing) scenario, the future scenario and a future scenario under climate change.

Current Scenario

The current scenario implies estimating groundwater recharge values using the existing climate data and current land use scenario. The CANWET model was run using long-term climate data from 1976 to 1995 and the existing land use features. The simulated annual groundwater recharge was then averaged to estimate the groundwater supply. According to the Ontario Ministry of the Environment (2007), the monthly groundwater supply is to be calculated simply by dividing the annual numbers by 12 months.

Future Scenario

The future scenario implies estimating groundwater supply using the existing climate data and the future land use scenario. The CANWET model was run using climate data from 1976 to 1995 and land use features expected after 25 years. The simulated annual groundwater recharge was then averaged to estimate the groundwater supply under future conditions.

Future Scenario with Climate Change
The groundwater supply for future land use scenario under climate change was estimated by running the CANWET model using land use features expected after 25 years and change in climate predicted for years 2021 to 2040 by the CGCM2 model. The simulated annual groundwater recharge was then averaged to estimate the annual groundwater supply under future conditions and changed climate. A monthly supply was estimated by dividing the annual estimate by 12.

Water Demand Estimation

In this water budget and water quantity stress assessment, the estimation of monthly consumptive demand for surface and groundwater is a critical element. Water demand needs to be calculated as the "consumptive" use, which refers to water taken from groundwater or surface water and not returned locally in a reasonable time period. From the calculation perspective, total consumptive demand estimation comprises the permitted water use estimation and non-permitted water use estimation, which includes non-permitted agricultural and non-permitted residential water use. The groundwater and surface water demands were calculated separately for further stress assessments. It should be noted that the non-consumptive returns are not considered as per Ontario Ministry of the Environment (2007).

Permitted Water Use

The primary source of information for water demand estimation is the MOE Permit to Take Water (PTTW) database. Water users that take more than 50,000 litres/day (L/d) are required to obtain a PTTW from the Ministry of the Environment, with the exception of agricultural and livestock uses. However, the PTTW database does not contain any direct information about the amount of water actually taken and no detailed information about when the water consumption occurs for each permitted use.

The new PTTW management database, containing data up to 2005, was developed by MOE to supplement the old PTTW database by accounting for multi-site permits, consumptive use and seasonal variability. Therefore, the new PTTW management database was selected as a basis for permitted water demand estimation. For the purpose of water demand estimation, the database was carefully screened and updated by Ganaraska Region Conservation Authority staff through the following steps.

- Screened the validity of all permits that expired before December 31 2002. Expired permits were not considered in the water demand calculation. In addition, permitted takings from large water bodies (Lake Ontario and Rice Lake), together with temporary takings, were identified and not considered in water demand calculations.
- Updated database with new permits issued from 2005 to 2007
- Replaced maximum water taking rate by actual pumping rates where the actual records were available
- Reviewed all multiple sources and multiple factors in permits

- Applied default monthly adjustments on PTTW and adjusted by reviewing individual permits
- Applied consumptive factors: the default consumptive factors in Ontario Ministry of the Environment (2007) are applied, except those uses that removed water from original sources (study unit) and did not return the water to same unit within a reasonable time period (e.g., water bottling).

The locations of PTTW sites considered in the Wilmot Creek watershed water budget are shown in Figure 3.55 and detailed information regarding these takings is listed in Table 3.12.

Table 3.12: Permit to Take Water

Permit	Source	General Purpose	Specific Purpose	Demand Proportion	Consumptive Factor	Max Per Day (L/day)	Consumptive Annual Taking (m^3)
7578-6C5NRC	Surface	Commercial	Other - Commercial	1	1	22,73,045	69,328
1652-645RX7	Ground	Commercial	Bottled Water	1	1	218,869	79,878
00-P-3088	Surface	Agricultural	Fruit Orchards	1	0.8	1,180,000	26,936
01-P-3076	Surface	Agricultural	Sod Farm	1	0.9	2,864,640	144,758
6085-6GYRSV	Surface	Agricultural	Tender Fruit	1	0.8	680,000	15,522
01-P-3077	Ground	Industrial	Aggregate Washing	1	0.25	1,912,617	102,834
2022-6EHET	Ground	Industrial	Aggregate Washing	1	0.25	2,520,000	135,491
8314-64NRLJ	Ground	Water Supply	Municipal	0.5	0.2	1,308,960	12,401
8314-64NRLJ	Ground	Water Supply	Municipal	0.5	0.2	1,308,960	12,401
95-P-3009	Ground	Industrial	Aggregate Washing	1	0.25	1,912,435	102,825

In the Wilmot Creek watershed, non-permitted water use generally includes groundwater takings from private water supply wells in municipally unserviced areas, and surface water takings from streams and ponds for agricultural use. This was determined upon review of land use and local water use patterns.

Non-serviced Residential Water Demand

As prescribed in Ontario Ministry of the Environment (2007), water demand for non-serviced residential areas is calculated by combining population density with typical per-capita water use rates. It was recommended to use Statistics Canada Census data at the dissemination area (DA) level to estimate total population and then estimate non-serviced population by removing municipally serviced populations. When the non-serviced population distribution is generated, non-serviced residential demand can be calculated using the typical water usage rate of 335 litre per day per person (L/D/person).

Upon review of local water use, it has been determined that in the Wilmot Creek watershed, non-serviced residents take their water from the groundwater system. The consumptive factor was designated to be 0.2 because most of the removed water will be returned to the groundwater system through septic systems.

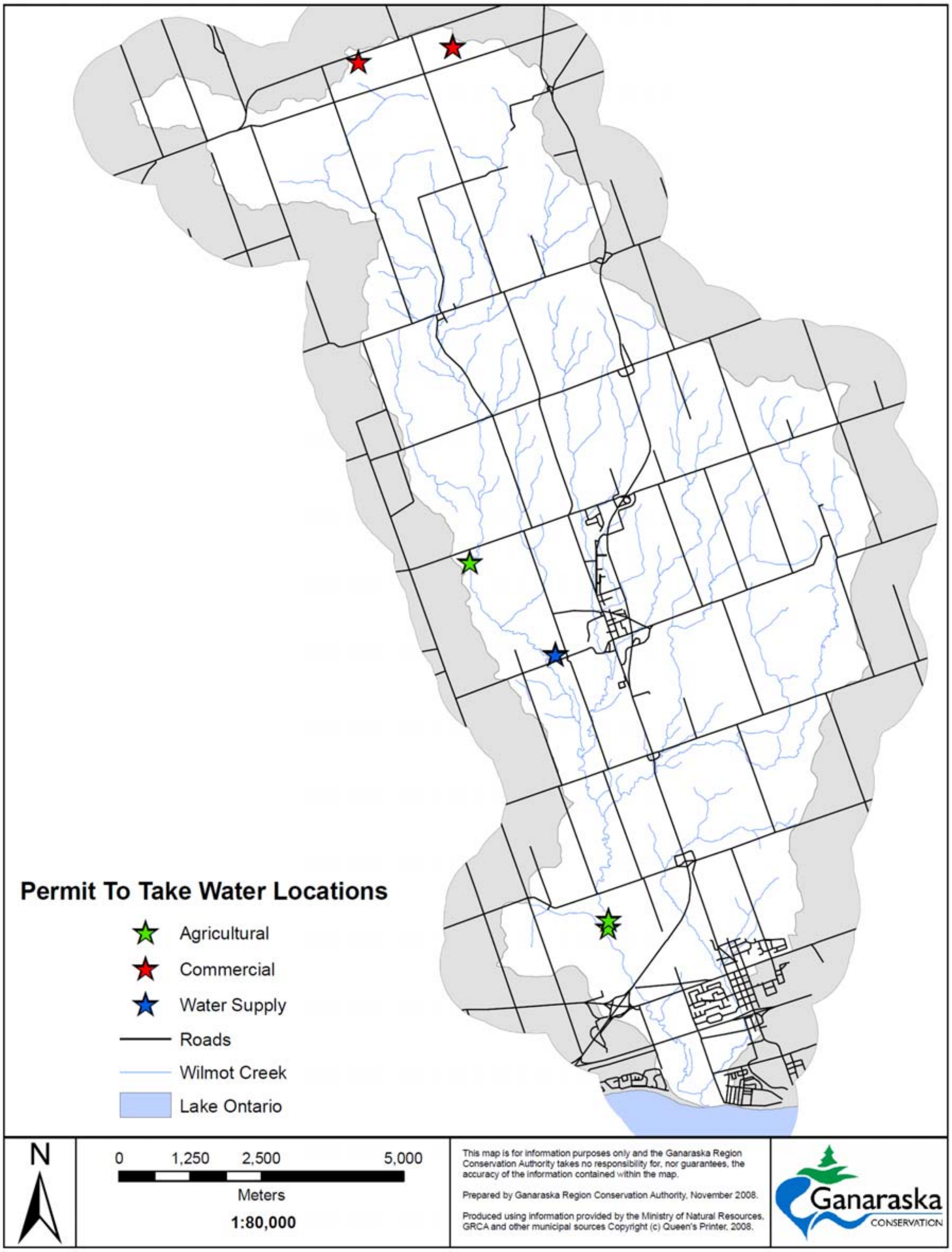


Figure 3.55: Permit to Take Water

Total population estimation and serviced population

The total population for the Wilmot Creek watershed is calculated using 2006 Statistics Canada data. The population in the Wilmot Creek watershed is 8,258, with a population density of 82 people/km^2. 5,616 people or 68% of population is serviced by municipal drinking water systems. 1,783 people are serviced from the Orono Well supply, with the rest of the serviced population relying on the Newcastle Water Supply System. 2,642 people rely on private water systems for water.

Non-serviced water demand

Non-serviced water demand is calculated by combining non-serviced population and the recommended water usage rate of 335 litres per day per person. The results are presented in Table 3.13.

Table 3.13: Existing non-serviced residential water use

Watershed population	Serviced Population	Non-serviced Population	Percent Serviced	Non-serviced Residential Water Demand	
8258	5616	2642	68	323,093 m^3	3.22 mm

Non-permitted Agricultural Water Demand

Ontario Ministry of the Environment (2007) recommends the use of the De Loë (2002) method that estimates agricultural water use based on the Statistics Canada 2001 agricultural census data at Census Consolidates Subdivision (CCS) level. Considering the fact that land use in the Wilmot Creek watershed has not experienced measurable changes in the past five years, the results from the De Loë method (2002) were used directly. This was done by overlaying the De Loë layer on the Wilmot Creek watershed polygons and aggregating the data. Non-permitted agricultural water use was estimated by subtracting permitted takings of water for agricultural purposes. The following three assumptions were applied during the calculation.

Non-permitted agricultural uses are assumed to be exclusively surface water takings. The applied consumptive factor is 0.78. The seasonal water use occurs in summer (July and August). The non-permitted agricultural demand for the Wilmot Creek watershed is 3,352 m^3/month.

Future Scenario

For 25-year future scenarios, water demand was estimated by taking into account the increase in population serviced by water sources other than Lake Ontario. The water demand for the municipal areas serviced by Lake Ontario is assumed to be a constant. The amount of 13.2% was estimated to represent the increases over the 25-year time frame in the rural area of the Municipality of Clarington.

<u>Water Reserve Estimation</u>

The concept of “water reserve” is designed to set aside water for purposes other than uses that are currently permitted (Ontario Ministry of the Environment 2007), such as natural ecosystem uses (e.g., instream needs, springs and wetlands) and other human uses (e.g., waste assimilation, power generation, navigation and recreation). The reserve quantity is subtracted from the total water source supply prior to evaluating the percent water demand.

Upon review of the current situation and future developments in the Wilmot Creek watershed, there are no significant water reserve requirements for waste assimilation or navigation. Recreational uses are primarily limited to Lake Ontario. Other activities such as canoeing, kayaking and navigation on local streams were assumed to be negligible. Therefore, the main function of reserved water in the Wilmot Creek watershed is to maintain the health of the natural ecosystem.

Surface Water Reserve

The Ontario Ministry of the Environment (2007) recommended two methods to estimate water reserve for surface water stress assessments.

- Calculation of lower decile flow (Q_{p90}) on a monthly basis
- Calculation of reserve values using the Tessman method.

Due to limited monitoring data (only two years available), simulated streamflow from the CANWET model was used for surface water reserve estimation. Both Q_{p90} and the Tessman method were applied on simulated stream flows and monitoring data over the simulation period of 1976 to1995 at two gauge stations, 02HD012 in Ganaraska River and 02HD009 in Wilmot Creek. After comparison, it was found that the monthly water reserve based on simulated stream flows and monitoring data are in better agreement when using the Tessman method. Therefore, the Tessman method was believed to be more reliable on simulated data since:

- Q_{p90} is determined by one ranked position at lower decile after ranking streamflow from the largest value to the smallest value. It was less reliable when this method was used in simulated streamflows instead of observed streamflows.
- The Tessman method estimates water reserve based on mean values and the reserve values are not easy to be affected by simulation errors.

However, when the two methods were applied on observed data, the monthly water reserves recommended by Q_{p90} were slightly higher than those by Tessman. This point is supported by the Wilmot Creek Ecological Flow Assessment Study (Bradford et al. 2005, Bradford et al. 2006). In the Wilmot Creek Ecological Flow Assessment Study, several low flow methods were compared based on flow data from the Concession 3 gauging station (02HD009). The study indicated that the Tessman method estimates for monthly low flow were outside the natural range of variability, falling well below the 10^{th} percentile flow from October through December and April through May, and may be too low to ensure that natural stream functions can be sustained in the Wilmot Creek watershed. For this reason, in the Q_{p90} method was used on monitoring data.

Under the future scenario with climate change prediction, the Tessman method is not appropriate for calculations of watershed reserve values, because during the dry months, the monthly water reserve is larger than the water supply. Due to this situation, Q_{p90} was used. More investigation is required to determine the effect of climate change on water reserve.

Groundwater Reserve

The Ontario Ministry of the Environment (2007) recommends that a simplified estimation method be applied for analysis whereby the reserve is estimated as 10% of the existing groundwater discharge. However, there is no theoretical basis for this value and it may be low considering that in Ganaraska Region Conservation Authority watersheds, baseflow represents 40 to 60% of stream flow. Therefore, the required reserve for the Wilmot Creek watershed was estimated, and simplified as 10% of the average annual and monthly groundwater supply, however this assumption is questionable.

Stress Assessment Calculation

The objective of the stress assessment is to screen the Wilmot Creek watershed and indicate whether there is a significant or medium stress level. The Ontario Ministry of the Environment (2007) indicates that the stress assessment is evaluated by percent water demand, which is the ratio of the consumptive water demand to water supplies, minus water reserves. Using a comparison between thresholds and estimated percent water demand, the Wilmot Creek watershed is then assigned a stress level.

In the Drinking Water Source Protection program, a low level of stress requires no further water budgeting and assessment work, but monitoring, database maintenance and assessment updating are encouraged. A moderate to significant level of stress, plus the presence of municipal drinking water systems, requires a Tier 2 assessment. A moderate to significant level of stress, without the presence of municipal drinking water systems is highlighted for more consideration under other regulatory programs (e.g., PTTW, *Fisheries Act,* etc.).

The Wilmot Creek watershed stress assessments evaluate surface water and groundwater independently and for the three different scenarios: current scenario, future scenario and climate change scenario. The resulting assigned stress level is the maximum of the three scenarios.

Surface Water Stress Assessment Current Scenario

Water supply and water reserve were calculated based on monthly simulated stream flows and monitored flows. Water demands were distributed to each month, considering the seasonal usage to investigate typical peak demand situations in the summer. Then the percent water demands were calculated as a relative indicator for each month by using the following equation (Eq.1). The largest monthly percent water demand was used to classify the stress level by comparing calculated values with surface water stress thresholds (Table 3.14).

$$\%\ \text{Water Demand (Surface Water)} = \frac{Q_{\text{DEMAND (SW)}}}{Q_{\text{SUPPLY (SW)}} - Q_{\text{RESERVE (SW)}}} \times 100 \qquad \text{[Eq.1]}$$

Table 3.14: Surface water stress thresholds

Surface Water Quantity Stress Level Assignment	All Scenarios Maximum Monthly Percent Water Demand
Significant	> 50%
Moderate	20% to 50%
Low	< 20%

Future Scenario and Future Scenario with Climate Change

The goal of the current scenario is designed to identify stress as a result of existing water use, while the goal of the 25-year future scenario is to identify watersheds that may become stressed as a result of future urbanization and/or additional drinking water requirements. The surface water percent water demand equation (Eq. 1) was also used in the future scenario. Finally, the stress level was determined by comparing results with the default surface water stress thresholds in Table 3.16. The percent water demand calculation and stress assessment for the climate change scenario use the same methodology, equation and threshold described above.

Groundwater Stress Assessment Current Scenario

Following similar procedures in surface water stress assessment, the concept of percent water demand for groundwater was calculated by the following equation (Eq.2). The stress level was determined by comparing results with groundwater stress thresholds listed in Table 3.15. Because groundwater sources and demand tend not to demonstrate significant seasonal variability, annual supply values are deemed to be more appropriate for this exercise. However, peak monthly groundwater demand was also assessed to determine if the groundwater source could be temporarily over-stressed in the specific months. The resulting groundwater stress level assigned is the maximum of the current and future assessment values for both annual and monthly conditions.

$$\%\ \text{Water Demand (Groundwater)} = \frac{Q_{\text{DEMAND (GW)}}}{Q_{\text{SUPPLY (GW)}} - Q_{\text{RESERVE (GW)}}} \times 100 \qquad \text{[Eq.2]}$$

Table 3.15: Groundwater stress thresholds

Groundwater Quantity Stress Level Assignment	All Scenarios	
	Average Annual	Monthly Maximum
Significant	>25%	>50%
Moderate	>10%	>25%
Low	0 to10%	0 to 25%

Future Scenario and Future Scenario with Climate Change

The equation (Eq.2) of percent water demand for groundwater was also used for the future scenario and the future scenario with climate change. Finally, the stress level was classified by comparing results with the default stress thresholds.

Uncertainty

Uncertainty is inherent in the water budget estimation and stress assessment process. The accuracy of estimates is reliant on the quality of input data, methodology, modeling, and conceptual understanding of the watershed. Overall, the issues related to uncertainty, and data and knowledge gaps are complex and highly qualitative. There is a degree of uncertainty associated with every aspect of the water budget analyses, however, it is impossible to provide a quantitative assessment of this level of uncertainty. Rather one can only say, in very general terms, that the level is low, moderate or high.

It is quite difficult to quantify the uncertainty. However, uncertainty can be evaluated as "low" in watersheds where:

- A long-term historical record is available
- High quality dense monitoring data with good quality are provided
- Complex numerical modeling is applied
- Relative studies and research have been conducted to enhance the understanding of the water system.

According to the Ontario Ministry of the Environment (2007), the uncertainty becomes particularly important if a watershed has been assigned a low stress level and the percent water demand estimate is near the threshold of moderate stress. For that situation, estimates should be checked to make sure that they are conservative.

The Wilmot Creek watershed is a gauged watershed with over 40 years of stream flow data. Wilmot Creek has been subjected to intensive research for several decades in conjunction with a variety of provincial water management and fisheries initiatives. The knowledge of the Wilmot Creek system gained through these studies enhances the conceptual understanding of the system. The uncertainty can be evaluated as a "low" level for Wilmot Creek.

Water Budget Results for Wilmot Creek Watershed

The CANWET model was calibrated for the Wilmot Creek watershed for a 20 year period (1976 to 1995) against the observed streamflow data recorded at gauge 02HD009 on the main branch of Wilmot Creek at Concession Road 3. Figure 3.56 indicates a good agreement between observed and simulated stream flows. The calibrated model was therefore run for the three scenarios.

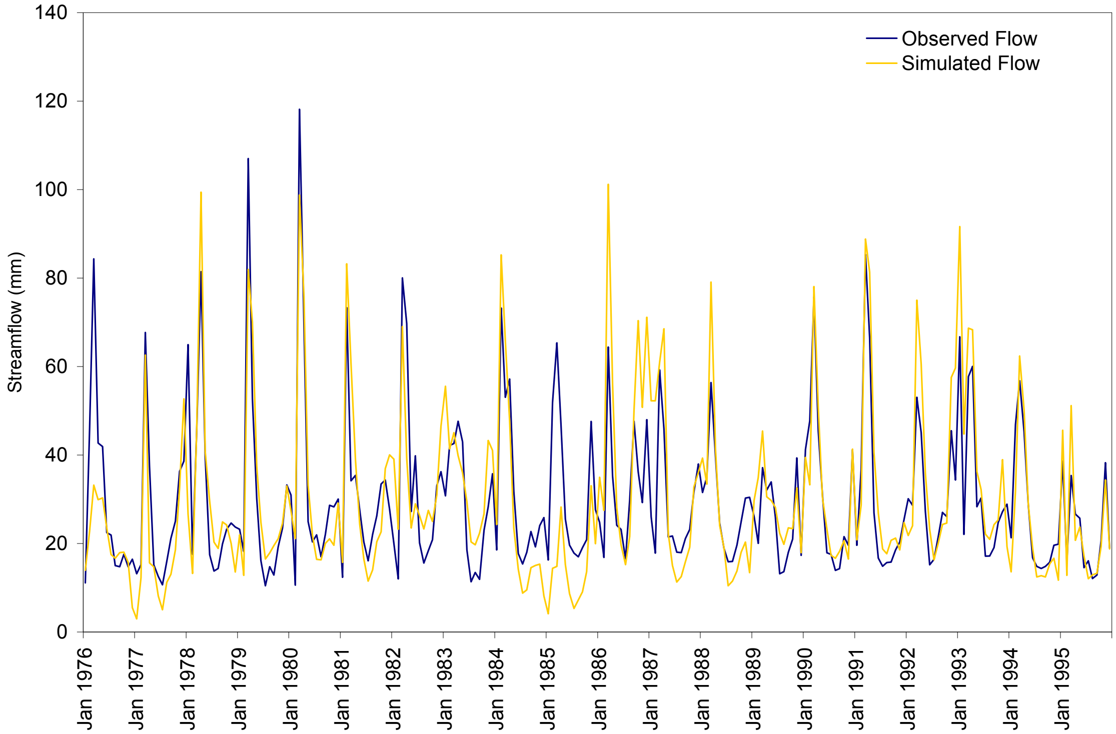


Figure 3.56: Simulated and observed monthly streamflow at the Concession Road 3 gauge station

Existing Scenario

Figure 3.57 and Table 3.16 describe the elements of the water budget simulated by CANWET using long-term data for the Wilmot Creek watershed under the existing land use scenario.

Future Scenario

Figure 3.58 and Table 3.17 describe the elements of the water budget simulated by CANWET for the Wilmot Creek watershed using long-term existing climate data under the projected future land use scenario. The results showed negligible increase in stream flow compared to the existing land use scenario.

Future Scenario with Climate Change

Figure 3.59 and Table 3.18 describe the elements of the water budget simulated by CANWET for the Wilmot Creek watershed using long-term climate data simulated by the Canadian Global Climate Model (CGCM) considering climate change for the 2021 to 2040 period under the projected future land use scenario.

The CGCM predicts considerable increase in annual precipitation (about 40%) and as a result, the CANWET model simulates significant increase in stream flow.

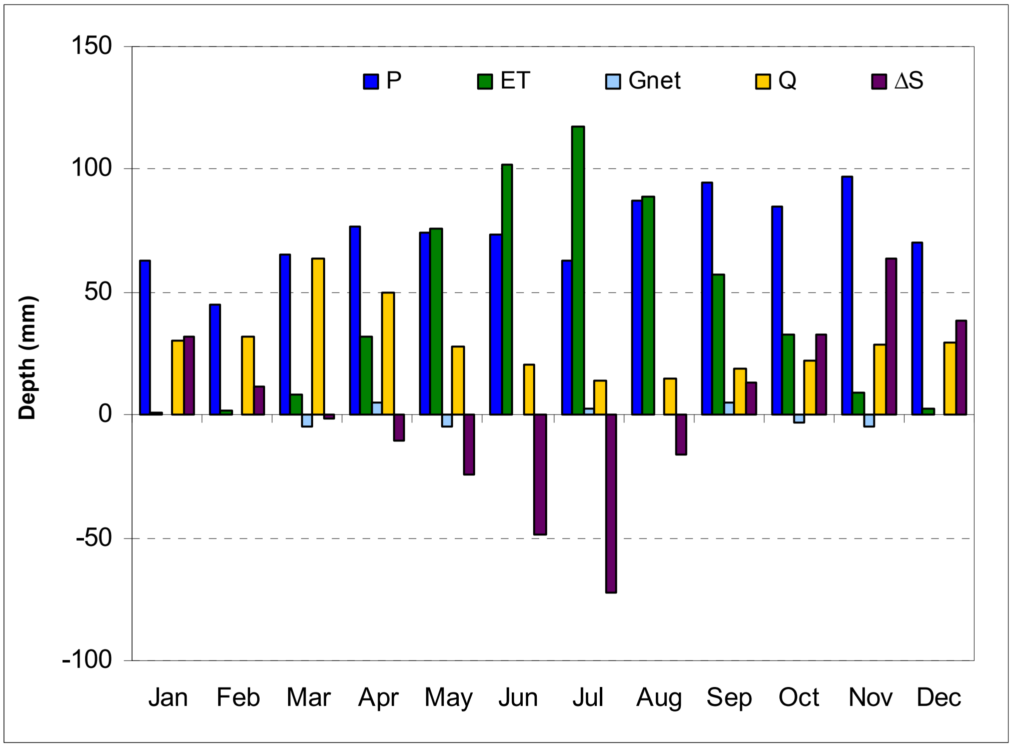


Figure 3.57: Wilmot Creek watershed under existing land use scenario

Table 3.16: Existing land use scenario

Month	**(P) Precipitation (mm)**	**(ET) Evapotranspiration (mm)**	**(G_{net}) Net Groundwater Flow In and Out (mm)**	**(Q) Stream Flow (mm)**	**△S Change in Storage (mm)**
January	63.2	1.0	0	30.2	32.0
February	45.2	1.6	0	31.8	11.8
March	65.5	8.5	-5	63.6	-1.6
April	76.4	31.8	5	49.8	-10.2
May	74.3	75.6	-5	27.8	-24.1
June	73.7	102.2	0	20.3	-48.8
July	62.7	117.8	3	14.1	-72.2
August	87.1	88.7	0	14.9	-16.5
September	94.7	57.4	5	19.1	13.2
October	84.8	32.9	-3	22.3	32.6
November	96.8	9.4	-5	28.7	63.7
December	69.9	2.4	0	29.3	38.2
Annual	894.3	529.3	-5	351.9	

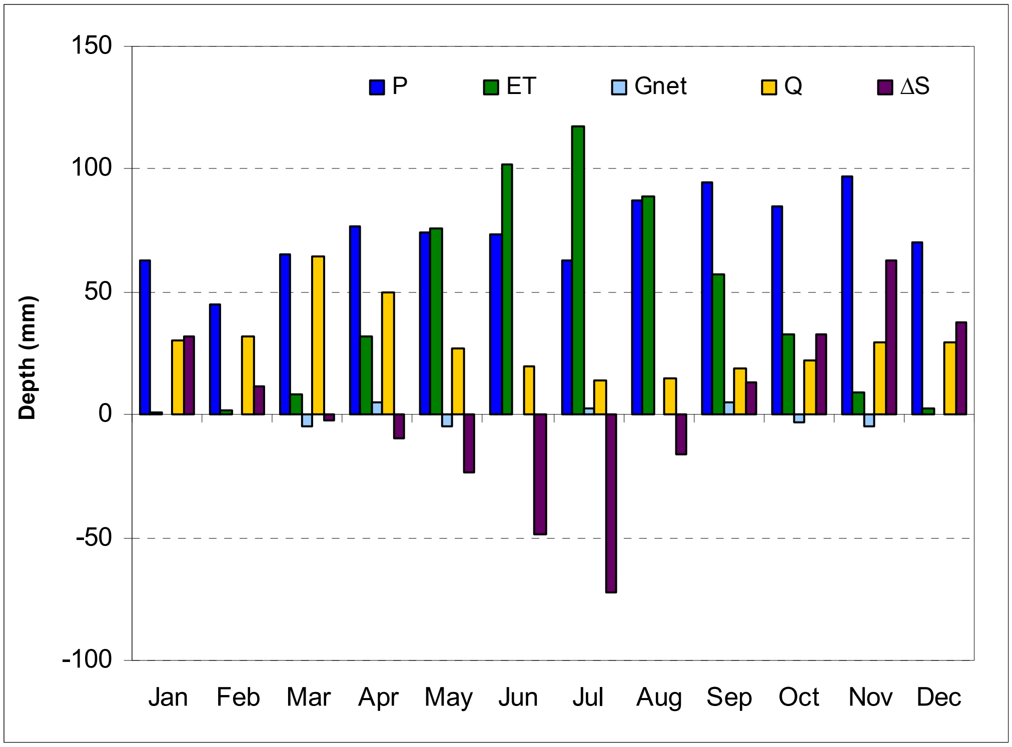


Figure 3.58: Wilmot Creek watershed under future land use scenario

Table 3.17: Future land use scenario

Month	(P) Precipitation (mm)	(ET) Evapotranspiration (mm)	(G_{net}) Net Groundwater Flow In and Out (mm)	(Q) Stream Flow (mm)	△S Change in Storage (mm)
January	63.2	1.0	0	30	32.2
February	45.2	1.6	0	31.9	11.7
March	65.5	8.5	-5	64.3	-2.3
April	76.4	31.8	5	49.6	-10.0
May	74.3	75.6	-5	27.3	-23.6
June	73.7	102.2	0	20	-48.5
July	62.7	117.8	3	13.9	-72.0
August	87.1	88.6	0	14.8	-16.3
September	94.7	57.4	5	19	13.3
October	84.8	32.9	-3	22.3	32.6
November	96.8	9.4	-5	29.6	62.8
December	69.9	2.4	0	29.5	38.0
Annual	894.3	529.2	-5	352.2	

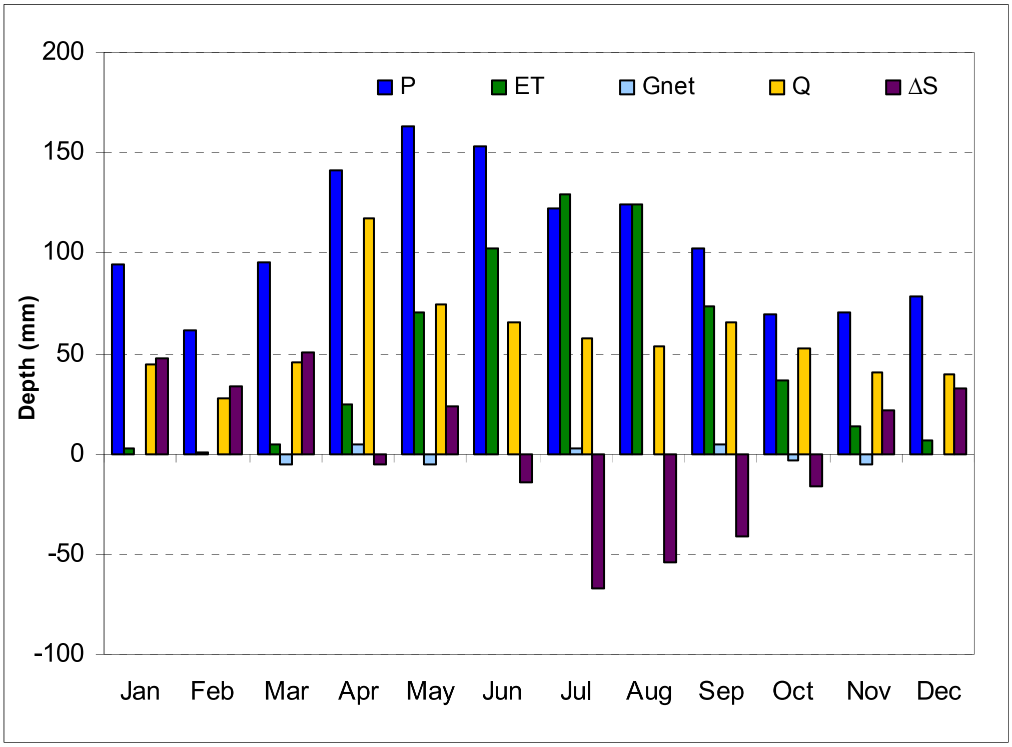


Figure 3.59: Wilmot Creek watershed under future land use scenario with climate change

Table 3.18: Future land use scenario with climate change

Month	(P) Precipitation (mm)	(ET) Evapotranspiration (mm)	(G_{net}) Net Groundwater Flow In and Out (mm)	(Q) Stream Flow (mm)	ΔS Change in Storage (mm)
January	94.5	2.6	0	44.5	47.4
February	61.6	1.1	0	27.2	33.3
March	95.5	4.8	-5	45.4	50.3
April	141.6	24.5	5	117.4	-5.3
May	163.1	70.0	-5	74.1	24.0
June	153.2	102.1	0	65.1	-14.0
July	121.9	128.9	3	57.0	-67.0
August	124	123.8	0	53.9	-53.7
September	102.6	73.0	5	65.4	-40.8
October	69.3	36.5	-3	52.3	-16.5
November	70.1	13.2	-5	40.2	21.7
December	78.9	6.3	0	39.6	33
Annual	1276.3	586.8	-5	682.1	

Stress Assessment

Water Supply and Water Reserve

Water supply and water reserve are estimated using the methodology described above and the results are reported in Table 3.19 to 3.24.

Water Demand

The two Orono municipal groundwater supply wells that are located in the central part of watershed experience an annual pump volume of 124,012 m^3 (2006 Data). These wells service a population of 1,783 people. In the watershed, 32% of the residents are serviced by individual wells, with an estimated annual consumptive volume of 64,618 m^3.

A water taking permit located in the central part of watershed has been issued to withdraw water from Wilmot Creek for sod production. Three Permit to Take Water takings located in the north area are commercial water takings, capturing springs below the Oak Ridges Moraine for aggregate washing. In addition, there are two surface water intakes in the downstream reach of Wilmot Creek used for agricultural irrigation.

Together with non-permitted water demand, the total water demand for the existing scenario is 658,006 m^3 (6.66 mm) per year, of which 84% is recorded in the PTTW database, 10% is estimated as non-serviced residential use, and 6% is estimated as non-permitted agricultural use. The detailed breakdown of groundwater and surface water demand for each month is shown in Table 3.19. For both groundwater and surface water, the non-uniform usage over the year is indicated. Surface water usage is higher in summer, and groundwater sources are extracted intensively from May to November for industrial aggregate washing. The surface water demand was kept constant, and only a minor increase in groundwater demand is presented in the future scenario, as shown in Table 3.20.

Stress Assessment

Percent water demand was calculated using both the Tessman method and Q_{10} on monitoring station stream flow data. Examining Tables 3.21 and 3.22, it is found that the Q_{10} method results in more conservative results which define the final stress level to be "moderate". Table 3.22 shows that the maximum monthly percent water demand is less than the 'moderate threshold' under the future scenario. To be conservative, the final stress level for surface water is recommended as "moderate".

The average annual percent water demand of groundwater for the different scenarios is lower than 10%, and the maximum monthly percent water demand is lower than the monthly moderate threshold of 25%. The resulting stress level for groundwater is evaluated as "low".

Water Budget and Stress Assessment Summary

Overall, water quantity for drinking water does not appear to be an immediate concern, since the Oak Ridges Moraine provides significant water recharge to Wilmot Creek. However, water quantity may potentially be a concern within specific areas such as areas with water takings or in areas where water quantity is controlled by the geology and other natural features.

The Community of Orono municipal wellfield, as well as other water takings in the area result in a baseflow losing reach which was first realized by the Geological Survey of Canada in 2005 (Hinton 2005). In this investigation the large decrease (-5%) in baseflow, located between the two highest baseflow contribution areas was found along the central main branch of Wilmot Creek (Ganaraska Region Conservation Authority 2007). This baseflow losing reach was further confirmed by the Ganaraska Region Conservation Authority baseflow monitoring program in 2004. Fish community surveys in the watershed also illustrate a noticeable shift in fish communities in the losing reach (Desjardins and Stanfield 2005).

The Ganaraska Region Conservation Authority and the Regional Municipality of Durham through their consultant, Jagger Hims Limited, completed a detailed investigation of the losing reach in the central part of the watershed. Joint analysis of Ganaraska Region Conservation Authority surface water monitoring data and Jagger Hims Limited groundwater monitoring data revealed that the surface water flow in the central section of Wilmot Creek experienced a perched condition during certain time of the year with a noticeable hydrologic link to the wellfield and a potential link to other Permits to Take Water in the area such as the sod farm (Jagger Hims Limited 2006; Peacock et al. 2006). The analysis also showed that Wilmot Creek retained its gaining status further down-stream below the Iroquois Plain, as discussed in Water Budget Conceptual Understanding (Ganaraska Region Conservation Authority 2007).

As the surface water stress assessment results in a “moderate” level of stress, it is recommended that Wilmot Creek proceed to a Tier 2 study for the purposes of drinking water source protection. A Tier 2 study will focus on the water contributing to the Orono Municipal Water Supply wells.

Table 3.19: Existing water demand estimation

Unit: m^3

	Annual	January	February	March	April	May	June	July	August	September	October	November	December
PTTW	**553,168**	**2,055**	**1,707**	**1,950**	**1,868**	**51,726**	**86,044**	**109,736**	**109,810**	**85,442**	**51,357**	**49,620**	**1854**
Groundwater	365,952	2,055	1,707	1,950	1,868	51,726	50,448	51,724	51,798	49,846	51,357	49,620	1854
Surface Water	187,216	0	0	0	0	0	35,596	58,012	58,012	35,596	0	0	0
Non-Serviced Residential (G)	**64,618.6**	**5,385**	**5,385**	**5,385**	**5,385**	**5,385**	**5,385**	**5,385**	**5,385**	**5,385**	**5,385**	**5,385**	**5385**
Non-PTTW Agriculture (S)	**40,219**	**3,352**	**3,352**	**3,352**	**3,352**	**3,352**	**3,352**	**3,352**	**3,352**	**3,352**	**3,352**	**3,352**	**3352**
Total	**658,006**	**10,791**	**10,443**	**10,686**	**10,604**	**60,463**	**94,781**	**118,473**	**118,546**	**94,179**	**60,093**	**58,356**	**10590**
Groundwater	430,571	7,440	7,091	7,335	7,253	57,111	55,833	57,109	57,183	55,231	56,742	55,004	7239
Surface Water	227,435	3,352	3,352	3,352	3,352	3,352	38,948	61,363	61,363	38,948	3,352	3,352	3352

Unit: mm

	Annual	January	February	March	April	May	June	July	August	September	October	November	December
PTTW	**5.60**	**0.02**	**0.02**	**0.02**	**0.02**	**0.52**	**0.87**	**1.11**	**1.11**	**0.86**	**0.52**	**0.50**	**0.02**
Groundwater	3.70	0.02	0.02	0.02	0.02	0.52	0.51	0.52	0.52	0.50	0.52	0.50	0.02
Surface Water	1.89	0.00	0.00	0.00	0.00	0.00	0.36	0.59	0.59	0.36	0.00	0.00	0.00
Non-Serviced Residential	**0.65**	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**
Non-PTTW Agriculture	**0.41**	**0.03**	**0.03**	**0.03**	**0.03**	**0.03**	**0.03**	**0.03**	**0.03**	**0.03**	**0.03**	**0.03**	**0.03**
Total	**6.66**	**0.11**	**0.11**	**0.11**	**0.11**	**0.61**	**0.96**	**1.20**	**1.20**	**0.95**	**0.61**	**0.59**	**0.11**
Groundwater	4.36	0.08	0.07	0.07	0.07	0.58	0.56	0.58	0.58	0.56	0.57	0.56	0.07
Surface Water	2.30	0.03	0.03	0.03	0.03	0.03	0.39	0.62	0.62	0.39	0.03	0.03	0.03

Table 3.20: Future water demand estimation

Unit: m^3

	Annual	January	February	March	April	May	June	July	August	September	October	November	December
PTTW	**554,337**	**2,322**	**1,928**	**2,204**	**2,111**	**52,026**	**86,385**	**110,036**	**110,119**	**83,649**	**51,609**	**49,853**	**2,095**
Groundwater	367,121	2,322	1,928	2,204	2,111	52,026	50,789	52,024	52,107	48,053	51,609	49,853	2,095
Surface Water	187,216	0	0	0	0	0	35,596	58,012	58,012	35,596	0	0	0
Non-Residential (G)	**73,226**	**6,102**	**6,102**	**6,102**	**6,102**	**6,102**	**6,102**	**6,102**	**6,102**	**6,102**	**6,102**	**6,102**	**6,102**
Non-Agriculture(S)	**40,219**	**3,352**	**3,352**	**3,352**	**3,352**	**3,352**	**3,352**	**3,352**	**3,352**	**3,352**	**3,352**	**3,352**	**3,352**
Total	**667,782**	**11,776**	**11,382**	**11,657**	**11,564**	**61,480**	**95,839**	**119,490**	**119,573**	**93,103**	**61,062**	**59,307**	**11,549**
Groundwater	440,347	8,424	8,031	8,306	8,213	58,128	56,891	58,126	58,210	54,155	57,711	55,955	8,197
Surface Water	227,435	3,352	3,352	3,352	3,352	3,352	38,948	61,363	61,363	38,948	3,352	3,352	3,352

Unit: mm

PTTW	**5.61**	**0.02**	**0.02**	**0.02**	**0.02**	**0.53**	**0.87**	**1.11**	**1.11**	**0.85**	**0.52**	**0.50**	**0.02**
Groundwater	3.72	0.02	0.02	0.02	0.02	0.53	0.51	0.53	0.53	0.49	0.52	0.50	0.02
Surface Water	1.89	0.00	0.00	0.00	0.00	0.00	0.36	0.59	0.59	0.36	0.00	0.00	0.00
Non-Residential	**0.74**	**0.06**	**0.06**	**0.06**	**0.06**	**0.06**	**0.06**	**0.06**	**0.06**	**0.06**	**0.06**	**0.06**	**0.06**
Non-Agriculture	**0.41**	**0.03**	**0.03**	**0.03**	**0.03**	**0.03**	**0.03**	**0.03**	**0.03**	**0.03**	**0.03**	**0.03**	**0.03**
Total	**6.76**	**0.12**	**0.12**	**0.12**	**0.12**	**0.62**	**0.97**	**1.21**	**1.21**	**0.94**	**0.62**	**0.60**	**0.12**
Groundwater	4.46	0.09	0.08	0.08	0.08	0.59	0.58	0.59	0.59	0.55	0.58	0.57	0.08
Surface Water	2.30	0.03	0.03	0.03	0.03	0.03	0.39	0.62	0.62	0.39	0.03	0.03	0.03

Table 3.21: Surface water stress calculation by Q_{90} (existing scenario)

Month	Water Supply (Q_{p50})		Water Reserve (Q_{p90})		Water Supply - Water Reserve		Water Demand (Q demand)			Stress Level	Uncertainty
	m^3/s	mm/month	m^3/s	mm/month	m^3/s	mm/month	m^3	mm/month	% Water Demand		
January	0.82	25.73	0.40	12.60	0.42	13.13	3351.61	0.034	0.26	Low	Low
February	0.89	27.83	0.44	13.83	0.45	14.01	3351.61	0.034	0.24	Low	Low
March	1.89	59.15	1.15	35.96	0.74	23.19	3351.61	0.034	0.15	Low	Low
April	1.52	47.70	1.08	33.92	0.44	13.78	3351.61	0.034	0.25	Low	Low
May	0.89	27.82	0.70	22.02	0.18	5.80	3351.61	0.034	0.58	Low	Low
June	0.63	19.61	0.49	15.31	0.14	4.30	38947.7	0.394	9.17	Low	Low
July	0.52	16.32	0.35	10.89	0.17	5.43	61363.5	0.621	11.44	Low	Low
August	0.51	16.00	0.43	13.61	0.08	2.39	61363.5	0.621	25.93	Moderate	Low
September	0.64	19.94	0.43	13.43	0.21	6.51	38947.7	0.394	6.05	Low	Low
October	0.72	22.56	0.57	17.92	0.15	4.64	3351.61	0.034	0.73	Low	Low
November	0.96	30.11	0.65	20.46	0.31	9.65	3351.61	0.034	0.35	Low	Low
December	0.95	29.84	0.61	19.30	0.34	10.55	3351.61	0.034	0.32	Low	Low

Table 3.22: Surface water stress calculation (future scenario)

Month	Water Supply (Q_{p50})		Water Reserve (Tessman)		Water Supply - Water Reserve		Water Demand (Q demand)			Stress Level	Uncertainty
	m^3/s	mm/month	m^3/s	mm/month	M^3/s	mm/month	m^3/s	mm/month	% Water Demand		
January	1.00	26.22	0.47	12.35	0.53	13.87	3352	0.034	0.24	Low	Low
February	1.05	27.66	0.50	13.11	0.55	14.55	3352	0.034	0.23	Low	Low
March	2.50	65.65	0.99	26.07	1.51	39.58	3352	0.034	0.09	Low	Low
April	1.84	48.34	0.77	20.16	1.07	28.18	3352	0.034	0.12	Low	Low
May	1.11	29.07	0.46	11.97	0.65	17.10	3352	0.034	0.20	Low	Low
June	0.84	22.00	0.46	11.97	0.38	10.03	38948	0.394	3.93	Low	Low
July	0.61	16.07	0.46	11.97	0.16	4.10	61363	0.621	15.14	Low	Low
August	0.63	16.46	0.46	11.97	0.17	4.49	61363	0.621	13.83	Low	Low
September	0.75	19.58	0.46	11.97	0.29	7.61	38948	0.394	5.18	Low	Low
October	0.80	20.94	0.46	11.97	0.34	8.97	3352	0.034	0.38	Low	Low
November	1.24	32.58	0.46	12.18	0.78	20.41	3352	0.034	0.17	Low	Low
December	1.05	27.54	0.46	12.13	0.59	15.41	3352	0.034	0.22	Low	Low

Table 3.23: Surface water stress calculation (future scenario with climate change)

Month	Water Supply (Q_{p50})		Water Reserve (Q_{p90})		Water Supply - Water Reserve		Water Demand (Q demand)			Stress Level	Uncertainty
	m^3/s	mm/month	m^3/s	mm/month	m^3/s	mm/month	m^3/s	mm/month	% Water Demand		
January	1.93	50.11	0.54	13.92	1.39	36.19	3352	0.034	0.09	Low	High
February	1.04	27.07	0.40	10.39	0.64	16.68	3352	0.034	0.20	Low	High
March	1.61	41.71	0.86	22.39	0.74	19.33	3352	0.034	0.18	Low	High
April	4.24	110.12	2.41	62.57	1.83	47.55	3352	0.034	0.07	Low	High
May	2.48	64.33	1.69	43.95	0.78	20.38	3352	0.034	0.17	Low	High
June	2.55	66.10	1.60	41.50	0.95	24.61	38948	0.394	1.60	Low	High
July	2.22	57.66	1.29	33.39	0.93	24.27	61363	0.621	2.56	Low	High
August	1.99	51.65	1.24	32.20	0.75	19.46	61363	0.621	3.19	Low	High
September	2.38	61.93	1.60	41.60	0.78	20.32	38948	0.394	1.94	Low	High
October	1.73	44.93	1.29	33.51	0.44	11.42	3352	0.034	0.30	Low	High
November	1.29	33.41	0.95	24.68	0.34	8.73	3352	0.034	0.39	Low	High
December	1.39	36.03	0.60	15.46	0.79	20.56	3352	0.034	0.16	Low	High

Table 3.24: Groundwater stress calculation (existing scenario)

Month	Water Supply (Q_r+Q_{net})		Water Reserve (10% supply)		Water Supply - Water Reserve		Water Demand (Q demand)			Stress Level	Uncertainty
	m^3/s	mm/month	m^3/s	mm/month	m^3/s	mm/month	m^3	mm/month	% Water Demand		
January	0.96	24.80	0.096	2.48	0.86	22.32	7440	0.075	0.34	Low	Low
February	0.96	24.80	0.096	2.48	0.86	22.32	7091	0.072	0.32	Low	Low
March	0.96	24.80	0.096	2.48	0.86	22.32	7335	0.074	0.33	Low	Low
April	0.96	24.80	0.096	2.48	0.86	22.32	7253	0.073	0.33	Low	Low
May	0.96	24.80	0.096	2.48	0.86	22.32	57111	0.578	2.59	Low	Low
June	0.96	24.80	0.096	2.48	0.86	22.32	55833	0.565	2.53	Low	Low
July	0.96	24.80	0.096	2.48	0.86	22.32	57109	0.578	2.59	Low	Low
August	0.96	24.80	0.096	2.48	0.86	22.32	57183	0.579	2.59	Low	Low
September	0.96	24.80	0.096	2.48	0.86	22.32	55231	0.559	2.50	Low	Low
October	0.96	24.80	0.096	2.48	0.86	22.32	56742	0.574	2.57	Low	Low
November	0.96	24.80	0.096	2.48	0.86	22.32	55004	0.557	2.49	Low	Low
December	0.96	24.80	0.096	2.48	0.86	22.32	7239	0.073	0.33	Low	Low
Annual	11.46	297.60	1.146	29.76	10.31	267.84	430571	4.357	1.63	Low	Low

Table 3.25: Groundwater stress calculation (future scenario)

Month	Water Supply (Q_r+Q_{net})		Water Reserve (10% supply)		Water Supply - Water Reserve		Water Demand (Q demand)			Stress Level	Uncertainty
	m^3/s	mm/month	m^3/s	mm/month	m^3/s	mm/month	m^3	mm/month	% Water Demand		
January	0.96	24.80	0.096	2.48	0.86	22.32	7440	0.075	0.34	Low	Low
February	0.96	24.80	0.096	2.48	0.86	22.32	7091	0.072	0.32	Low	Low
March	0.96	24.80	0.096	2.48	0.86	22.32	7335	0.074	0.33	Low	Low
April	0.96	24.80	0.096	2.48	0.86	22.32	7253	0.073	0.33	Low	Low
May	0.96	24.80	0.096	2.48	0.86	22.32	57111	0.578	2.59	Low	Low
June	0.96	24.80	0.096	2.48	0.86	22.32	55833	0.565	2.53	Low	Low
July	0.96	24.80	0.096	2.48	0.86	22.32	57109	0.578	2.59	Low	Low
August	0.96	24.80	0.096	2.48	0.86	22.32	57183	0.579	2.59	Low	Low
September	0.96	24.80	0.096	2.48	0.86	22.32	55231	0.559	2.50	Low	Low
October	0.96	24.80	0.096	2.48	0.86	22.32	56742	0.574	2.57	Low	Low
November	0.96	24.80	0.096	2.48	0.86	22.32	55004	0.557	2.49	Low	Low
December	0.96	24.80	0.096	2.48	0.86	22.32	7239	0.073	0.33	Low	Low
Annual	11.46	297.60	1.146	29.76	10.31	267.84	430571	4.357	1.63	Low	Low

Table 3.26: Groundwater stress calculation (future scenario with climate change)

Month	Water Supply (Q_r+Q_{net})		Water Reserve (10% supply)		Water Supply - Water Reserve		Water Demand (Q demand)			Stress Level	Uncertainty
	m^3/s	mm/month	m^3/s	mm/month	m^3/s	mm/month	m^3	mm/month	% Water Demand		
January	1.83	47.62	0.183	4.76	1.65	42.86	8157	0.085	0.20%	Low	High
February	1.83	47.62	0.183	4.76	1.65	42.86	7809	0.081	0.19%	Low	High
March	1.83	47.62	0.183	4.76	1.65	42.86	8052	0.084	0.20%	Low	High
April	1.83	47.62	0.183	4.76	1.65	42.86	7970	0.083	0.19%	Low	High
May	1.83	47.62	0.183	4.76	1.65	42.86	57828	0.588	1.37%	Low	High
June	1.83	47.62	0.183	4.76	1.65	42.86	56550	0.576	1.34%	Low	High
July	1.83	47.62	0.183	4.76	1.65	42.86	57827	0.588	1.37%	Low	High
August	1.83	47.62	0.183	4.76	1.65	42.86	57900	0.589	1.37%	Low	High
September	1.83	47.62	0.183	4.76	1.65	42.86	55948	0.548	1.28%	Low	High
October	1.83	47.62	0.183	4.76	1.65	42.86	57459	0.584	1.36%	Low	High
November	1.83	47.62	0.183	4.76	1.65	42.86	55722	0.566	1.32%	Low	High
December	1.83	47.62	0.183	4.76	1.65	42.86	7956	0.083	0.19%	Low	High
Annual	22.01	571.40	2.201	57.14	19.80	514.26	439178	4.456	0.87%	Low	High

3.5.5 Duration of Flows

An evaluation of the duration of flow maintenance in Wilmot Creek can provide information on the ability of the stream to maintain its aquatic ecology. That is, if it can be demonstrated that the stream maintains a minimum flow deemed to be required to maintain the ecology, then the stream and its ecology can be seen as healthy and sustainable.

A flow duration curves indicates the percentage of time a stream flows at a particular rate. This simple graph can be interpreted to provide information on the resilience of a stream.

Ecological Flow Modeling

Using stream gauge data from the Concession Road 3 gauge station (02HD009) between 1976 and 1995, ecological flow needs were determined. Figure 3.60 shows that the percentage of time flow in Wilmot Creek at the gauge station is higher than the minimum required flows of ecological needs, calculated as the reserve value in the water budget stress assessment process. This value has been calculated at 0.39 cubic metres per second (cms). This means that 94% of the time, Wilmot Creek above the Concession Road 3 gauge is experiencing flows that meet or exceeds the minimum requirements of the aquatic ecology. Table 3.27 shows monthly flows and modeled ecological flow requirements.

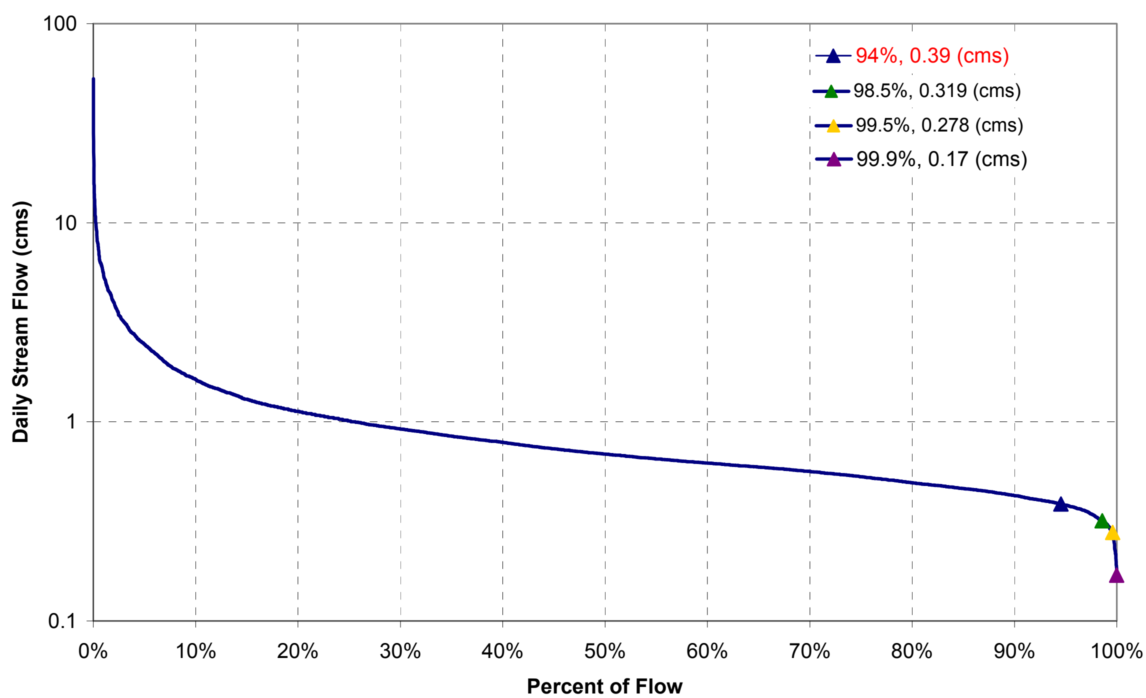


Figure 3.60: Flow duration curve at the Concession Road 3 gauge

Table 3.27: Monthly flow characteristics at the Concession Road 3 gauge

	Flows			
	Monthly Mean	**Q50***	**Q90***	**Tessman**
January	0.92	0.82	0.40	0.39
February	1.14	0.89	0.44	0.46
March	2.06	1.89	1.15	0.82
April	1.64	1.52	1.08	0.66
May	0.93	0.89	0.70	0.39
June	0.68	0.63	0.49	0.39
July	0.52	0.52	0.35	0.39
August	0.54	0.51	0.43	0.39
September	0.67	0.64	0.43	0.39
October	0.75	0.72	0.57	0.39
November	0.99	0.96	0.65	0.40
December	0.96	0.95	0.61	0.39

* Ranked average monthly discharges for the period of record.

This same type of analysis has been undertaken for Ganaraska River and Cobourg Creek. The Ganaraska River was able to produce a minimum flow (reserve value) of 98%, and Cobourg Creek was 79% at the William Street station. The analysis of Wilmot Creek might indicate that there is little variance in flows compared to Cobourg Creek. Aquatic biology also supports this idea of little variance in flow, given that ecological functions are generally not stressed (Section 4.0).

Wilmot Creek Ecological Flows Assessment Studies

Clear targets are needed for effective decision making with respect to watershed development and management strategies. While the ultimate goal of such strategies may be to maintain or restore ecosystem integrity, including healthy communities of aquatic biota, biotic targets are not yet able to directly predict the outcome of management activities because biotic responses are complex. Better tools currently exist to help understand the connections between landscape activities and the streamflow regime. In turn, streamflow is strongly correlated with many stream characteristics such as water temperature, channel geomorphology and habitat diversity, which are critical to sustaining the ecological integrity of streams; and in fact, streamflow may be considered a “master variable” determining the form and function of streams (Poff et al. 1997).

Traditionally water management has sought to dampen natural fluctuations in streamflow in the interest of providing steady supplies of water, for various instream and out-of-stream uses, and for moderating extreme drought and flood conditions. However, there is increasing recognition that the natural variations in flows (both within and between years) are needed to maintain and restore the natural form and function of aquatic ecosystems. Determining a single, minimum, threshold flow, to the exclusion of other ecologically relevant flows, is no longer an acceptable approach to instream flow management. As a result of the important functions of “extreme” flows, it is also necessary to go beyond maintaining “means” or a subdued replica of the natural hydrograph. As Poff et al. (1997) explain, “… half of the peak discharge will not move half of the sediment, half of the migration motivational flow will not move half of the fish, and half of an overbank flow will not inundate half of the floodplain.” Needs with respect to the frequency, timing and duration of flows of various magnitudes need to be determined; a target flow regime is needed.

Within the province, many agencies are working toward methods and protocols that help to determine target flows for maintaining or improving ecological integrity (Grand River Conservation Authority et al. 2005). Building upon work already initiated throughout the province and across North America, ecological flow assessments have been piloted in the Wilmot Creek watershed (Bradford et al. 2005, Bradford et al. 2006).

The increased understanding developed thought Wilmot Creek pilot studies will aid in defining low flow target requirements to be used in watershed management. Understanding natural variations in flows (both within and between years) is needed to maintain and restore the natural form and function of aquatic ecosystems. It must be stressed that determining a single minimum threshold flow, to the exclusion of other ecologically relevant flows, is no longer an acceptable approach to instream flow management.

3.6 Groundwater Quality

Groundwater quality is spatially variable, is affected by seasonal changes and local climate, and by the types of soils and rocks through which water moves. When water from rain or snowmelt moves overland and through the ground, water dissolves minerals found in rocks and soils, percolates through organic material such as roots and leaves, and reacts with algae, bacteria and other microscopic organisms. Each of these natural processes changes groundwater quality. In addition to natural controls over groundwater quality, human influences such as contamination can alter the quality of groundwater.

In the Wilmot Creek watershed, the most common dissolved substances groundwater are minerals and salts; as a group, referred to as dissolved solids. Dissolved solids include common constituents such as calcium, sodium and chloride; nutrients such as nitrogen and phosphorus; and trace elements such as selenium, chromium and arsenic (Morrison Environmental Limited 2004). In general, the common, naturally dissolved substances are not considered harmful to human health or aquatic organisms, although some constituents can affect the taste, smell or clarity of water.

Nutrients and trace elements in water can be harmful to human health and aquatic life if they exceed standards or guidelines set out by the province through the *Ontario Drinking Water Objectives*. Dissolved gases such as oxygen and methane are common in groundwater in the Wilmot Creek watershed.

Groundwater quality data for the Wilmot Creek watershed is potentially available from a wide variety of sources including the Ministry of the Environment Water Well Records Database, the Provincial Groundwater Monitoring Network, private well sampling, municipal water sampling programs, and local and site-specific groundwater studies. The first step in reporting groundwater quality is to collect all the available data to allow a water quality comparison, on a spatially (vertically in aquifer/aquitard units and horizontally within an individual aquifer) and temporal scale for a variety of parameters. At this time there is limited data, data gaps and other limitations affecting groundwater quality analysis. In addition, water quality data can only be inferred to a site specific location, and not necessarily to an aquifer.

3.6.1 Groundwater Quality in Private Water Supply Wells

The majority of residents in the Wilmot Creek watershed rely on private water wells. Many of these private wells supply water to permanent residents, whereas other wells are used for agricultural purposes including livestock watering, irrigation, and a small number of wells are used for commercial and industrial purposes.

It is important to identify aquifer types when assessing groundwater quality which can be done using the Ministry of the Environment Water Well Record Database. The sand and gravel deposits of glaciofluvial and glaciolacustrine origins are the main aquifers in the area. In the Wilmot Creek watershed, overburden, bedrock, and flowing artesian wells have been identified. Overburden wells are more important as a source of private water supply wells. Generally bedrock wells are concentrated in the southern part of the watershed and tend to be where overburden is relatively thin.

General information related to the quality of groundwater is available from MOE Water Well Record Database. A considerable number of wells are reported to have some natural water quality problems. For example, some bedrock wells have been reported to have salty, sulphurous or mineral water, and other well water contains gas (Singer et al. 2003). Singer et al. (2003) have not provided a detailed description of groundwater quality in the overburden aquifers. The description of groundwater quality in the overburden was given in terms of quality parameters and water type rather than in terms of specific overburden units. The parameters that were considered include sodium, iron, chloride, sulphate, nitrate, total hardness and total dissolved solids.

Most of the Ministry of the Environment Water Well Record Database includes information related to groundwater encountered such as fresh, salty, sulphurous, or containing iron or gas. The well driller, as part of the well record requirements, normally submits this information to the Ministry. Usually the driller visually examines a water sample taken from the well for clarity. The driller then smells and tastes the water and enters appropriate observations into the well record.

These observations are very useful especially when the water tastes salty or smells like a rotten egg, showing the presence of sodium chloride or hydrogen sulphide. However, the driller's observations are subjective and are therefore inadequate for determining the suitability of groundwater for drinking purposes.

Due to the limited data availability at this time, the above sections provide general information about regional groundwater quality in the Wilmot Creek watershed. In addition, it is known that site-specific groundwater quality issues occur in the Wilmot Creek watershed, however details of these occurrences are unknown. Many times however, it is poor private well maintenance and conditions that lead to negative groundwater quality results, rather than contaminated aquifers.

3.6.2 Municipal Wellfield Groundwater Quality

In 2003, the Regional Municipality of Durham completed a Wellhead Protection study for the Community of Orono municipal wells. Groundwater chemistry data and analysis for the two municipal wells were provided in Jagger Hims Limited (2003). This study indicated that the inorganic chemistry was acceptable and typical of groundwater, and pesticides and PCB's were below laboratory detection limits.

A sample of groundwater from municipal well MW4 and a sample of surface water from Wilmot Creek were collected during the 24-hours pumping test program of May 14, 2004. Result showed that levels of total dissolved solids, sulphate, sodium, hardness, iron, conductivity, chloride, and zinc are higher in the groundwater at MW4 than in Wilmot Creek. These concentrations are typical of groundwater in the area. Table 3.28 shows the water quality comparison of well MW4 and Wilmot Creek (Jagger Hims Limited 2003). The report indicated that the lower concentrations of chemicals in Wilmot Creek than in groundwater might be related to dilution from runoff in the creek. The report concluded that chemical differences suggest the well water is characteristic of groundwater with no apparent indications of surface water influences at the time of testing.

Table 3.28: Water quality comparison of MW4 and Wilmot Creek

Chemical	Ontario Drinking Water Standards	Units	Wilmot Creek May 14, 2003	Well MW4 May 14, 2003
Alkalinity	30-500 os	mg/L	202	225
Aluminum	0.1 os	mg/L	0.07	<0.05
Ammonia as N	None	mg/L	<0.03	<0.03
Barium	1.0 MAC	mg/L	0.060	0.112
Boron	5.0 1 MAC	mg/L	0.01	0.02
Cadmium	0.005 MAC	mg/L	<0.005	<0.005
Calcium	None	mg/L	75.1	115
Chloride	250 as	mg/L	23.3	55.8
Chromium	0.05 MAC	mg/L	<0.005	<0.005
Colour	5 as	TCU	12	14
Conductivity	None	mg/L	483	695
Copper	1.0 as	us/cm	0.005	0.040
Dissolved Organic	5.0 as	mg/L	2.1	3.7
Hardness (as $CaCO_3$)	80-100 os	mg/L	237	334
Iron	0.30 as	mg/L	0.13	0.26
Lead	0.01 MAC	mg/L	<0.001	0.009
Magnesium	None	mg/L	12.0	11.7
Manganese	0.05 as	mg/L	0.019	0.056
Methane	3.0 as	L/m^3		
Nickel	None	mg/L	<0.02	<0.02
Nitrate (as N)	10 MAC	mg/L	1.1	1.7
Nitrite (as N)	1 MAC	mg/L	<0.2	<0.2
Organic Nitrogen (as N)	0.1 SOS	mg/L		
Orthophosphate (as P)	None	mg/L	<0.3	<0.3
pH	6.5 – 8.5 as	None	8.28	7.71
Phosphorus	None	mg/L	<0.1	<0.1
Potassium	None	mg/L	2	2
Reactive Silica	None	mg/L	10.4	8.6
Sodium	200 as	mg/L	10.4	24.3
Sulphate	500 as	mg/L	22.0	53.0
Tannins and Lignins	None	mg/L		
Total Dissolved Solids	500 as	mg/L	281	412
Total Kjeldahl Nitrogen	None	mg/L	0.32	0.42
Turbidity	5.0 AS	NTU	4.6	2.7
Zinc	5.0 AS	mg/L	0.008	0.939
Total Coliform	5 h*	Count/100		
E. coli	0 h*	Count/100		
Ion balance	None	%	0.05	2.18

Notes

as: aesthetic standard (relates to taste, odour and appearance of water)
IMAC: Interim Maximum Acceptable Concentration
MAC: Maximum Acceptable Concentration
os: operational standard (municipal treatment)
blank cell: not analysed
h* heath unit guideline
none: there is no standard
(Jagger Hims Limited 2003)

3.6.3 Provincial Groundwater Monitoring Network Groundwater Quality

Groundwater quality sampling in the Ganaraska Region Conservation Authority is being conducted as part of the Ministry of the Environment Provincial Groundwater Monitoring Network (PGMN). PGMN wells are not used for private or public drinking water supplies. They do however provide information on regional groundwater aquifers that supply drinking water. The information from the Provincial Groundwater Monitoring Network will provide an early warning system for changes in water levels caused by climatic conditions, as well as changes in water quality from natural or anthropogenic (man-made) causes.

There are seven PGMN wells at three locations in the Wilmot Creek watershed (Table 3.29, Figure 3.61). Groundwater quality sampling has been completed in 2002, 2006, 2007 and 2008. Samples were tested for most parameters specified in the Ontario Drinking Water Quality Standards Regulation (O. Reg. 169/03) as well as operational guideline requirements. All of the sampling procedures, storage and laboratory testing are carried out according to MOE guidelines.

Parameters that affect operation and well infrastructure (such as pumps and pipes) that exceeded recommended guidelines at most monitoring wells included organic nitrogen, iron and total suspended solids. Hard water was prevalent at monitoring wells along with manganese as a result of local geology. Sodium is the only parameter that exceeded drinking water standards, however at low concentrations. However, it should be noted that parameters that exceeded guidelines were temporally variable in concentration, and did not always exceed guidelines when sampled.

Table 3.29: PGMN wells

Well Number	Well Depth (m)	Aquifer (relative location)
GA113	40.28	Deep
GA138	153.92	Very Deep
GA139	215.8	Very Deep
GA189	67	Deep
GA114-3	12.09	Shallow
GA114-4	15.12	Middle
GA114-2	8.49	Shallow

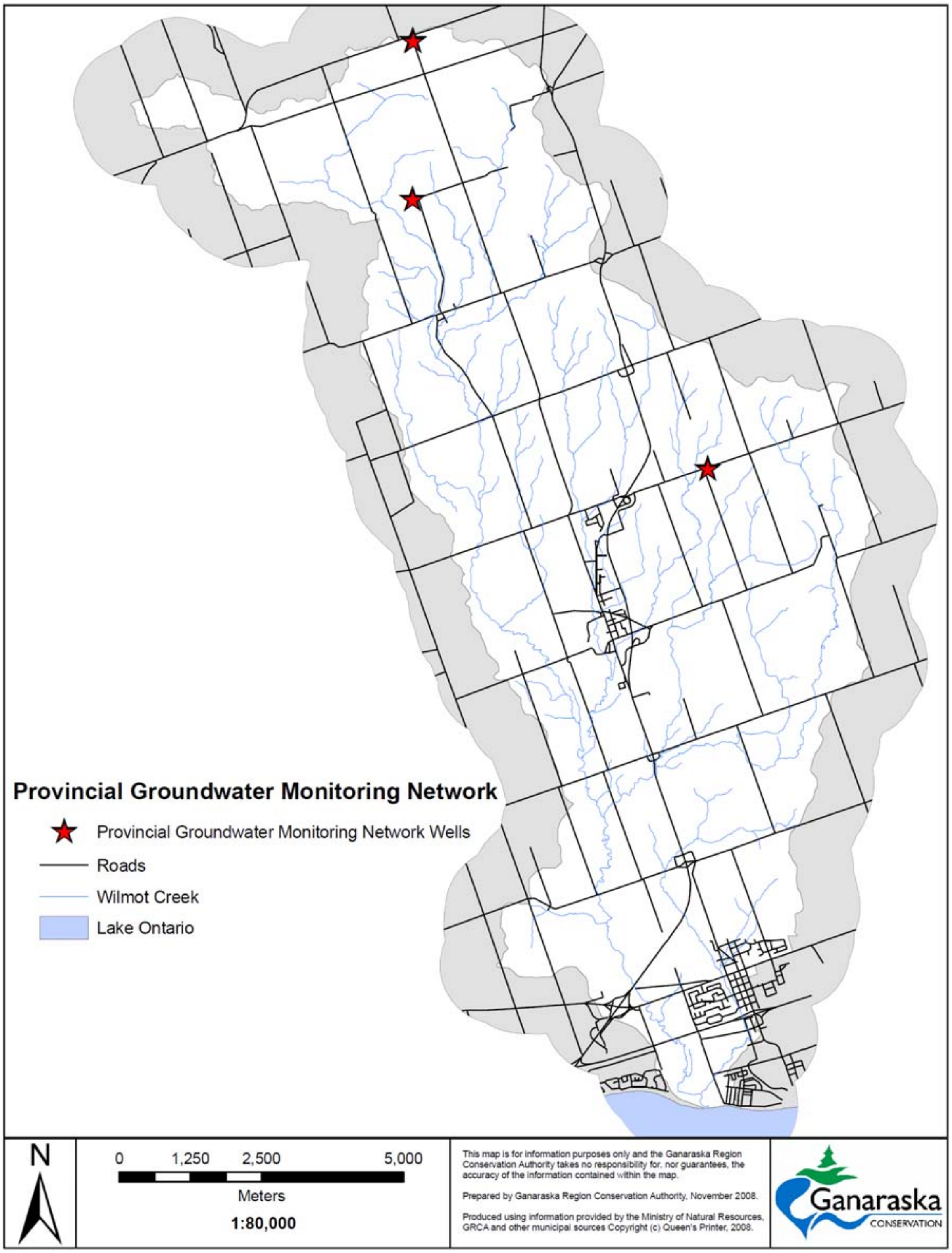


Figure 3.61: Provincial Groundwater Monitoring Network wells

3.7 Surface Water Quality

The quality of surface water is influenced by the surrounding landscape and in stream transformations. Land use and cover in a watershed can influence water chemistry and integrity of the stream environment. Non-point sources (i.e., runoff) that enter surface water contain components of the drainage area. Surrounding land use and cover therefore play an important role in the type and amount of nutrient, bacteria, chemical and metal loading that occurs in a water system. Modes of transportation into a water body such as a stream include point sources (direct) and non-point sources (indirect), atmospheric deposition (precipitation and dust), internal transportation (nutrient cycling), and groundwater inputs. Surface water quality modeling helps to understand how the landscape and land uses contribute to surface water quality. At this time however, surface water quality modeling is not yet available for the Wilmot Creek watershed. It is anticipated that a model will be available by 2010 through a drinking water source protection initiative.

Quality water is needed for a healthy aquatic ecosystem, from an entire ecosystem perspective and from a human needs standpoint. Many guidelines exist that set out limits for certain parameters as they relate to aquatic organism toxicity levels, unsafe use of water for recreational activities, and water use for agricultural purposes and for human consumption. In Ontario the provincial government has set out *Provincial Water Quality Objectives* based on uses such as aquatic life needs and recreation (Ontario Ministry of the Environment and Energy 1999).

In addition to provincial guidelines, the federal government has set out *Canadian Water Quality Guidelines* based on aquatic life, recreation and agricultural use (Canadian Council of Ministers of the Environment 2006). Both governments also have drinking water quality objectives or guidelines that set limits on water quality parameters so that drinking water is safe for human consumption (Ontario Ministry of the Environment 2003; Canadian Council of Ministers of the Environment 2006). These guidelines and objectives help to rank and understand water quality in terms of an environmental or human need.

When analyzing surface water quality of Wilmot Creek, *Provincial Water Quality Objectives* related to aquatic life tolerance or recreational water usage will be used. Where provincial objectives do not exist, *Canadian Water Quality Guidelines* for aquatic life tolerance will be used. In order to characterize the surface water quality of Wilmot Creek, water quality parameter trends through time will be analyzed and current surface water quality will be examined.

3.7.1 Methods

Surface Water Quality Data Sets

Presently, three surface water quality programs exist within Wilmot Creek: the Ganaraska Region Water Quality Monitoring Network (GRWQMN), the

Ganaraska Region Conservation Authority Municipal Salt Monitoring Program, and the Provincial Water Quality Monitoring Network. In the Wilmot Creek watershed, 17 GRWQMN sample sites exist. Combinations of these sites were sampled once a month in 2005 and 2006, ranging in months from June to September. Table 3.30 outlines the GRWQMN sample sites and Figure 3.62 shows their locations.

Table 3.30: GRWQMN sampling frequency

Site	Sample Dates
WIL-01-06 to WIL-13-06	June 13, July 11, August 8, September 12, 2006
W-01-05	July 19, August 30, September 27, 2005
FO-01-06	June 13, July 11, August 8, September 12, 2006
FO-02-06	June 13, July 11, August 8, September 12, 2006
FO-01-05	July 19, August 30, September 27, 2005

A Municipal Salt Monitoring Program is conducted by the Ganaraska Region Conservation Authority. The study area is located within and around the community of Orono. Samples are taken from Orono Creek from Concession Road 7 south to Concession Road 4 (Figure 3.63). Starting in February 2006 water quality samples were taken from 10 sites within the study area. Samples in 2006 were taken in February, March, June, July, August and December. In 2007 sampling occurred from January to May, and October to December.

In 2009 a Baseflow Water Quality Monitoring Program was carried out in Wilmot Creek. Since a stream or river experiences baseflow conditions (groundwater contribution only) 70% of the time, water quality should be consistent 70% of the time unless it is affected by point source contamination. 50 sites (Figure 3.64), of which 3 were dry, were sampled between August 25th and 26th, during a period of no rain and baseflow conditions.

The largest surface water data set exists through the Provincial Water Quality Monitoring Network (PWQMN), operated in partnership by the Ontario Ministry of the Environment (MOE) and the Ganaraska Region Conservation Authority. Throughout the existence of the program, 51 parameters have been analyzed. Two active and one historic PWQMN station are located in Wilmot Creek below Concession Road 4. Figure 3.65 shows the locations of the active PWQMN stations and Table 3.31 outlines the years of data available.

Table 3.31: PWQMN station and sampling frequency

Station	PWMQN Station ID	Years Sampled	Status
Wilmot Creek at Highway 401	06011700102	1965 to 1972	Inactive
Orono Creek at Squair Road	06011700202	1964 to present*	Active
Wilmot Creek at Regional Road 2	06011700302	1973 to present**	Active

- * No sampling occurred from 1991 to 2001
- **No sampling occurred in 1995 and 1998 to 2001
- Turbidity sampling stopped at both stations in December 2006

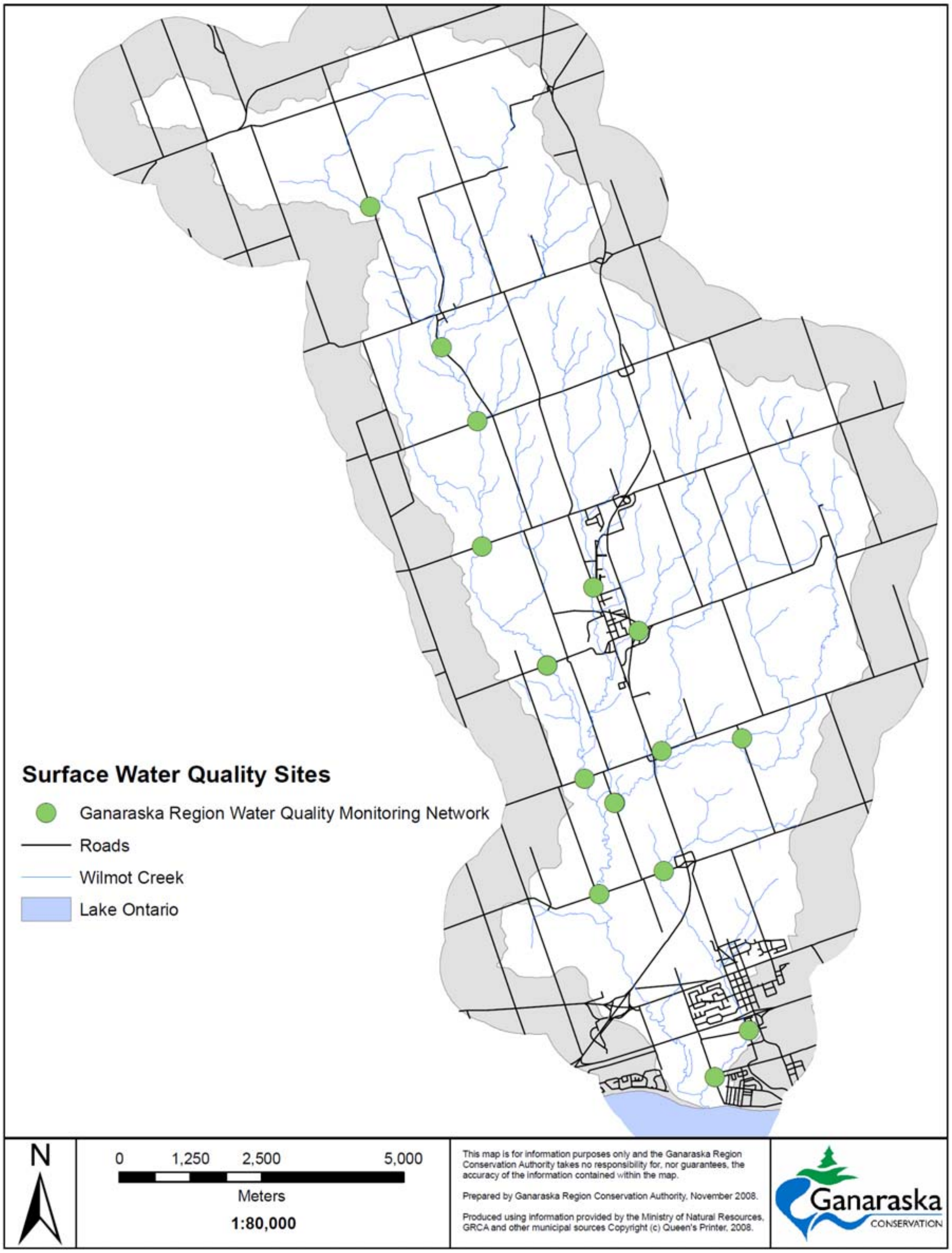


Figure 3.62: Ganaraska Region Water Quality Monitoring Network sites

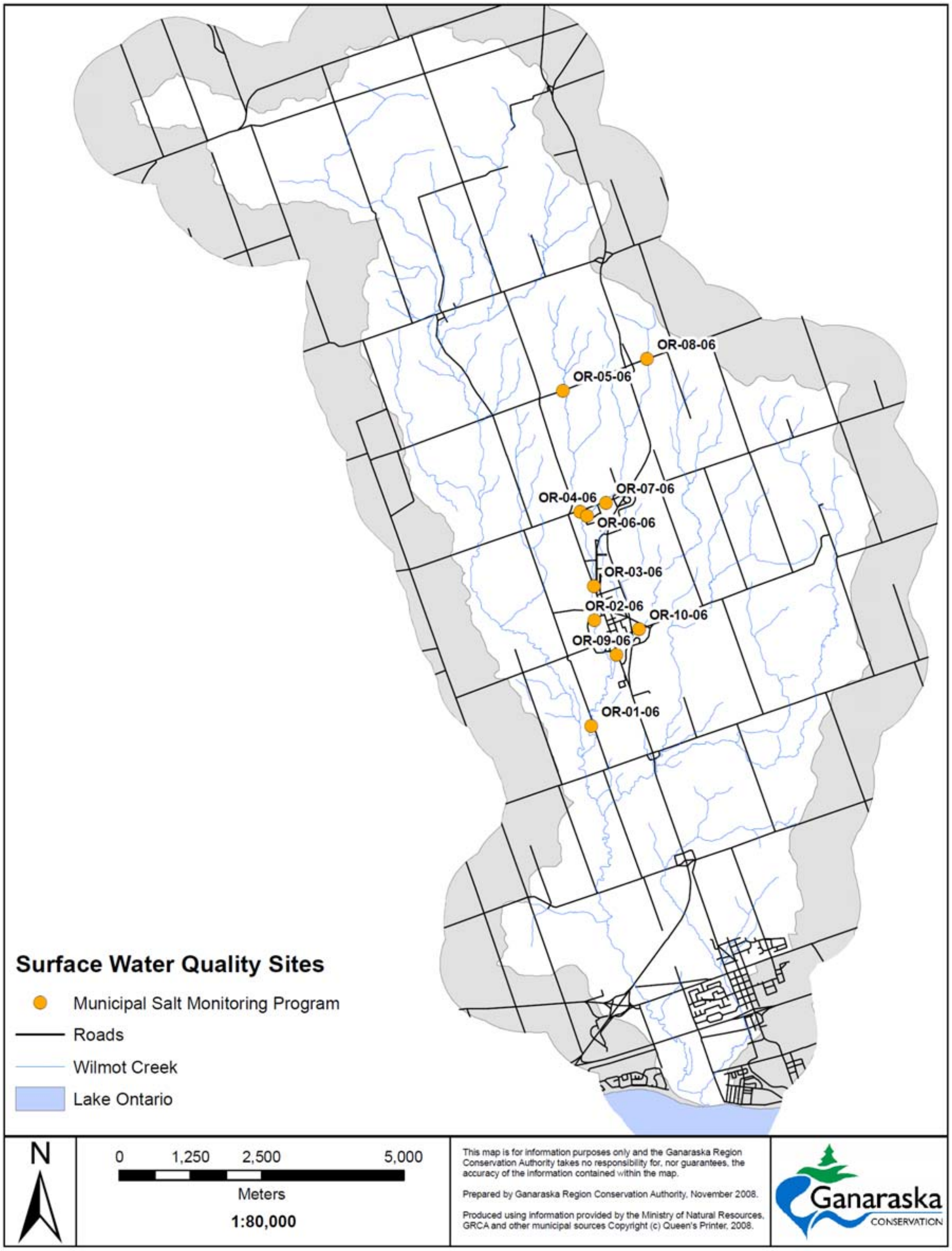


Figure 3.63: Municipal Salt Monitoring Program sites

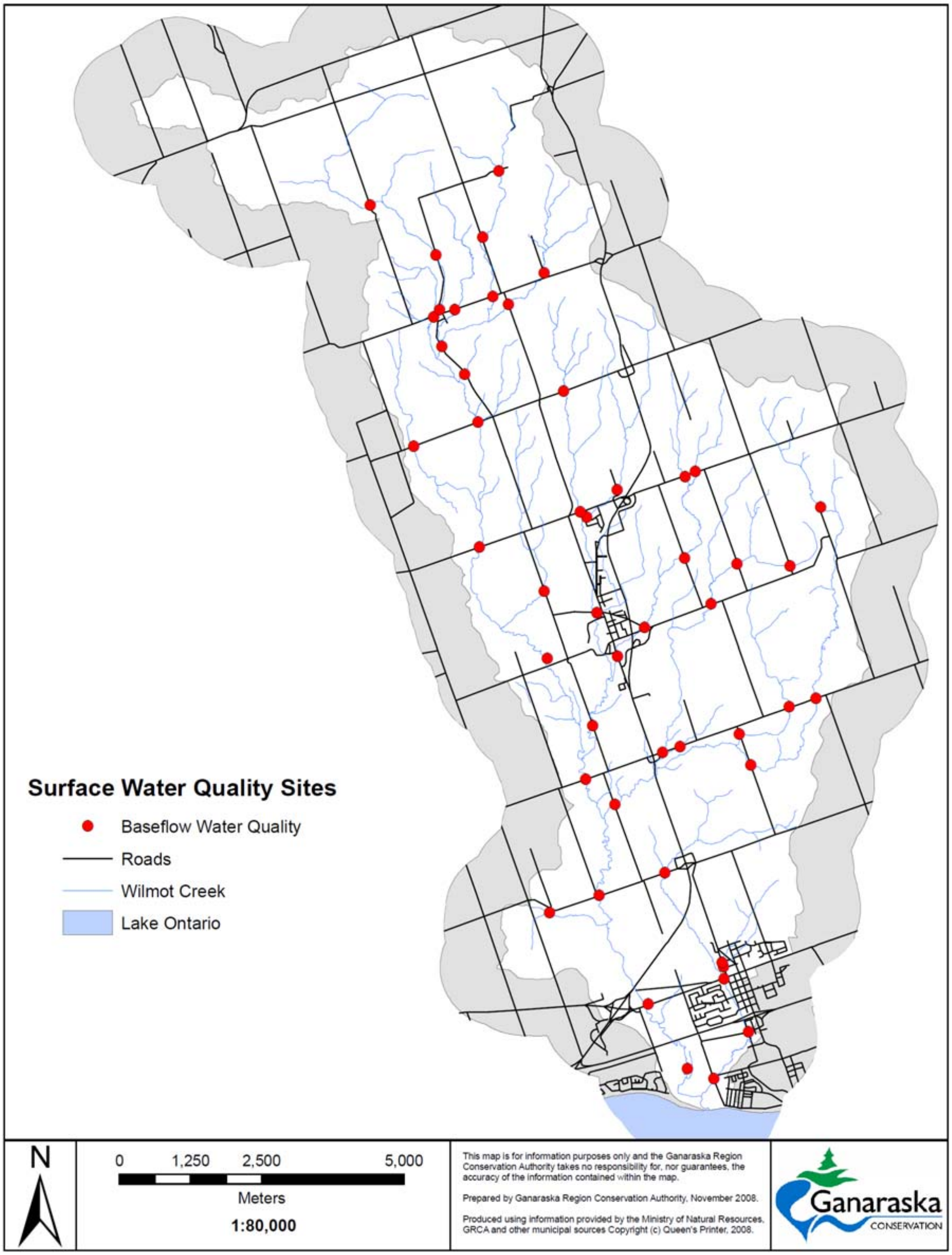


Figure 3.64: Baseflow Water Quality Monitoring Network sites

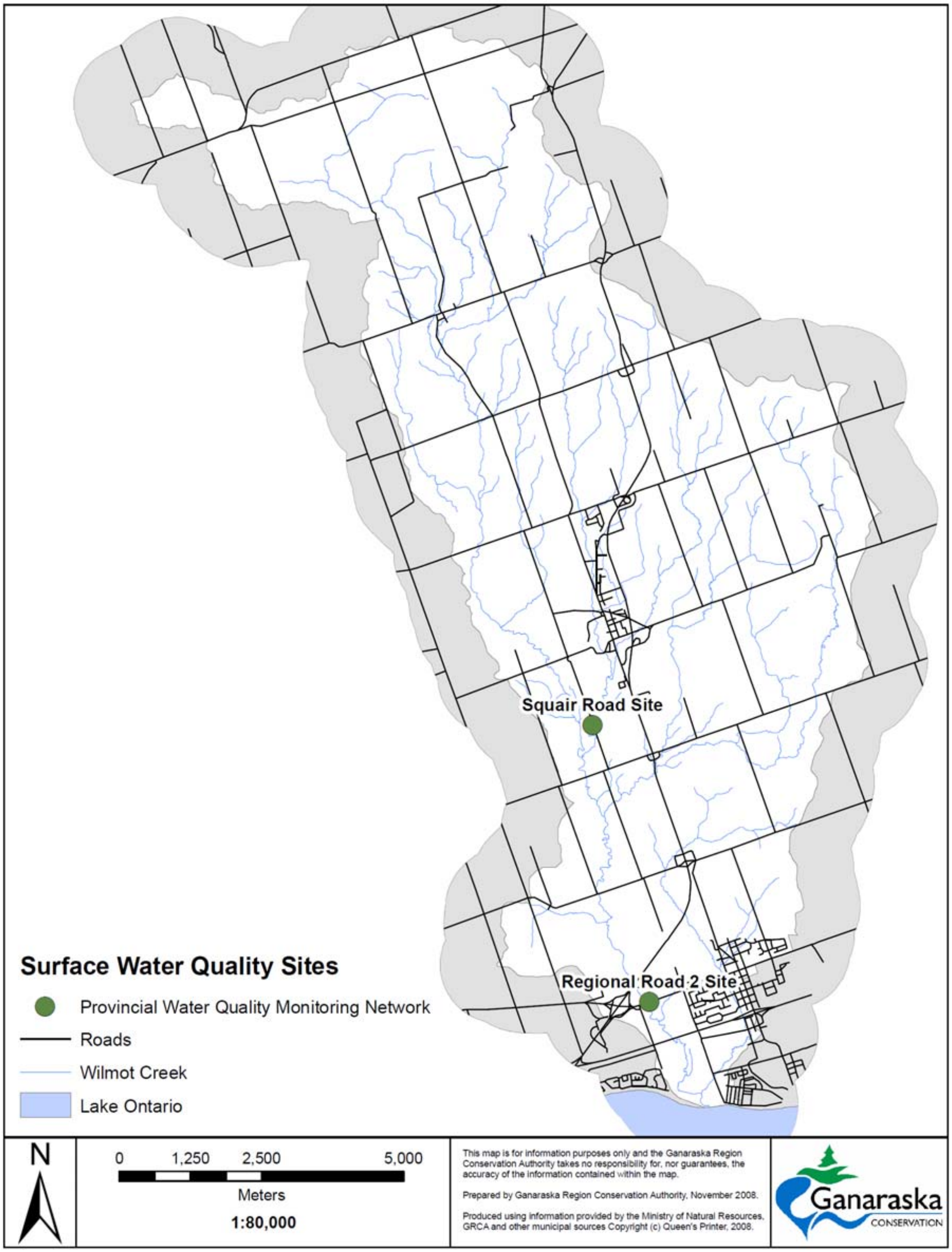


Figure 3.65: Provincial Water Quality Monitoring Network sites

Water Quality Sampling Methods

Since 2002 surface water quality sites have been monitored using a YSI™ 600QS model water quality probe. Parameters include temperature, salinity, pH, dissolved oxygen, total dissolved solids and conductivity.

For the GRWQMN program, surface water was analyzed for alkalinity, total suspended solids, nitrate, nitrite and chloride concentrations in-house using a HACH DR/2010 Portable Datalogging Spectophotometer. The Spectophotometer method used to analyze alkalinity was the sulphuric acid method with a digital titrator; total suspended solids was the photometric method; nitrate was the calcium reduction method; nitrite was the diazotisation method; and chloride was the Mercuric Thiocyanate method (HACH Company 1989).

Along with in-house analysis, samples were sent to SGS Lakefield Research Limited for analysis of total phosphorus, ammonia-ammonium, unionized ammonia, *Escherichia coli* and total coliform.

The chloride monitoring program is carried out by collecting surface water using a 500ml bottle and analyzed in-house using the HACH DR/2010 Portable Datalogging Sectophotometer with the Mercuric Thiocyanate method (HACH Company 1989).

The baseflow water quality monitoring analysis was conducted by SGS Lakefield Research in 2009 for total phosphorus, nitrate, nitrite, total suspended solids, ammonia-ammonium, unionized ammonia, *Escherichia coli* and total coliform. Turbidity was sampled in the field with a HACH 2100P Turbidimetre.

Since the Provincial Water Quality Monitoring Network is run as a partnership, samples are taken by the Ganaraska Region Conservation Authority and analyzed by the MOE at a provincial lab. Surface water was taken from the sample site in 500 ml bottles, preserved if needed and shipped to the MOE lab. Parameters analyzed by the MOE lab since 1964 include those outlined in Table 3.32.

In 2007 the Ganaraska Region Conservation Authority, through a MOE partnership with Environment Canada, sampled for pesticides in Wilmot Creek. Eight samples were taken from June to November, 2007 at the Regional Road 2 PWQMN station. The MOE Lab analyzed these samples for concentrations of 2,4-D, Atrazine, Glyphosate and Metolachlor.

Table 3.32: List of water quality parameters sampled through PWQMN

Parameter Category	Parameters
Physical	dissolved oxygen, biological oxygen demand, conductivity, pH, alkalinity, carbon, colour, turbidity, residues, dissolved inorganic carbon, dissolved organic carbon, chemical oxygen demand
Major Ions/Anions	calcium, magnesium, sodium, potassium, hardness, chloride, silicates
Metals and Chemicals	aluminum, barium, beryllium, cadmium, cobalt, chromium, copper, iron, manganese, molybdenum, nickel, lead, strontium, titanium, vanadium, zinc, phenolics, cyanide, arsenic, sulphate, mercury
Nutrients	total ammonium, nitrite, nitrate, phosphate, total phosphorus, total kjeldahl nitrogen
Bacteria	Fecal Streptococcus, Fecal Coliforms, Total Coliforms, *Escherichia coli*, *Pseudonom Aeruginosa*

Water Quality Data Screening

Although the PWQMN data contain the most surface water quality data, not all of the 51 parameters are usable. Some parameters were sampled in a short time period and therefore are statistically irrelevant. Others were only sampled during the 1960s or during time periods prior to 2002 when the PWQMN program was restarted after being cancelled in 1998. Therefore certain parameters and sample sites have been removed from the water quality analysis.

The Wilmot Creek at Highway 401 station has been removed from data analysis since it was only sampled from 1965 to 1972, and not enough data exists to determine relevant trends through time.

The following parameters were not analyzed because the data is historic and does not reflect current conditions (prior to 1997) or there are less than 30 sample points making them statistically invalid. As a result of these conditions, the following parameters were not analyzed.

- Cyanide: two sample in 1980
- Arsenic: sampled between 1980 and 1990
- Sulphate: six samples in 1973 and 1994
- Silicates: eight samples in 2007
- Phenolics: sampled prior to 1994
- Turbidity reported in JTU: sampled prior to 1972
- Any nitrite or nitrate sampled prior to 1987 due to differences in analysis
- Total Residue: sampled prior to 1997
- Filtered Residue: sampled prior to 1997
- Mercury: two samples in 1980
- Colour: one samples in 1969

- Dissolved Organic Carbon: sampled in 1972 and 1973
- Chemical Oxygen Demand: five samples in 1984
- *Pseudonom Aeruginosa* MF: six samples in 1994
- Fecal Streptococcus MF: sampled prior to 1994
- Fecal Coliform MF: sampled prior to 1993
- *Escherichia coli*: six samples in 1994
- Total Coliform: sampled prior to 1986.

Trends in metals were analyzed using data from 2002 to 2007 to eliminate invalid results due to MOE laboratory detection limit changes that have occurred since the 1970s.

<u>Surface Water Quality Guidelines</u>

Surface water quality guidelines were used to evaluate measured water quality parameters. Table 3.33 outlines the guidelines used and the source.

Table 3.33: Surface water quality guidelines or objectives

Parameter	Guideline or Objective	Parameter	Guideline or Objective
pH *	6.5-8.5	Cobalt*	0.9 µg/L
Total Suspended Solids⟵	25 mg/L	Iron*	300 µg/L
Dissolved Oxygen*	5 to 8 mg/L (temperature dependant)	Lead*	5 µg/L
Nitrate-Nǂ	2.9 mg/L	Molybdenum*	40 µg/L
Nitrite-Nǂ	0.197 mg/L	Nickle*	25 µg/L
Unionized Ammonia*	0.02 mg/L	Vandium*	6 µg/L
Total Phosphorus*	0.03 mg/L	Total Chromium †	2 µg/L
*Escherichia coli**	100 cfu/100ml (recreation)	Zinc*	30 µg/L
Chlorideǂ	250 mg/L	Atrazine ǂ	1.8 µg/L
Aluminum*	75 µg/L	Glyphosate ǂ	65 µg/L
Beryllium*	11 µg/L	Metolachlor *	3 µg/L
Cadmium*	0.2 µg/L	2,4-D ǂ	4 µg/L
Copper*	5 µg/L		

* Ontario Ministry of the Environment and Energy (1999)
ǂCanadian Council of Ministers of the Environment (2006)
† Pawlisz et al. (1997)
⟵Department of Fisheries and Oceans Canada (2000)

<u>Water Quality Sampling Flows</u>

Stream flow was measured at the Wilmot Creek at Concession Road 3 stream gauge during sampling events for the GRWQMN (Figure 3.66) and the PWQMN (2002 - 2007) (Figure 3.67). The flows at the Concession Road 3 gauge station were compared against parameter concentrations using nonparametric Spearman's Ranks Correlation.

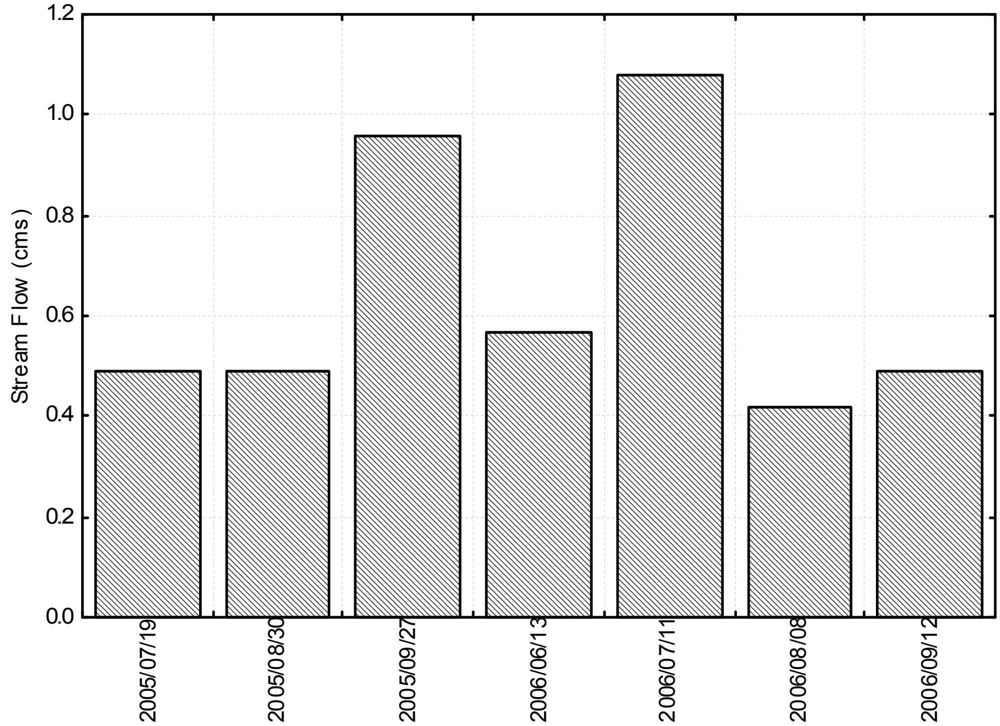


Figure 3.66: Stream flow of Wilmot Creek measured at the Concession Road 3 gauge station during GRWQMN sampling

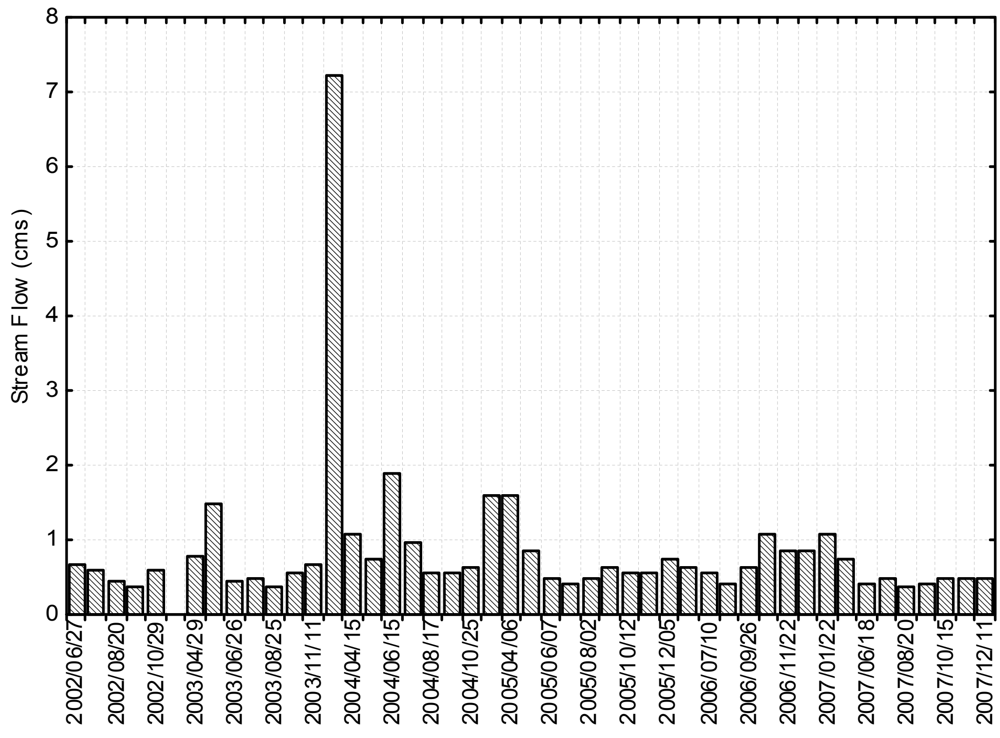


Figure 3.67: Stream flow in Wilmot Creek measured at the Concession Road 3 gauge station during PWQMN sampling, 2002 to 2007

Statistical Analysis

All statistical analysis was done using the computer statistical package Statistica using non-parametric tests.

- *GRWQMN Data Analysis*: Basic descriptive statistics on the GRWQMN data were conducted and median values were calculated due to the non-parametric nature of the data. Geometric means were calculated for bacteria data. Analysis comparing dissolved oxygen to stream temperature and parameter relationships with stream discharge is described using Spearman's Ranks Correlation.

- *Municipal Salt Monitoring Program Data Analysis*: Comparison between months dominated by rain (May to October inclusive) and snow/mixed precipitation and snowmelt runoff (November to April inclusive) was analyzed using the Mann-Whitney U non-parametric test. Comparison between sample sites and streams was analyzed using the Kruskal-Wallis non-parametric test.

- *Baseflow Water Quality Data Analysis*: Basic descriptive statistics on the baseflow water quality data were conducted and median values were calculated due to the non-parametric nature of the data. Geometric means were calculated for bacteria data. Catchment areas contributing to each sample site were defined using Arc Hydro. Each catchment area was then evaluated for land use types with 2002 Ecological Land Classification data. These land use types were used to infer a relationship to the water quality parameters sampled at each site.

- *PWQMN Data Analysis*: Analysis of trends over time and relationships to flow using PWQMN data was done with Spearman's Ranks Correlation. Comparisons were completed for each parameter (dependent variable) compared against time (independent variable). The level of significance was set at $\alpha = 0.05$. Therefore, if *$p < 0.05$ there is statistical significance* in the strength of the linear relationship (r – linear correlation coefficient) between a particular parameter and time. If significance is found in the r value, then the regression equation ($y = b0 + b1(x)$) can be used to predict future chemical concentrations or to fill in data gaps. Before predictions can be made, the coefficient of determination (r^2) must be close to 1 (preferably >0.6). This indicates that the regression line describes a significant amount of the parameter.

3.7.2 Ganaraska Region Water Quality Monitoring Network Results

The Ganaraska Region Water Quality Monitoring Network allows a watershed-wide analysis of water quality. Given the small data set of each GRWQMN station, all stations will be grouped to give an overall picture of water quality in Wilmot Creek.

Physical Parameters

The physical parameters of the surface water within Wilmot Creek indicate the base conditions water quality. Table 3.34 describes the physical conditions of the Wilmot Creek surface water as sampled through the GRWQMN. All physical parameters are within acceptable ranges and concentrations are dependent on stream conditions such as flow and temperature.

Table 3.34: Range of physical parameters sampled through the GRWQMN

Variable	n*	Median	Minimum	Maximum	10^{th} Percentile	90^{th} Percentile
pH	65	7.73	6.3	8.37	6.48	8.30
Dissolved Oxygen (mg/L)	63	10.7	1.4	16.8	8.6	15.2
Conductivity (µs/cm)	65	561	335	1527	453	938
Salinity (%)	65	0.27	0.16	0.77	0.22	0.46
TDS (g/L)	59	0.36	0.22	1.00	0.29	0.59
Alkalinity (mg/L as CaCO3)	65	192	102	334	132	254
TSS (mg/L)	61	8	0	234	2	26
Turbidity (mg/L)	65	1	0.21	11.4	0.36	5.9

*n represents the number of samples

Results show the following:

- pH levels are close to or within the acceptable range of 6.5 to 8.5.
- Total suspended solids (TSS) rarely (1% of samples greater than 25mg/L) exceeded the recommended 25 mg/L.
- The median TSS concentration of 8 mg/L reflects the usual condition without influences of high flows.
- TSS is affected by high flows (discharge), increasing as flows increase ($n=61$, $r^2=0.14$, $r_s=0.38$, $p=<0.05$).
- Dissolved oxygen ranging between 1.4 and 16.8 mg/L are within acceptable ranges during sampling.
- Dissolved oxygen is noted to decline as stream temperatures increase ($n=63$, $r_s = -0.6744$, $p = 0.00$) (Figure 3.68)

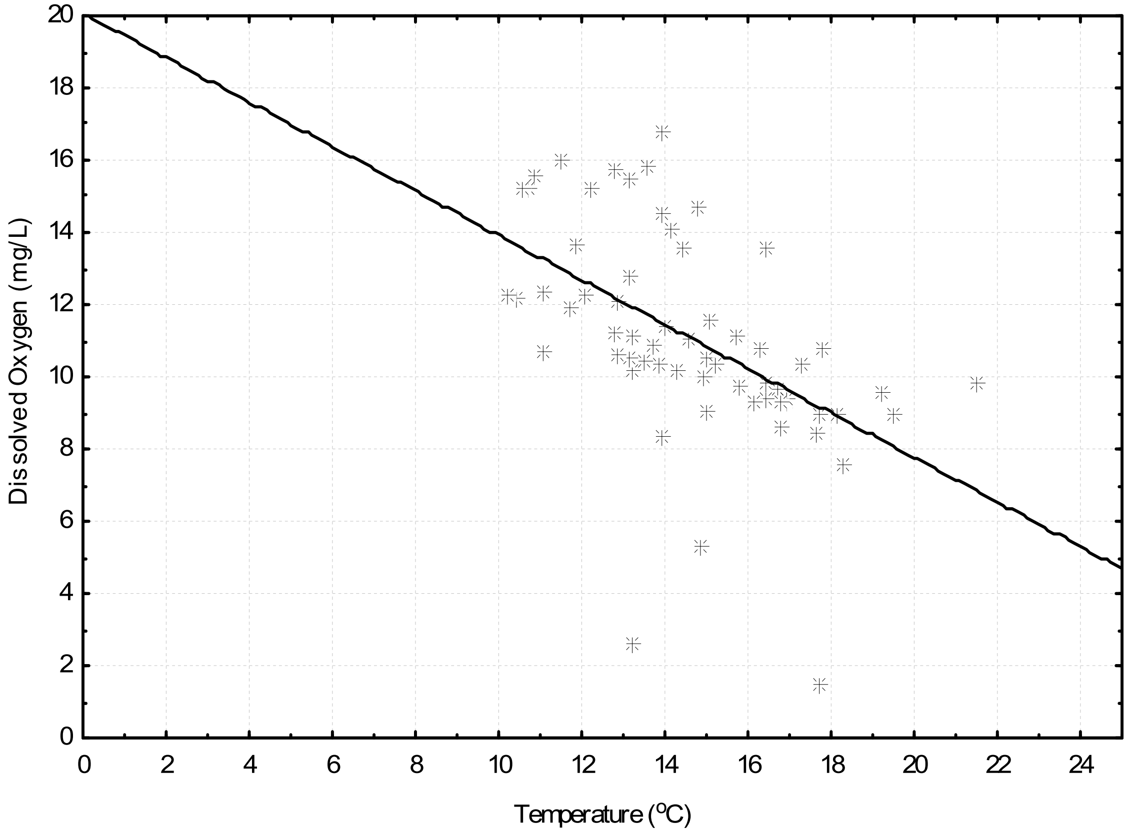


Figure 3.68: Dissolved oxygen concentrations in relation to stream temperature

Nutrients
Five nutrient parameters have been sampled through the GRWQMN and concentration ranges are found in Table 3.33.

- Nitrate-N concentrations exceeded the Canadian Water Quality Guideline (CWQG) of 2.9 mg/L 17% of the time and nitrite-N concentrations never exceeded the CWQG of 0.197 mg/L when sampled through the GRWQMN.
- Ammonia-ammonium limits are dependent on stream temperature and unionized ammonia has a PWQO of 0.02 mg/L. Based on this objective unionized ammonia at sampled GRWQMN stations has exceeded the PWQO 19% of the time.
- Total phosphorus has also exceeded the PWQO of 0.03 mg/L 45% of the time.
- Unionized ammonia median concentration is below the PWQO, whereas total phosphorus is equal to the PWQO (Table 3.35).

Table 3.35: Nutrient concentrations as sampled through the GRWQMN

Variable	n	Median	Min	Max	10th Percentile	25th Quartile	75th Quartile	90th Percentile
Nitrate-N (mg/L) (CWQG = 2.9mg/L)	65	1.0	0.0	5.2	0.6	0.1	2.0	3.5
Nitrite-N (mg/L) (CWQG = 0.197mg/L)	65	0.005	0.002	0.09	0.004	0.003	0.009	0.034
Ammonia-ammonium (mg/L)	65	0.1	0.04	0.3	0.1	0.1	0.2	0.2
Unionized Ammonia (mg/L) (PWQO = 0.02mg/L)	63	0.01	0.005	0.051	0.005	0.005	0.017	0.024
Total Phosphorus (mg/L) (PWQO = 0.03mg/L)	65	0.03	0.01	0.17	0.01	0.01	0.06	0.10

Bacteria

Ranges of *Escherichia coli* frequently exceed the PWQO as sampled through the GRWQMN (Table 3.36). Concentrations give an idea of bacteria within Wilmot Creek. However samples are only taken once per site per sampling time and are not based on five samples per site. Therefore results must be generally interpreted.

- *Escherichia coli* exceed the PWQO 65% of the time throughout the entire Wilmot Creek watershed.
- Total coliform and *Escherichia coli* are affected by high flows, increasing as flows increase (n=65, r^2=0.11, r_s=0.33, p=<0.05; n=65, r^2=0.07, r_s=0.27, p=<0.05 respectively).

Table 3.36: Bacteria concentrations as sampled through the GRWQMN

Variable	n	Geometric Mean	Min	Max	10th Percentile	90th Percentile
Escherichia coli (cfu/100ml)(PWQO = 100cfu/100ml)	65	262	20	7400	40	1600
Total Coliform (cfu/100ml)	65	1944	102	14900	540	5300

3.7.3 Wilmot Creek Municipal Salt Monitoring Program Results

Chloride concentrations sampled through the Municipal Salt Monitoring Program within Orono Creek ranged from 1.3 to 162 mg/L (Figure 3.69). None of the samples exceeded the Canadian Environmental Quality Guideline of 250 mg/L. During months that receive snow or mixed precipitation and snowmelt runoff (November to April) chloride concentrations were higher than in the months that were dominated by rain (May to October) ($z=6.01$, $p = 0.00$).

Although 10 sample sites were chosen, site OR-08-06 was almost always dry at the time of sampling and was removed from analysis. When comparing sample sites, OR-10-06, located on Sommerville Road and to the east of Highway 115/35 has lower chloride concentrations than sites OR-01-06, OR-02-06, OR-03-06, OR-06-06, and OR-07-06. OR-06-06 also has higher concentrations of chloride than OR-04-06 (H (8, N= 178) =44.42 p =0.00) (Figure 3.69).

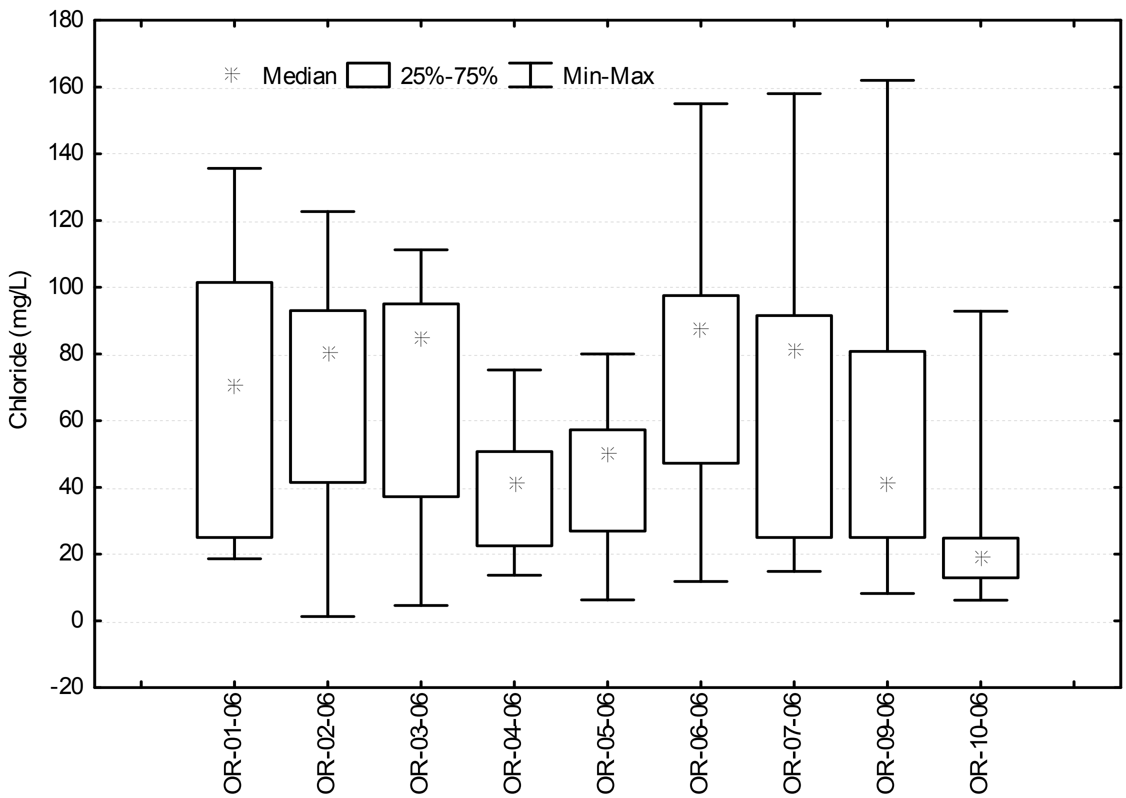


Figure 3.69: Differences in chloride concentrations at sample sites

3.7.4 Baseflow Water Quality Monitoring Program Results

The Ganaraska Baseflow Water Quality Monitoring Program allows a watershed-wide analysis of water quality during baseflow conditions. Baseflow occurs 70% of the time in a year. Therefore, water quality is more likely to be a result of groundwater quality or very local land uses (e.g., point source contamination). By sampling numerous sites, a detailed picture of areas that have uniform water quality can be seen, given that surface water runoff and precipitation inputs are controlled.

Physical Parameters
The physical parameters of the surface water within Wilmot Creek suggest the background conditions of the quality of water. Table 3.37 describes the physical conditions of Wilmot Creek surface water as sampled through the Baseflow Water Quality Monitoring Program. All physical parameters are within acceptable ranges, with concentrations dependent on stream conditions such as flow and temperature. TSS exceeded the recommended 25 mg/L 9% of the time; the median concentration of 4 mg/L reflects the usual condition of Wilmot Creek.

Table 3.37: Range of physical parameters through the Baseflow Water Quality Monitoring Program

	n	Median	Minimum	Maximum	10^{th} Percentile	90^{th} Percentile
Temperature (^{o}C)	47	16.2	11.1	21.0	11.7	19.0
Dissolved Oxygen (mg/L)	47	12.7	7.7	14.5	10.3	138
Conductivity (us/cm)	47	605	141	1067	411	936
Salinity (%)	47	0.29	0.13	0.53	0.20	0.46
pH	47	7.98	7.66	8.16	7.9	8.09
TDS (mg/L)	47	0.39	0.18	0.70	0.27	0.61
Turbidity (mg/L)	47	2	0.5	35	0.95	22.0
TSS (mg/L)	47	4	2	58	2	22.0

Nutrients
Five nutrient parameters were sampled through the Baseflow Water Quality Monitoring Program and concentration ranges are found in Table 3.38.

- Nitrate–N exceeded the CWQG of 2.9 mg/L at eleven sites, or 23% of the time.
- Nitrite–N never exceeded the CWQG of 0.197 mg/L.
- Unionized ammonia concentrations at sample sites were always the PWQO.
- Total phosphorus exceeded the PWQO of 0.03 mg/L at seven sites, or 15% of the time at sampled baseflow water quality monitoring stations.
- Nitrite-N, nitrate-N and total phosphorus median values were below the respective water quality guidelines (Table 3.38).

Table 3.38: Nutrient concentrations sampled through the Baseflow Water Quality Monitoring Program

	n	Median	Minimum	Maximum	10th Percentile	90th Percentile
Nitrite-N (mg/L)	47	0.06	0.06	0.06	0.06	0.06
Nitrate-N (mg/L)	47	1.71	0.05	9.01	0.28	4.84
Total Ammonia (mg/L)	47	0.10	0.04	0.21	0.04	0.10
Unionized Ammonia (mg/L)	47	0.005	0.005	0.02	0.005	0.07
Total Phosphorus (mg/L)	47	0.01	0.01	0.12	0.01	0.07

Bacteria
Ranges of *Escherichia coli* frequently exceed the PWQO as sampled through the Baseflow Water Quality Monitoring Program. Sample concentrations give an idea of bacteria concentrations in Wilmot Creek, however samples were only taken once per site and are not based on five samples per site. Therefore, results must be generally interpreted. *Escherichia coli* exceed the PWQO at 16 sites, or 34% of the time. Total coliform concentrations range between 120 and 3100 counts/100ml.

Effects of Land Use on Baseflow Water Quality Monitoring Water Quality
Catchment areas were delineated for each sample point using Arc Hydro to determine land uses within the drainage areas contributing to the sample sites. Of the 50 sample sites, 11 sites were dominated by natural areas (forests, meadows, thickets, wetlands, open areas and open water), four sites were dominated by development (roads, rail, urban areas, rural development or aggregates), and 35 sites were dominated by agricultural land use (intensive and non intensive agriculture). Catchments that were dominated by agriculture (35 sites) had concentrations of total phosphorus (six sites) and nitrate (seven sites) above the PWQO or CEQG. Natural area dominated catchments (11 sites) concentrations of total phosphorus (one site) and nitrate (two sites) were above the PWQO or CEQG. Of the four catchments dominated by development two of the sites exceeded the nitrate guideline and one site exceeded the total phosphorus guideline. *Escherichia coli* exceeded at 23 sites and occurred in catchments that were dominated by agriculture, natural areas or development.

Although this coarse analysis of land use relationships to water quality provides an indication that land uses associated with human disturbances (e.g., agriculture and development) can cause increases in bacteria and nutrients, the same is seen with land uses associated with natural areas. It must be noted that at 14 sites where catchment were dominated by agricultural land use, no exceedances in water quality parameters such as bacteria and nutrients occurred. It appears there is a possible relationship between water quality and local land use activities and presence/condition of riparian areas, however further investigation into causes of higher concentrations of bacteria and nutrients needs to occur.

3.7.5 Provincial Water Quality Monitoring Network Results

Physical Parameters
Table 3.39 describes the physical conditions as sampled at the two Provincial Water Quality Monitoring Network (PWQMN) sites in Wilmot Creek. All physical parameters are within acceptable ranges (ranging between the 10^{th} and 90^{th} percentiles) and the extreme ranges as indicated by the minimum and maximum values are attributed to sampling anomalies, extreme flow or temperature conditions. Particulate residue measured between 2002 and 2007 at the Regional Road 2 station is related to increases in discharge, as measured at the Concession Road 3 gauge station ($n=46$, $r_s = 0.38$, $p<0.05$).

Table 3.39: Physical parameters as sampled at the PWQMN stations

PWQMN Station	n	Median	Minimum	Maximum	10^{th} Percentile	90^{th} Percentile
Turbidity (FTU)						
Squair Road	218	1.6	0.28	86.0	0.6	8.3
Regional Road 2	188	3.1	0.54	102	1.2	12.1
Particulate Residue (mg/L)						
Squair Road	212	5.0	0	396	1.0	15.0
Regional Road 2	281	6.5	0	284	2.35	25.9
pH (infield and laboratory readings)						
Squair Road	359	8.17	6.76	8.75	7.60	8.34
Regional Road 2	429	8.29	6.35	9.62	7.76	8.45
Dissolved Oxygen (mg/L)						
Squair Road	327	10.7	1.06	18.4	8.1	13.6
Regional Road 2	283	11.3	1.48	19.8	8.8	14.4
Alkalinity (mg/L) as CaCO3						
Squair Road	185	236	117	285	251	262
Regional Road 2	207	213	119	254	188	236
Conductivity (μs/cm)						
Squair Road	47	946	533	1050	828	992
Regional Road 2	47	600	399	658	560	638

Other Parameters
As previously mentioned, 51 water quality parameters have been sampled since 1964 through the PWQMN, however some parameters have been removed from this analysis of surface water quality. By relating water quality parameters to the *Provincial Water Quality Objectives* or the *Canadian Water Quality Guidelines* these parameters can be listed as those that have exceeded the guidelines, those that have not, and those where no objective or guidelines exist (Table 3.40). For the purpose of this document, surface water quality parameters that exceed a PWQO or CWQG as well as chloride will be analyzed.

Table 3.40: PWQMN sampled parameters between 2002 and 2007 in relation to PWQO and CWQG

Sampled Concentrations Greater Than PWQO	Sampled Concentrations Less Than PWQO	Sampled Concentrations Greater Than CWQG	Sampled Concentrations Less Than CWQG	No PWQO or CWQG
Aluminum	Beryllium	**Nitrate-N**	**Chloride**	Total Ammonium
Cadmium	Copper	**Total Chromium**	**Nitrite-N**	Barium
Cobalt	Molybdenum			Calcium
Iron	Nickle			Carbon
Lead	Vandium			Hardness
Total Phosphorus	Zinc			Magnesium
				Manganese
				Phosphate
				Potassium
				Sodium
				Strontium
				Titanium
				Total Kjeldahl N

Bold signifies parameters to be further analyzed

Metal Concentrations

Six metal parameters in Wilmot Creek at Regional Road 2 and four metal parameters at Squair Road exceeded PWQO or CWQG between 2002 and 2007. Table 3.41 describes the range of metal concentrations and the percentage of samples that exceeded the PWQO or CWQG. Median concentrations of metals did not exceed PWQO or CWQG at either station with the exception of cadmium. Cadmium concentrations at Squair Road, between 2002 and 2007 had a median concentration of 0.21 µg/L, compared to a PWQO of 0.2 µg/L.

Metal Trends

Of the metals that exceeded PWQO or CWQG trends in time between 2002 and 2007 were analyzed. There is no linear relationship between time and total chromium, cobalt, lead or iron concentrations at the Regional Road 2 station; however, aluminum concentrations have decreased, and cadmium has increased between 2002 and 2007 at the Regional Road 2 station (Table 3.42). At the Squair Road station there is no linear relationship between time and lead or cobalt; however aluminum have decreased and cadmium and total chromium has increased between 2002 and 2007 (Table 3.42).

Table 3.41: Metal concentrations

Parameter				**Squair Road Station (2002 to 2007)**			
	n	**Median**	**Min***	**Max**	**10^{th} Percentile***	**90^{th} Percentile**	**% of Samples Exceeding Objective**
Aluminum µg/L (PWQO = 75µg/L)	47	16.2	-5.95	501	2.33	63.1	9
Cadmium µg/L (PWQO = 0.2µg/L)	47	0.15	-0.72	1.07	-0.36	0.72	47
Total Chromium µg/L (adapted CWQG = 2µg/L (Pawlisz et al. 1997))	47	0.19	-2.69	12.4	-0.70	0.78	4
Cobalt µg/L (PWQO = 0.9µg/L)	47	0.08	-2.14	1.18	-0.90	0.76	6
Lead µg/L (PWQO = 5µg/L)	47	-0.70	-19.9	6.0	-6.35	4.4	4
				Regional Road 2 Station (2002 to 2007)			
Aluminum µg/L	47	25.1	6.24	898	12.4	81.8	13
Cadmium µg/L	47	0.08	-0.50	2.0	-0.31	0.81	43
Total Chromium µg/L	47	0.21	-1.6	12.4	-0.19	1.43	4
Cobalt µg/L	47	0.10	-2.14	1.07	-0.65	0.72	4
Iron µg/L	47	42.5	26.1	1060.0	32.2	125.0	4
Lead µg/L	47	-0.29	-12.4	7.6	-6.08	3.0	4

*Concentrations less than 0 means that the concentrations are below analytical detection limits

Table 3.42: Metal trends at PWQMN stations

Parameter			**Squair Road Station**		
	Trend	**r^2**	**r_s**	**p**	**n**
Aluminum	↓	0.38	-0.62	0.00003*	47
Cadmium	↑	0.18	0.43	0.002*	47
Chromium	↑	0.12	0.35	0.02*	47
Cobalt	none	0.002	-0.04	0.81	47
Lead	none	0.0001	0.01	0.93	47
			Regional Road 2 Station		
Aluminum	↓	0.33	-0.57	0.00002*	47
Cadmium	↑	0.12	0.34	0.02*	47
Chromium	none	0.03	0.17	0.25	47
Cobalt	none	0.004	-0.06	0.69	47
Iron	none	0.04	-0.21	0.149	47
Lead	none	0.0009	-0.03	0.840	47

Note: * indicates a significance of $p < 0.05$

Chloride Concentration and Trend

Chloride concentrations sampled through the PWQMN ranged from 0.3 to 176 mg/L at the Squair Road, and 1.2 to 130.5 mg/L at the Regional Road 2 station. However irregularities may exist in the data (e.g., weather conditions) given that the 10th and 90th percentiles range from 17 to 139 mg/L at Squair Road, and 13.5 to 51 mg/L at the Regional Road 2 station (Table 3.43). In addition, the Squair Road station chloride concentrations is greater than the concentrations at the Regional Road 2 station (H (1, n= 607) =72.39 p =0.00).

Chloride concentrations at the Squair Road and Regional Road 2 PWQMN stations have increased considerably since 1964 and 1973 respectively (Table 3.41; Figures 3.70 and 3.71). However concentrations have never exceeded the Canadian Environmental Quality Guideline of 250mg/L. The r^2 value calculated for each of these stations (Table 3.43) indicates that time (in years) explains 76% of the variation at the Squair Road station and 74% at the Regional Road 2 station. Other factors (e.g., stream flow, precipitation, loading and water temperature) may also contribute to the concentration of chloride at these two stations.

Table 3.43: Chloride trends at PWQMN stations

Station	r^2	r_s	p	n
Squair Road	0.76	0.87	0.0000*	315
Regional Road 2	0.74	0.86	0.0000*	292

* indicates a significance of p <0.05

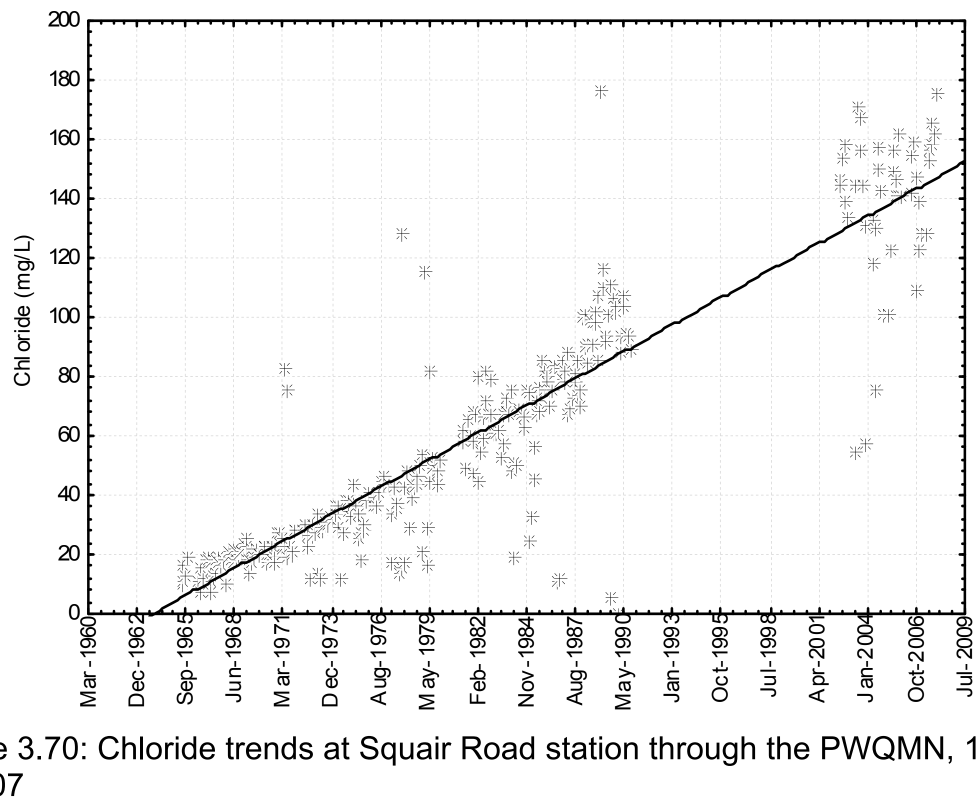


Figure 3.70: Chloride trends at Squair Road station through the PWQMN, 1964 to 2007

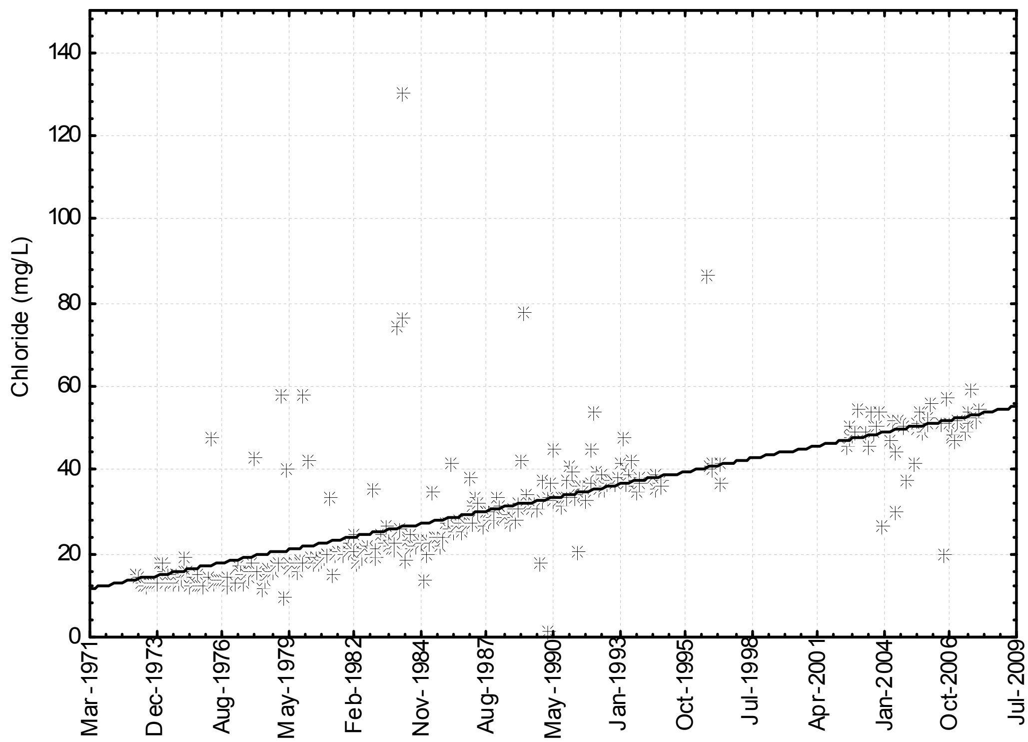


Figure 3.71: Chloride trends at Regional Road 2 station through the PWQMN, 1973 to 2007

Nutrient Concentrations

Since 2002 sampled total phosphorus has exceeded PWQO 11% of the time at Squair Road and 11% of the time at Regional Road 2 (Table 3.44), however median concentrations are below the PWQO at both stations. Since 2002 unfiltered nitrate-N has exceeded the 36% of the time at Squair Road and 2% of the time at Regional Road 2. Sampled nitrite-N did not exceed CWQG at either station since 2002.

Table 3.44: Nutrient concentrations at PWQMN stations, 2002 to 2007

Parameter	Squair Road Station						
	n	Median	Min	Max	10th Percentile	90th Percentile	% of samples exceeding
Total Phosphorus mg/L (PWQO = 0.03mg/L)	47	0.01	0.002	0.19	0.005	0.03	11
Nitrate-N Unfiltered mg/L (CWQG = 2.9mg/L)	47	2.83	0.45	3.47	2.43	3.25	36
Nitrite-N Unfiltered mg/L (CWQG = 0.197mg/L)	47	0.01	0.003	0.04	0.004	0.02	0
	Regional Road 2 Station						
Total Phosphorus mg/L	47	0.01	0.002	0.33	0.007	0.04	11
Nitrate-N Unfiltered mg/L	47	1.81	1.56	3.09	1.62	2.39	2
Nitrite-N Unfiltered mg/L	47	0.007	0.001	0.02	0.002	0.01	0

Nutrient Trends

- Although total phosphorus concentrations have exceeded the PWQO at both stations there has been a decline in total phosphorus concentrations at Squair Road since 1964 and Regional Road 2 since 1973 (Table 3.45).
- Nitrate-N has been increasing since 2002 at the Squair Road and Regional Road 2 station (Table 3.45).
- There is no linear trend in nitrate-N concentrations at the Squair Road station between 2002 and 2007; however nitrite-N has been declining at the Regional Road 2 station since 2002.
- Total phosphorus and nitrate-N increases with flow at the Regional Road 2 station (n=46, r_s = 0.46, $p<0.05$ and n=46, r_s = 0.37, $p<0.05$ respectively).

Table 3.45: Nutrient trends at PWQMN stations

Parameters		Squair Road Station			
	Trend	r^2	r	p	n
Total Phosphorus	↓	0.10	-0.32	0.00*	330
Nitrate-N	↑	0.27	0.52	0.0001*	47
Unfiltered Nitrite-N	none	0.07	-0.27	0.06	47
		Regional Road 2 Station			
Total Phosphorus	↓	0.04	-0.2	0.0004*	292
Nitrate-N	↑	0.12	0.34	0.02*	47
Unfiltered Nitrite-N	↓	0.12	-0.35	0.01*	47

* indicates a significance of $p < 0.05$

Pesticides

Six samples were taken for 2,4-D, Atrazine, Metolachlor and Glyphosate. Table 3.46 shows the concentrations of pesticides that were detected in Wilmot Creek. Metolahlor was below detection limits, and 2,4-D, Atrazine and Glyphosate are below their respective federal guidelines.

Table 3.46: Pesticide concentrations

Date Sampled	Pesticide	Guideline (μg/L)	Concentration (μg/L)
May 28, 2007	2,4-D	4	0.25
June 19, 2007	Glyphosate	65	0.16
June 19, 2007	Atrazine	1.8	0.11

3.7.6 Discussion of Wilmot Creek Surface Water Quality

Physical Parameters

The background conditions of surface water quality in Wilmot Creek are within acceptable ranges as described by *Provincial Water Quality Objectives*. The pH values at sample sites is within acceptable ranges indicating that there are no acidity or neutralizing problems in Wilmot Creek. Alkalinity concentrations indicate that Wilmot Creek has the ability to buffer acidic changes that might occur. Alkalinity ranges from 24 to 500 mg/L as $CaCO_3$ throughout Canada (Canadian Council of Resource and Environment Ministers 1987), a range in which Wilmot Creek water quality falls.

Quantifying dissolved and suspended solids in Wilmot Creek can be done using conductivity, salinity, total dissolved solids, total suspended solids, turbidity and particulate residue. In all cases, these parameters at sample sites were within acceptable ranges, and higher concentrations of particulates and suspended solids can be attributed to higher flows. Total suspended solids rarely exceeded the recommended 25 mg/L, and when they do, it is during high flows.

Dissolved oxygen concentrations at sample sites are also within acceptable ranges as related to *Provincial Water Quality Objectives*. Indicating that in stream nutrient cycling is not causing declines in oxygen levels. Dissolved oxygen as sampled through the GRWQMN has been shown to decline as stream temperatures increase, however rarely does it decline below acceptable concentrations.

The physical parameters of Wilmot Creek indicate that surface water quality can be resilient to anthropogenic actions related to acidification, eutrophication and chemical additions. Certain metal parameters have reduced toxicity effects in higher pH, in harder water, or in water that has a high buffering capacity such as Wilmot Creek. Therefore Wilmot Creek surface water has the appropriate physical background to mitigate some negative effects caused by human actions.

Chloride

Chloride is the principal component of road salts, and is the main contributing anion to salinity in surface water (Mayer et al. 1999). Road salts such as sodium chloride can affect the environment in different ways. Salts can affect the taste of drinking water, damage salt-sensitive vegetation, increase hardness and pH in soils and increase wildlife death from vehicle collisions since they are attracted to the salts near roads (Transportation Association of Canada 1999). Once in water, chloride can be toxic (acute and chronic) to aquatic organisms depending on the concentration the organism is subjected to and the stage of an organism’s life.

Chloride concentrations in Wilmot Creek have increased considerably since the 1960s and 1970s as seen through the Provincial Water Quality Monitoring Network (PWQMN). As well, the PWQMN station at the outlet of Orono Creek into the main branch of Wilmot Creek has higher chloride concentrations than the PWQMN station at Regional Road 2.

Snow and mixed precipitation, and snowmelt runoff months have higher chloride concentrations than rain dominated months, leading to believe that road salt application may be increasing chloride concentrations within Orono Creek. Given the concentrations of chloride measured through the PWQMN, it can be said that chloride concentrations in Wilmot Creek and specifically the Orono Creek tributary are increasing and levels may soon reach or exceed the CEQG of 250 mg/L especially during peak snowmelt or salt application times. In addition, Foster Creek tends to have higher concentrations of chloride, even during summer months given its urban nature (Gartner Lee Limited and Greenlands International 2001).

Chloride concentrations may also be higher in the winter in Wilmot Creek since salts tend to remain in water and do not have any removal mechanisms such as volatilization, degradation, sorption or oxidation (Mayer et al. 1999). As a result, only evaporation of water and addition or dilution of chloride will change the chloride concentrations in surface waters (Mayer et al. 1999). Wintertime stream conditions have increased flow over summertime baseflow conditions. This increase in flow can cause chloride to be diluted, yet winter chloride concentrations are higher than summer chloride concentrations, leading to the believe that chloride loadings outweigh the effects of dilution in the stream. The only way chloride can leave a river in winter is as of water leaving the system.

One option to lower concentrations of chloride in surface water is the proper management and application of chloride, and the consideration of reduced salt use in sensitive and vulnerable areas. Lake Ontario has been noted as having higher chloride levels than the other Great Lakes, but as early as 1993, Lake Ontario experienced a decline in chloride (Mayer et al. 1999). This decline in chloride can be attributed to lower loadings from industrial and domestic sources due to improved treatment of industrial and domestic effluents (Mayer et al. 1999). Therefore with proper chloride and road salt management plans, further declines of chloride or reduction in winter chloride concentration fluctuations within Wilmot Creek may be achieved.

Metals

Six metal parameters at the Regional Road 2 station and four metal parameters at the Squair Road station have exceeded PWQO or CWQG between 2002 and 2007, however median concentrations of the six metals are below the respective PWQO or CWQG, except for cadmium at the Squair Road station. Metals sampled in Wilmot Creek are not an immediate concern but should be continually monitored to ensure concentrations do not become elevated and to understand concentrations of cadmium in Wilmot Creek. In addition, proper urban landscape management (e.g., storm water management and industrial discharge) should occur to reduce the potential risk of metals within Wilmot Creek.

Aluminum concentrations have exceeded the PWQO 9% of the time at the Squair Road station, and 13% of the time at the Regional Road 2 station, however aluminum concentrations are somewhat misleading. The PWQO for aluminum is based on clay-free water quality samples. Samples collected as part of the PWQMN are not filtered and therefore are not considered clay free (A. Todd, MOE, Personal Communications). Elevated levels of aluminum in unfiltered samples are associated with sediments and therefore have a low toxicity since they are biologically unavailable.

In addition, analysis of metal concentrations in laboratories is not always accurate given the low detection limits of metals. Although the six metals has exceeded provincial or federal guidelines, these exceedances could be attributed to laboratory error, road or urban runoff during peak flows, or sampling anomalies.

Nutrients
Total phosphorus exceeds the PWQO more often than any other nutrient, but never more than 45% of the time. Since 1964 total phosphorus has declined at the Squair Road station, and there has been a decline since 1973 at the Regional Road 2 station. Unionized ammonia has been greater than the PWQO of 0.02 mg/L 19% of the time as sampled through the GRWQMN.

Nitrate-N exceeded the CWQG 17% of the time thorough the GRWQMN. At the Squair Road and Regional Road 2 PWQMN stations nitrate-N has been increasing since 2002, and exceeded the CWQG 36% of the time at the Squair Road station. At the Regional Road 2 PWQMN station, nitrite-N concentrations have been declining since 2002, and concentrations have never exceeded the CWQG since 2002 through the PWQMN and GRWQMN sampling programs.

Nutrients therefore can be considered the water quality parameter most capable of fluctuating beyond recommended guidelines however, exceedances may be related to high runoff due to storm events, or land use. Foster Creek tends to have higher concentrations of phosphorus and nitrate, even during dry conditions given its urban nature (Gartner Lee Limited and Greenlands International 2001). This condition was also seen during baseflow water quality as six of nine sites on Foster Creek exceeded guideline concentrations of nitrate and/or total phosphorous and/or *Escherichia coli*.

Phosphorus entering surface water is also a reflection of land management practices. The concentration of phosphorus in runoff is related to the amount of phosphorus in the surface layer of soil (0 to 5 cm), which reacts with rainfall runoff (Sharpley et al. 1996). Phosphorus runoff is also dependent on soil types, the amount of vegetative cover (Section 4.0.5), and whether or not manure or fertilizer was incorporated or how soon before a rainfall event that manure or fertilizer was applied (Sharpley et al. 1996).

Aquatic systems can benefit from phosphorus, by increasing productivity. Addition of phosphorus can also cause changes in a system by increasing plant and algal growth, which in turn alters the number, types and size of plants and animals, increases turbidity, and creates more organic matter, which results in losses of oxygen. Phosphorus can be directly toxic to aquatic organisms, but this is very rare (Environment Canada 2005; Carpenter et al. 1998). Indirect effects are a greater concern and occur when increases in the amount of decaying organic material cause declines in oxygen due to an increase in oxygen use by decomposers.

Nitrogen is converted to many forms in the environment. Ammonia changes to nitrite, which changes to nitrate (Csuros 1994). Nitrate is the most stable form of nitrogen in an aquatic system and therefore is a good indicator of nitrogen and its forms in surface water. Nitrate affects aquatic organisms both indirectly and directly. Similar to phosphorus, nitrates in excess can increase growth of plants and algae, which may result in indirect toxic effects such as reduced oxygen levels. Aquatic invertebrates and fish exposed to high levels of nitrate may be smaller, slower to mature, or have lower reproductive success. Under very extreme concentrations, aquatic invertebrates and fish may die (Environment Canada 2005b).

Proper management of nutrients will help to reduce high concentrations entering Wilmot Creek during high flows or storm events, and through direct methods such as storm drains and field tile drains. Carpenter et al. (1998) reported that more than 90% of phosphorus entering a water body comes from less than 10% of the land area during a few large storms. Methods to reduce the amount of nutrients entering Wilmot Creek are to increase riparian vegetation to reduce surface runoff (Section 4.0.5), and to mitigate stormwater directly entering surface water through drains in both urban and rural areas.

Pesticides

Through a partnership with the Ministry of the Environment and Environment Canada, background pesticide concentrations in Wilmot Creek have been analyzed. Six samples that were taken and analyzed for 2,4-D, Atrazine, Metolachlor and Glyphosate. These pesticides are commonly used in crop production throughout Ontario. Based on these background concentrations, pesticide concentrations in Wilmot Creek are either non-existent or very low. Continual monitoring should occur especially in light of increased cropping practices to take advantage of biofuels and ethanol production.

Bacteria

Escherichia coli exceed the recreational PWQO 65% of the time throughout the entire Wilmot Creek watershed and total coliforms ranged between 102 and 14,900 cfu/100ml. The presence of *Escherichia coli* in surface water indicates that fecal material of humans or other warm-blooded animals is present in the water. Common sources of *Escherichia coli* include municipal wastewater spills, septic leachate, agricultural or storm runoff, wildlife populations, or non-point sources of human or animal waste (An et al. 2002). A private sewage disposal survey conducted by Jagger Hims Limited (2001) in the urban area of Orono indicated that the impact of private sewage disposal systems on Wilmot Creek was minimal. However, contamination of shallow aquifers could contaminate Wilmot Creek. Total coliform includes all coliform species (*Escherichia coli* and its variants). Sources of total coliform are the same as *Escherichia coli*, however they are not necessarily from fecal matter, but also from plant and organic material.

Fecal coliforms are bacteria, which are single-celled living organisms. These bacteria can decay under certain environmental conditions. The rate of die-off increases with different factors such as increasing temperature, elevated pH, high dissolved oxygen levels, solar radiation, and predaceous microorganisms such as protozoa (An et al. 2002). Fecal coliforms such as *Escherichia coli* are known to cause negative health effects in humans, and therefore an associated Drinking Water Quality Objective of 0 cfu/100 ml is in place in the Province of Ontario (Ontario Ministry of the Environment 2003) and a recreational guideline of 100 cfu/100 ml.

Direct effects of coliforms and *Escherichia coli* on aquatic species are poorly understood and researched. The United States Environmental Protection Agency sets fecal coliform concentration criteria for shellfish harvesting. Although shellfish are not affected by fecal coliform, humans consuming shellfish exposed to fecal coliform can become ill (United States Environmental Protection Agency 1976). Although the direct effect of fecal coliform on aquatic organisms is uncertain, the proper management of sources of fecal coliform needs to be addressed in the Wilmot Creek watershed. In addition, surface water that serves as sources of drinking water for human or livestock consumption needs to be protected from coliform contamination.

Chapter 4 - Biotic Features

4.0 AQUATIC RESOURCES

Aquatic resources in Wilmot Creek include instream habitat and the aquatic organisms that rely on aquatic habitats, and riparian areas. The forms and functions of these resources are influenced by the quality and quantity of water systems and the contributing watershed areas.

4.0.1 Fisheries

Fishes are one of Ontario's most valued natural resources from an ecological, biological, economic, social and cultural perspective. Protecting and restoring the aquatic ecosystem results in a healthy fishery and environment. The Wilmot Creek watershed has long been recognized for its excellent trout and salmon fishery. The Wilmot Creek historically supported healthy Brook Trout and Atlantic Salmon populations. Through local restoration efforts and the Ontario Ministry of Natural Resources stocking programs, the river now supports a diverse coldwater and warm water fishery. Wilmot Creek also hosts a significant salmonid spawning run from the Lake Ontario basin.

A Fisheries Management Plan for Wilmot Creek has been created in partnership with the Ganaraska Region Conservation Authority and the Ontario Ministry of Natural Resources (2008). *"The Wilmot Creek Study: Spatial and Temporal Analysis of Fish Communities in the Wilmot Basin"* (Desjardins and Stanfield 2005) was created to assist in the development of the Fisheries Management Plan. Information pertaining to the Wilmot Creek fisheries presented in this document has been summarized from the Wilmot Creek Study (Desjardins and Stanfield 2005) and the *Wilmot Creek Fisheries Management Plan* (Ganaraska Region Conservation Authority and the Ontario Ministry of Natural Resources 2008).

Methods

Methods used in fisheries data are discussed in detail by Desjardins and Stanfield (2005). Wilmot Creek has been studied for over 20 years by the Ganaraska Region Conservation Authority, provincial and municipal agencies, consultants and academic institutions. In summary, 348 sampling events from 78 sites (68 in Wilmot Creek and 10 in Orono Creek) contained fish and/or habitat data. Datasets spanned the period of 1974 to1978, 1983, and 1987 to 1999.

Fish species were analyzed by biomass grams per square metre (g/m^2) and density (number of $fish/m^2$). Fisheries communities were determined using multivariate statistics (Principal Component Analysis). All species collected at each sampling station were included, except species found in less than 25% of the sampling sites and Chinook Salmon. The remaining data left for analysis were for the following species: Brook Trout (*Salvelinus fontinalis*), Brown Trout (*Salmo trutta*), Rainbow Trout (*Oncorhynchus mykiss*), Coho Salmon (*Oncorhynchus kisutch*), Blacknose Dace (*Rhinichthys atratulus*), Longnose Dace (*Rhinichthys cataractae*), Mottled Sculpin (*Cottus bairdii*), Slimy Sculpin

(*Cottus cognatus*), Rainbow Darter (*Etheostoma caeruleum*), Johnny Darter (*Etheostoma nigrum*), White Sucker (*Catostomus commersonii*), and a group called lamprey (*Petromyzontidae*) species.

Wilmot Creek Fisheries

Forty-four fish species have been found within Wilmot Creek, both historically and currently (Table 4.0)[2]. Nine have been introduced either intentionally or unintentionally. Of the remaining 35 species, all of which are native, two have been designated species at risk and another three species are considered potentially at risk and are candidates for further assessment (Table 4.1). The most common species (species found in more than 25% of the sampling sites) were subjected to further analysis. The following represents a summary of the distribution patterns of these species.

Atlantic Salmon (*Salmo salar*) are of special note in Wilmot Creek. Although extirpated from Lake Ontario Atlantic Salmon have been stocked in Wilmot Creek from 1987 to 2000. Approximately 262,000 individuals of various life history stages have been stocked during this time (Desjardins and Stanfield 2005). However, there is no record of adult Atlantic Salmon returning to Wilmot Creek.

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[2] Historically Lake Whitefish were found in Wilmot Creek.

Table 4.0: Fish species

Common Name	Scientific Name	Origin	Thermal	Last Observed
Alewife	*Alosa pseudoharengus*	Introduced	Cold	1978
American brook lamprey	*Lampetra appendix*	Native	Cold	2002
American eel	*Anguilla rostrata*	Native	Cool	1992
Atlantic salmon	*Salmo salar*	Native†	Cold	2000
Black crappie	*Pomoxis nigromaculatus*	Native	Cool	2006
Blacknose dace	*Rhinichthys atratulus*	Native	Cold	2002
Bluntnose minnow	*Pimephales notatus*	Native	Warm	2002
Brassy minnow	*Hybognathus hankinsoni*	Native	Cool	1978
Brook stickleback	*Culaea inconstans*	Native	Cool	1999
Brook trout	*Salvelinus fontinalis fontinalis*	Native	Cold	2002
Brown bullhead	*Ameiurus nebulosus*	Native	Warm	1991
Brown trout	*Salmo trutta*	Introduced	Cold	2002
Central mudminnow	*Umbra limi*	Native	Cool	1993
Chinook salmon	*Oncorhynchus tshawytscha*	Introduced	Cold	2002
Coho salmon	*Oncorhynchus kisutch*	Introduced	Cold	2002
Common carp	*Cyprinus carpio*	Introduced	Warm	1978
Common shiner	*Notropis cornutus*	Native	Cool	2002
Creek chub	*Semotilus atromaculatus*	Native	Cool	2002
Emerald shiner	*Notropis atherinoides*	Native	Cool	1978
Fathead minnow	*Pimephales promelas*	Native	Warm	1999
Iowa darter	*Etheostoma exile*	Native	Cool	1993
Johnny darter	*Etheostoma nigrum*	Native	Cool	2002
Logperch	*Percina caprodes*	Native	Warm	1992
Longnose dace	*Rhinichthys cataractae*	Native	Cool	2002
Longnose sucker	*Catostomus catostomus*	Native	Cold	1997
Mottled sculpin	*Cottus bairdi*	Native	Cold	2002
Northern brook lamprey	*Ichthyomyzon fossor*	Native	Cool	1999
Northern pike	*Exox lucius*	Native	Cool	1991
Northern redbelly dace	*Phoxinus eos*	Native	Cool	2002
Pink salmon	*Oncorhynchus gorbuscha*	Introduced	Cold	na
Pumkinseed	*Lepomis gibbosus*	Native	Warm	2002
Rainbow darter	*Etheostoma caeruleum*	Native	Cool	2002
Rainbow smelt	*Osmerus mordax*	Introduced	Cold	1978
Rainbow trout	*Oncorhynchus mykiss*	Introduced	Cold	2002
Rock bass	*Ambloplites rupestris*	Native	Cool	1999
Sea lamprey	*Petromyzon marinus*	Introduced	Cool	2002
Slimy sculpin	*Cottus cognatus*	Native	Cold	2002
Smallmouth bass	*Micropterus dolomieu*	Native	Warm	1997
Spottail shiner	*Notropis hudsonius*	Native	Cool	1992
Threespine stickleback	*Gasterosteus aculeatus*	Native	Cool	1978
Walleye	*Stizostedion vitreum vitreum*	Native	Cool	1992
White bass	*Morone chrysops*	Native	Warm	1978
White sucker	*Catostomus commersoni*	Native	Cool	2002
Yellow perch	*Perca flavescens*	Native	Cool	1999

† - *Atlantic Salmon were native before their extirpation and have been subsequently reintroduced*

(Ganaraska Region Conservation Authority and Ontario Ministry of Natural Resources 2008)

Table 4.1: Fish species at risk in the Wilmot Creek watershed

Common Name	Scientific Name	COSEWIC Status	COSSARO Status
Northern brook lamprey	*Ichthyomyzon fossor*	Special Concern	Special Concern
Atlantic salmon	*Salmo salar*	Extirpated	Extirpated
Brassy minnow*	*Hybognathus hankinsoni*	Group 2, Intermediate Priority	
Rainbow darter*	*Etheostoma caeruleum*	Group 2, Intermediate Priority	
American brook lamprey*	*Lampetra appendix*	Group 3, Mid Priority	

(* Potentially at risk – further assessment needed)
(Ganaraska Region Conservation Authority and Ontario Ministry of Natural Resources 2008)

Brook Trout (Salvelinus fontinalis)

Brook Trout are a valued native sport fish and they have been stocked intensively throughout Ontario because of their visual appeal and economical value. Requiring coldwater, Brook Trout are sensitive to habitat alteration and their presence is indicative of a coldwater stream. Approximately 4,000 Brook Trout were stocked in Wilmot Creek by the Ministry of Natural Resources from 1946-1972 (Desjardins and Stanfield 2005). It is unknown how many Brook Trout may have been stocked by private landowners.

Brook Trout catches are confined to the upper portions of both Wilmot and Orono Creeks with the highest biomass values obtained from sites north of Concession 6 on Orono Creek (Figure 4.0; Desjardins and Stanfield 2005).

Rainbow Trout (Oncorhynchus mykiss)

Rainbow Trout are native to the Pacific Ocean, the west coast of North American and East Asia. First introduced into Lake Ontario in the late 1800's Rainbow Trout now populate the Great Lakes. The adfluvial Lake Ontario populations spawn in late winter and spring, moving into streams from mid-September to June.

In 1922, the Canadian waters of Lake Ontario were first stocked with Rainbow Trout, but it was not until the early 1940s that abundant Rainbow Trout were established in Canadian Lake Ontario tributaries. Intensive stocking of approximately 82,000 individuals occurred in Wilmot Creek from 1972 to 1992 (Desjardins and Stanfield 2005).

Rainbow Trout are the most prevalent species sampled in Wilmot Creek with only a few sites recorded as having zero catches. Rainbow Trout are widely dispersed, with most biomass contained within the middle to lower portions of the watershed (Figure 4.1; Desjardins and Stanfield 2005).

Brown Trout (Salmo trutta)

Brown Trout are native to Europe and western Asia, and were introduced into North America in 1883 and 1884. Brown Trout spawn in the late fall (October to November) in shallow gravel substrate. In general, Brown Trout are considered to have the same habitat requirements as Brook Trout, which aids in their adaptation to local stream environments (Scott and Crossman 1998). In Wilmot Creek, Brown Trout were stocked in 1951 (1000 fingerlings) and in 2000 (25 adults) (Desjardins and Stanfield 2005).

Brown Trout are more prevalent in Wilmot Creek than are Brook Trout. For the most part, Brown Trout abundance and biomass are higher in the upstream portions of Wilmot Creek. A few sites lower in the drainage have high biomass values however, these results reflect the presence of a few large individuals (Figure 4.2; Desjardins and Stanfield 2005).

Chinook Salmon (Oncorhynchus tshawytscha)

Chinook Salmon are native to the Pacific Ocean and its freshwater tributaries. This large salmonid was first introduced into Lake Ontario from 1874 to 1881 (Scott and Crossman 1998) and has been intensively stocking since 1969. Spawning occurs during the fall (September and October). Females create large redds (nests) in riffle areas and guard the nests after spawning until death, which takes place from two days to two weeks post spawn. Fertilized eggs hatch the following spring and the juveniles stay within creek from three-four weeks to over a year when they smolt out to Lake Ontario.

The biomass and density values used in the analysis are from catches from the spring of 1997 only (<100mm in size). Spring samples better reflect the abundance of juvenile Chinook Salmon due to their early outmigration timing. Unfortunately, only one year of reliable Chinook spring sampling exists as most sampling occurred during summer baseflow conditions. Biomass during this period was highest in the middle portions of the watershed (Figure 4.3; Desjardins and Stanfield 2005).

The distribution of Chinook Salmon reflects their life history characteristics and agency management. The abundance of spawning adult Chinook Salmon in Wilmot Creek has not been assessed. However, their large body size and adfluvial spawning habits have made this Pacific salmon a popular sport fish in Wilmot Creek.

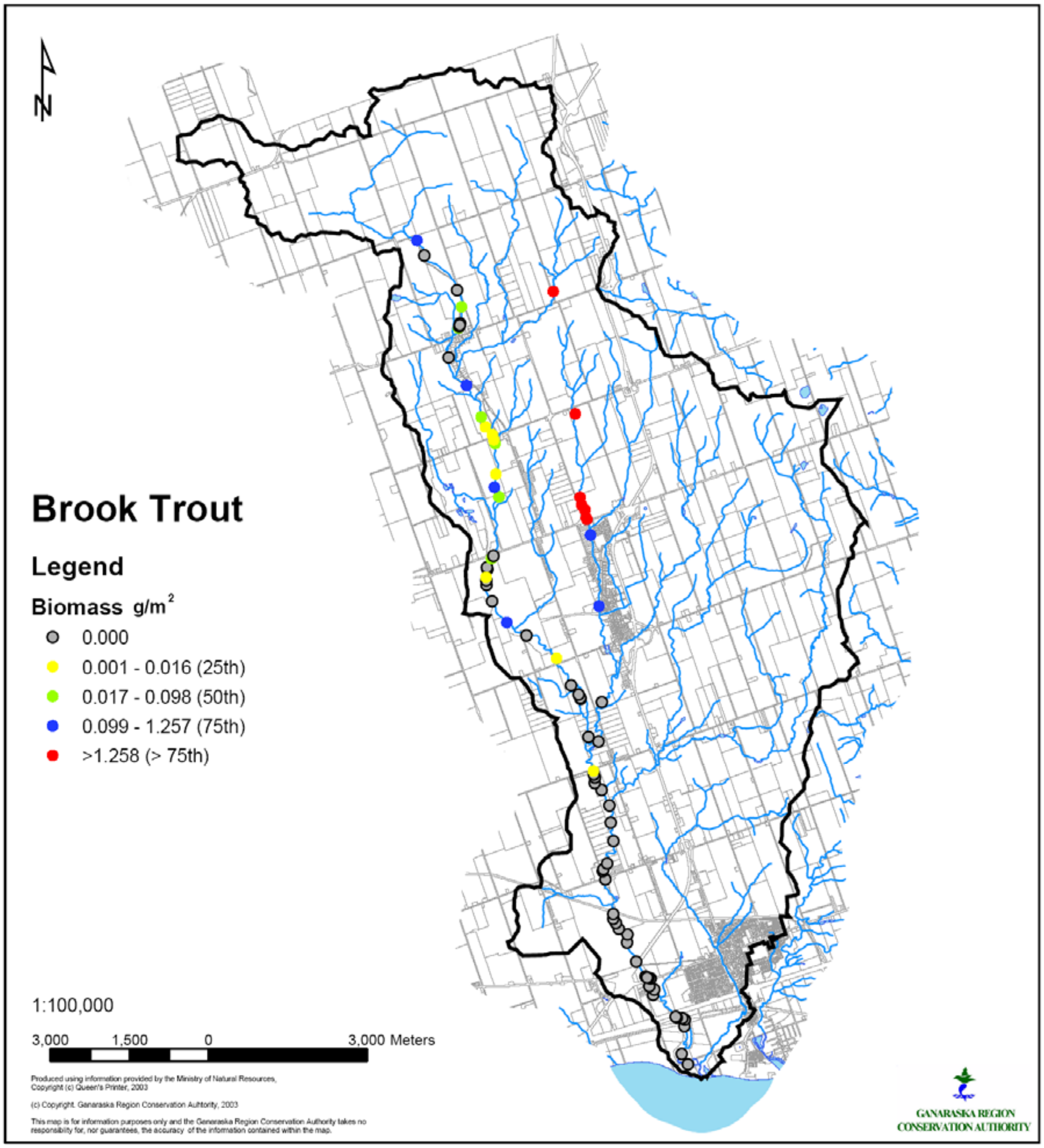


Figure 4.0: Brook Trout July/August distribution

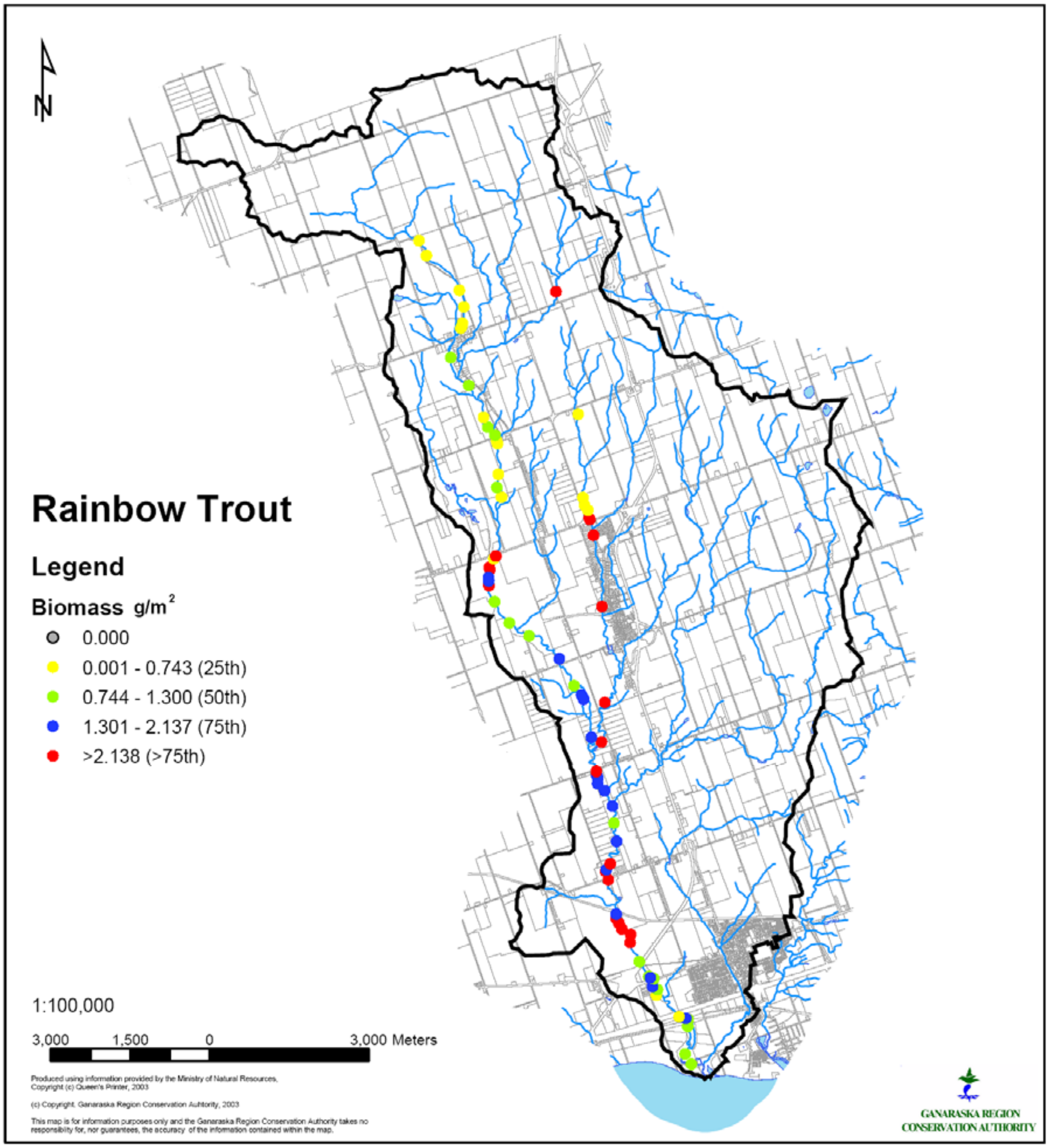


Figure 4.1: Rainbow Trout July/August distribution

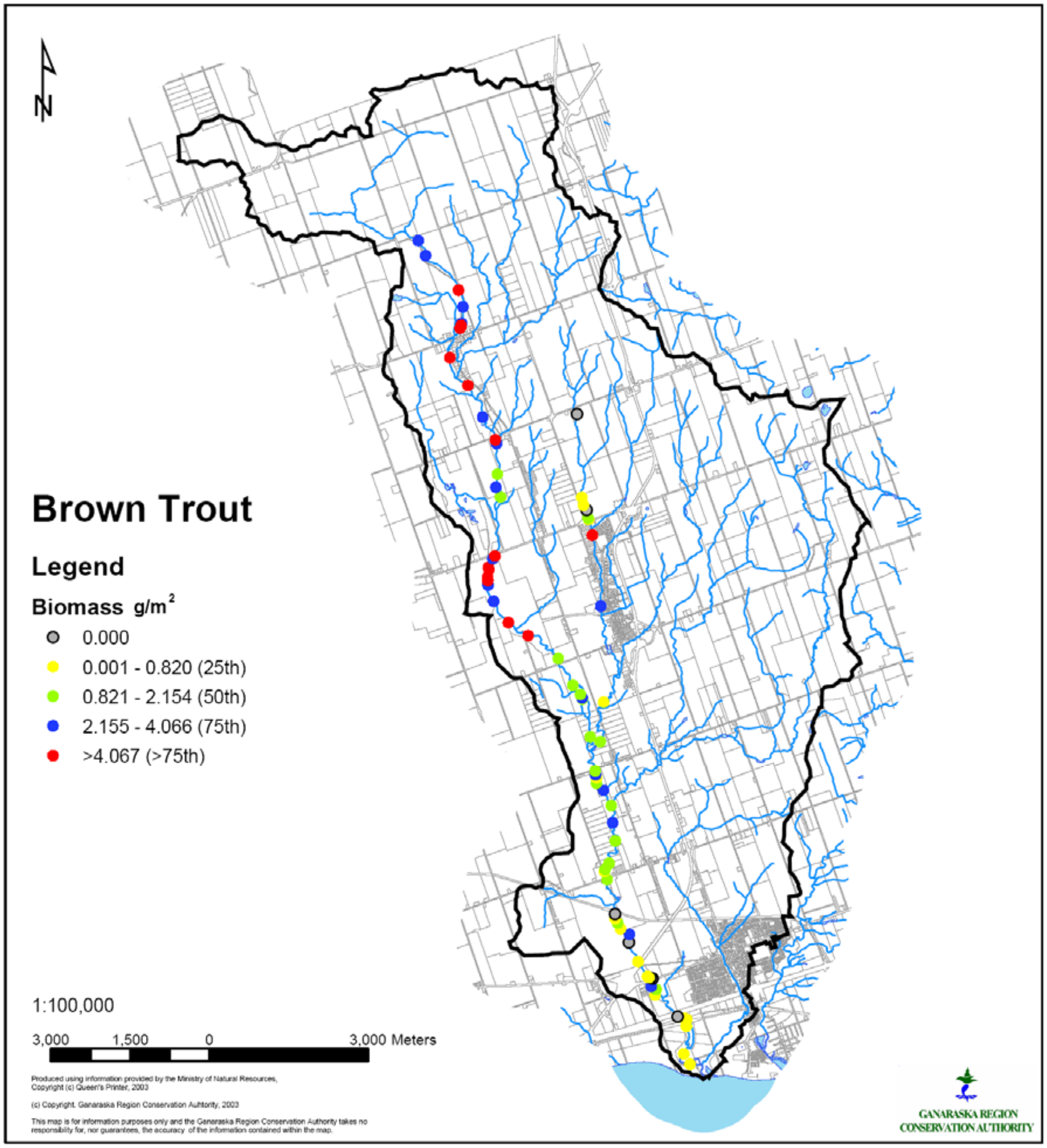


Figure 4.2: Brown Trout July/August distribution

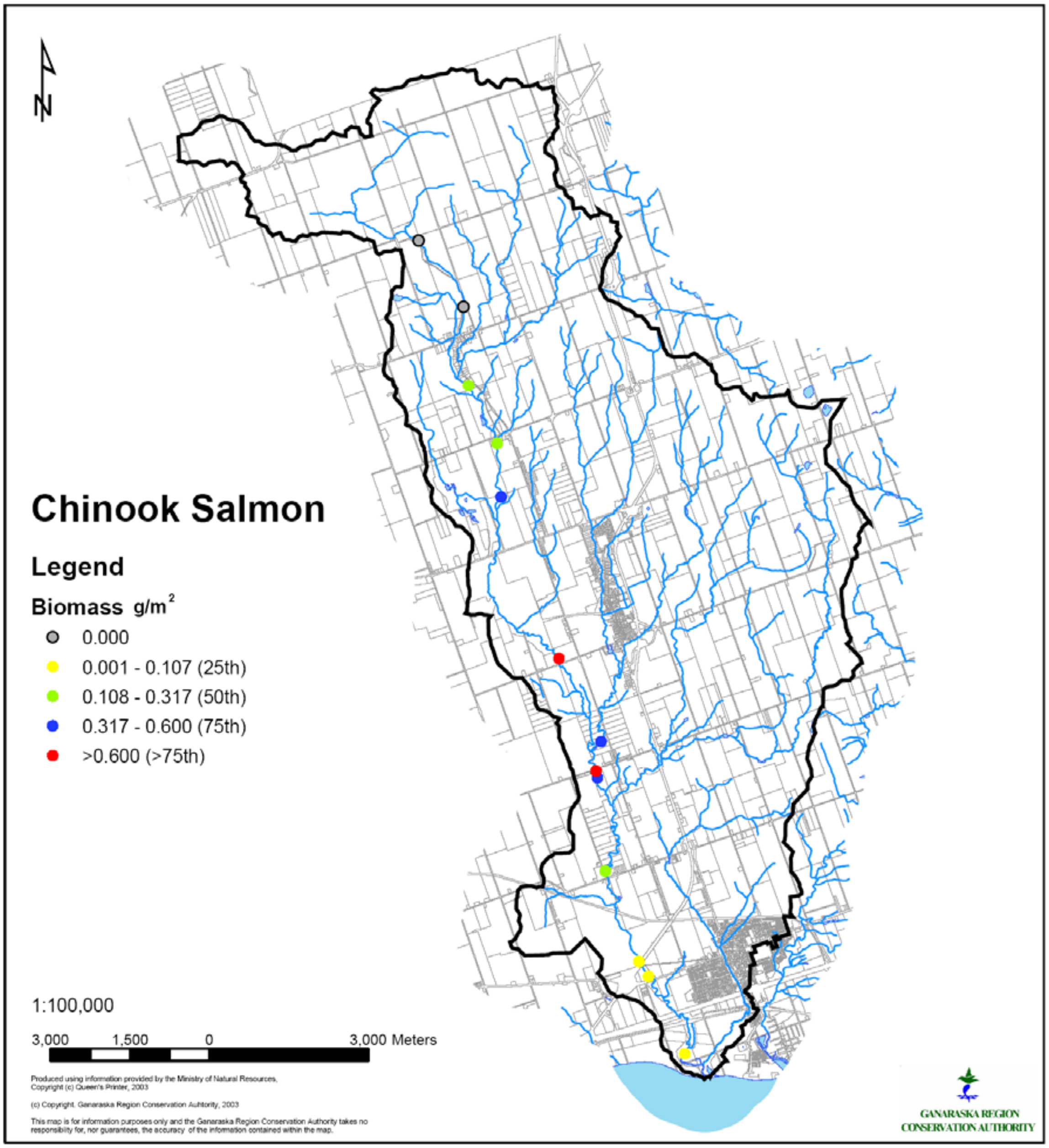


Figure 4.3: Juvenile Chinook Salmon July/August distribution

Coho Salmon (*Oncorhynchus kisutch*)
Coho Salmon are native to the Pacific Ocean and freshwater tributaries from the California to Alaska and Russia to Japan. This pacific salmonid was first introduced into Lake Ontario in the 1870's (Scott and Crossman 1998) with successful socking occurring after the 1970s. Spawning occurs during the fall, generally September/October. Females create redds (nests) in fast flowing waters over gravelly stream beds, and guard the nests after spawning until death, which takes place from two days to two weeks post spawn. Fertilized eggs hatch the following spring and the juveniles stay within creek from three to four weeks to over a year when they smolt out to Lake Ontario.

Coho Salmon are more prevalent in the middle to upper middle portions of the watershed. Their occurrence higher in the basin than Chinook Salmon likely reflects their life history and different spawning requirements (Figure 4.4; Desjardins and Stanfield 2005).

Rainbow Darter (*Etheostoma caeruleum*)
Rainbow Darters are a native species, and in Canada are only found in streams entering Lakes Ontario, Erie, St. Clair and Huron. This colourful fish spawns in the spring in coarse gravel, fine grave or rubble riffles. Eggs are buried in the gravel in the spawning area and hatch 10 to 12 days after in water temperatures of 17 to 18.5 ^{o}C (Scott and Crossman 1998).

Rainbow Darters were collected from sites located in the lower portion of the watershed. This species was found at only a few sites upstream of the CNR bridge (Figure 4.5; Desjardins and Stanfield 2005).

Lamprey Family (Petromyzontidae)
Five lamprey genera occur in the northern hemisphere, and inhabit temperate marine and fresh water. All lamprey undergo metamorphosis from ammocoetes to adult form. Adults have the characteristic fringed, well-toothed circular, suctorial mouth. Lamprey species can be parasitic, in the case of the sea lamprey (*Petromyzon marinus*), or non-parasitic, such as the American brook lamprey (*Lampetra appendix*). Some scientists believe that sea lamprey is native to Lake Ontario due to the connection to the Atlantic Ocean. Sea Lamprey is non-native to the upper Great Lakes.

This species group reflects all species of lamprey caught in the Wilmot Creek watershed. They were grouped due to identification difficulties (separating American brook and sea lamprey ammocoetes). Lampreys show a similar distribution pattern as Brown Trout being more prevalent in upper portions of the watershed. There were no recorded catches of lamprey in Orono Creek between 1987 and 1999 (Figure 4.6 Desjardins and Stanfield 2005).

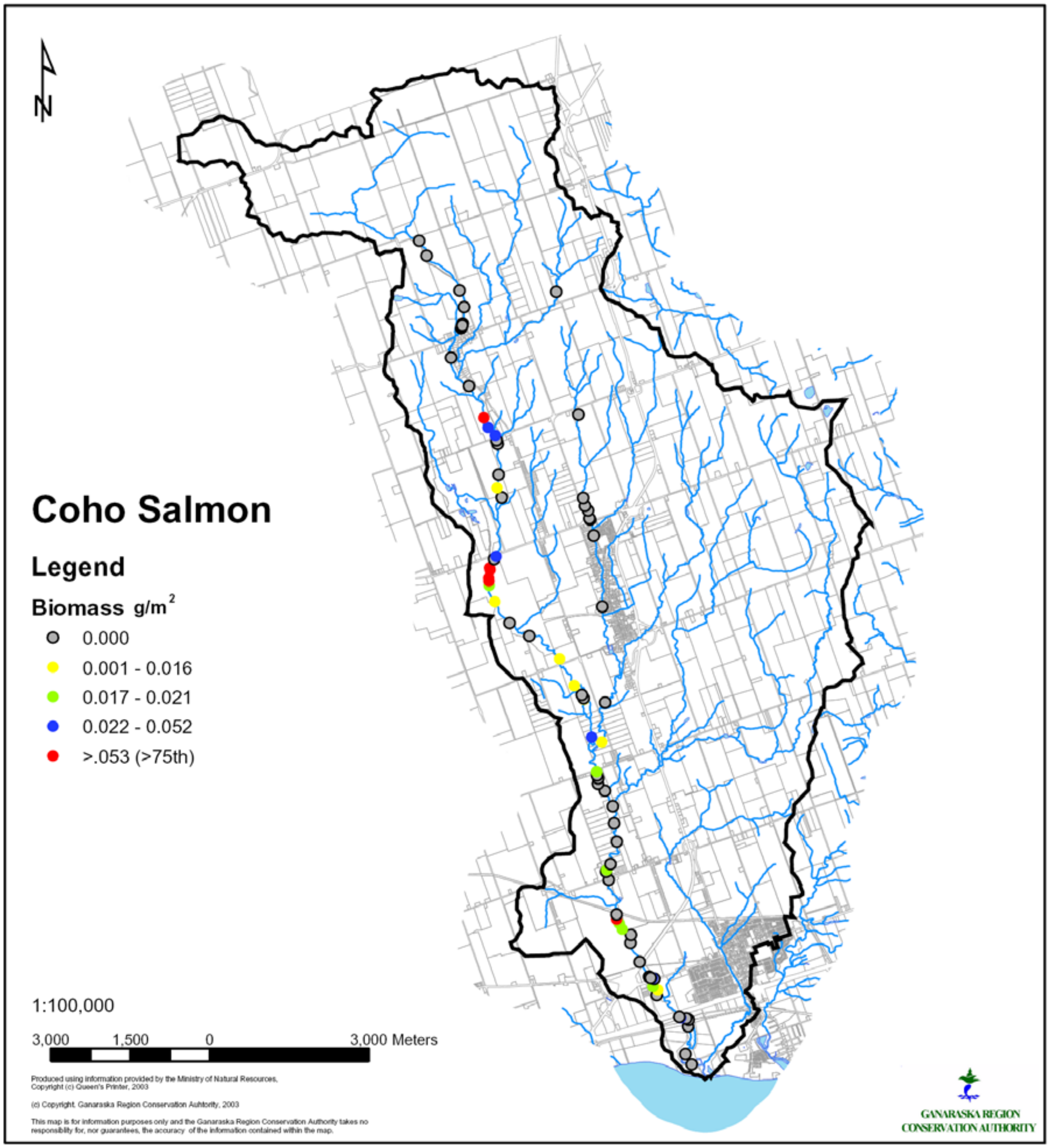


Figure 4.4: Juvenile Coho Salmon July/August distribution

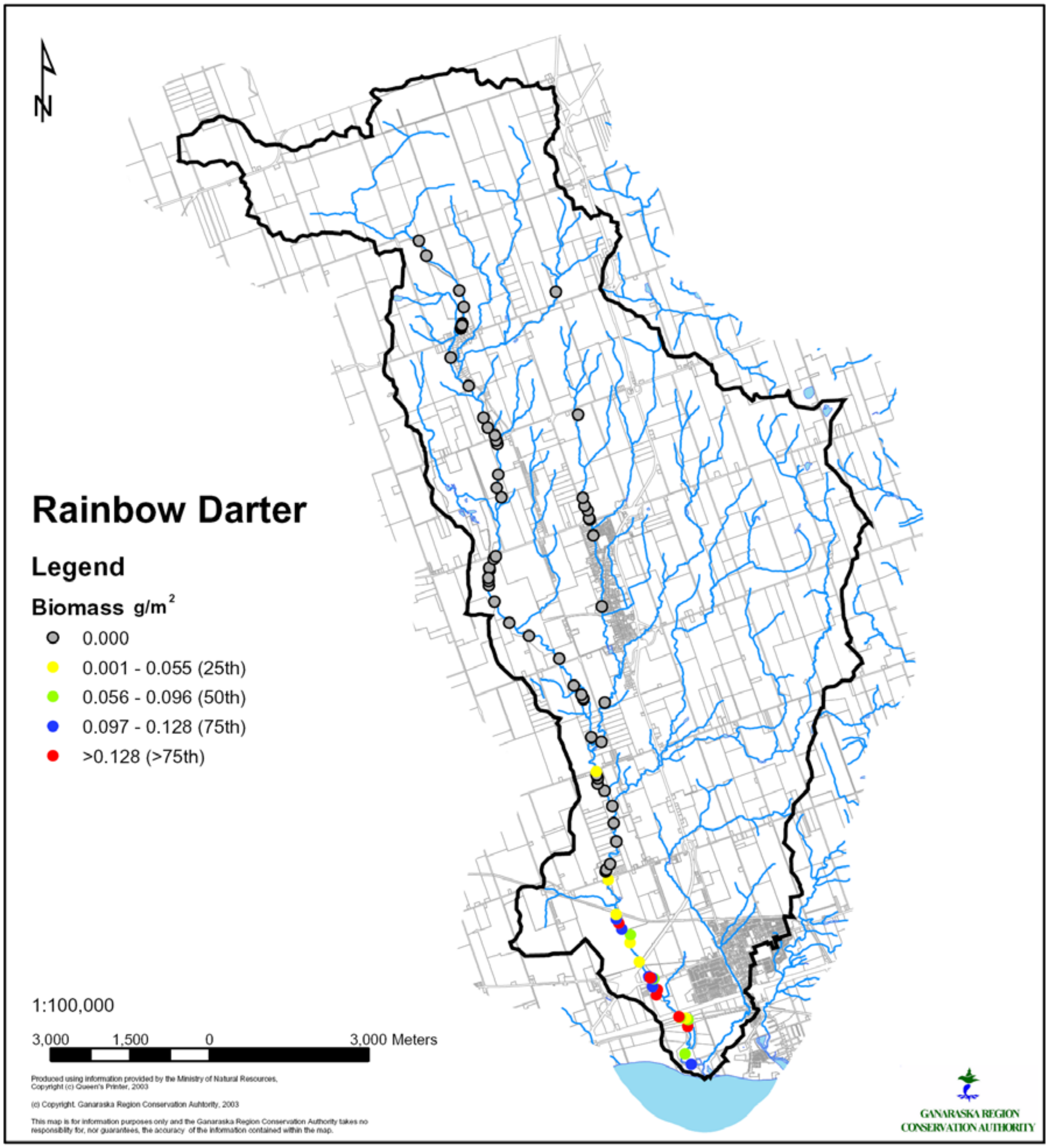


Figure 4.5: Rainbow Darter July/August distribution

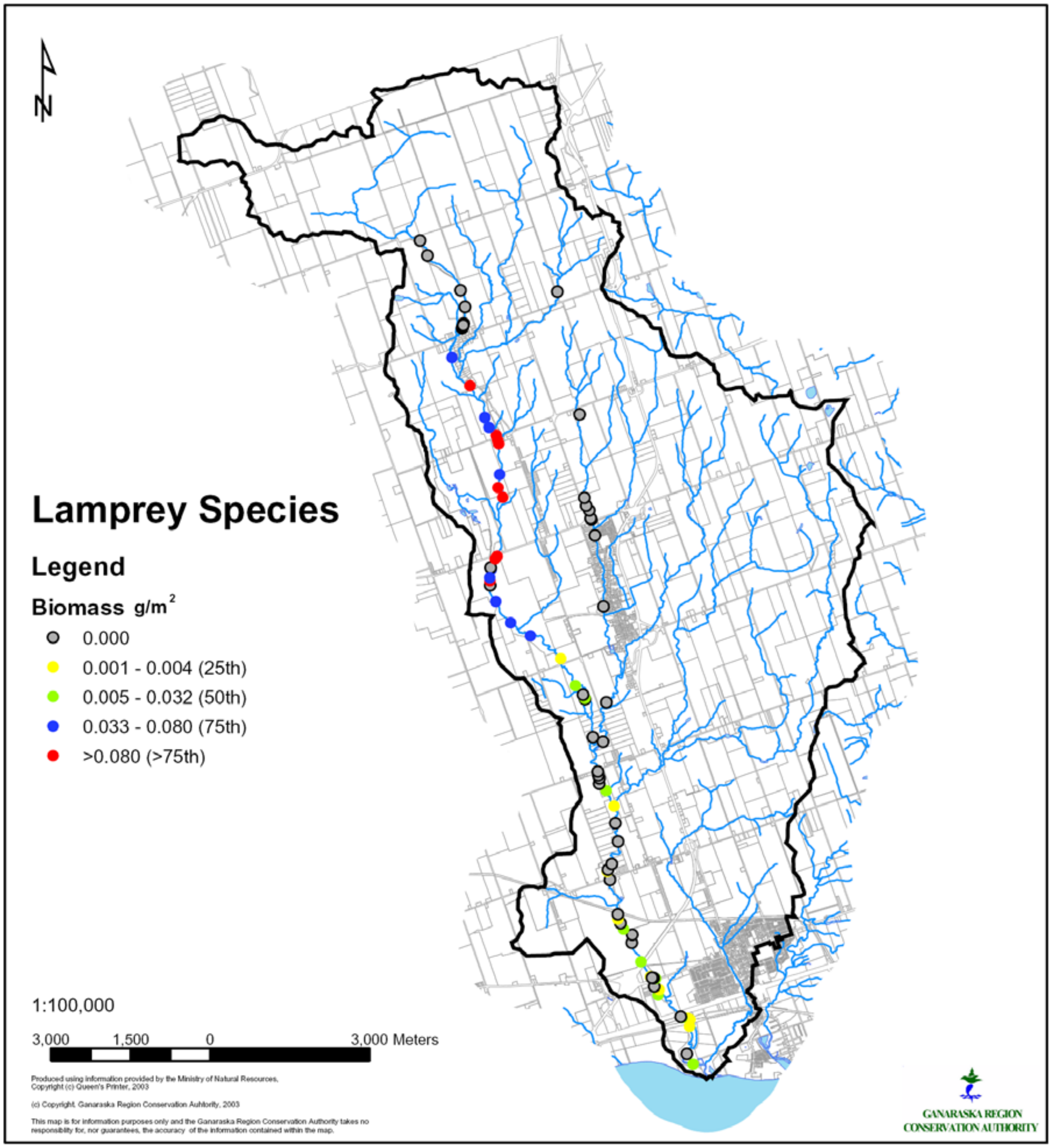


Figure 4.6: Lamprey species July/August distribution

Blacknose Dace (Rhinichthys atratulus) and Longnose Dace (Rhinichthys cataractae)

The Blacknose Dace is native and inhabits cool and clear streams, but is also abundant in degraded tributaries (Scott and Crossman 1998). This colourful fish is used as baitfish in the Eastern Great Lakes. Blacknose Dace spawn during the spring in fast, shallow riffles consisting of gravel substrate when water temperatures are approximate 21^{o}C. Males establish and defend territories but do not build nests (Scott and Crossman 1998).

Longnose Dace are native to North America and occur across Canada. The Longnose Dace is a benthic species inhabiting clear, fast-flowing streams and rivers as well as inshore lake habitats (Scott and Crossman 1998). In Canada, Longnose Dace are not commonly used as a baitfish, but are a valuable prey item for salmonids. Longnose Dace spawn in early spring on riffle bars over gravel substrate (Scott and Crossman 1998).

Blacknose Dace were collected throughout the watershed and as such is the most widely distributed cyprinid species in Wilmot Creek. Areas of highest Blacknose Dace biomass include portions of the mainstem below the Highway 35/115 overpass and the mainstem of Orono Creek north of Taunton Road (Concession Road 6) (Figure 4.7; Desjardins and Stanfield 2005).

Collections of Longnose Dace revealed a distribution very similar to that of Rainbow Darters. Like Rainbow Darters, Longnose Dace were mostly obtained from areas downstream of the CNR bridge. Only two stations upstream of this structure contained Longnose Dace (Figure 4.8; Desjardins and Stanfield 2005).

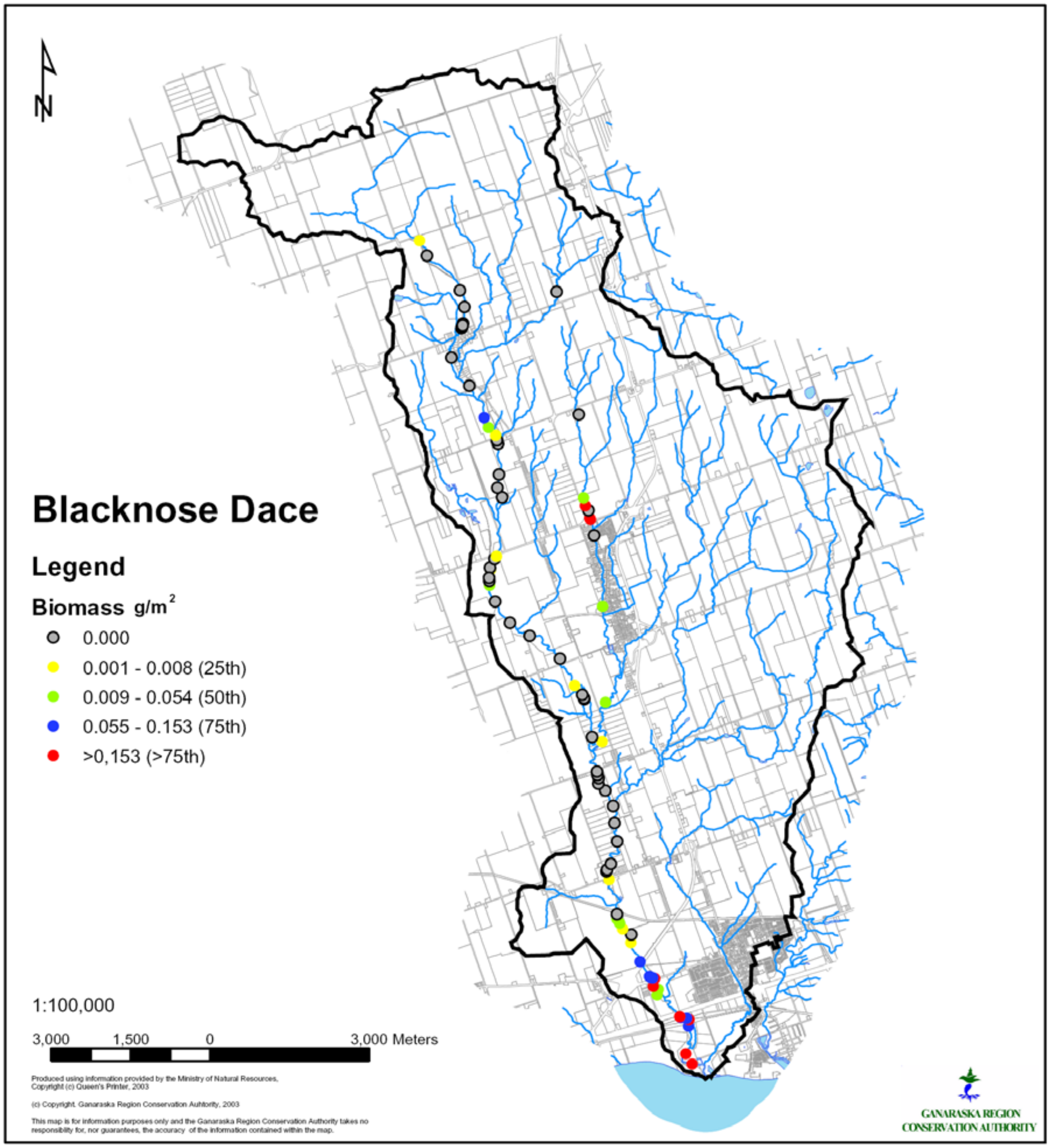


Figure 4.7: Blacknose Dace July/August distribution

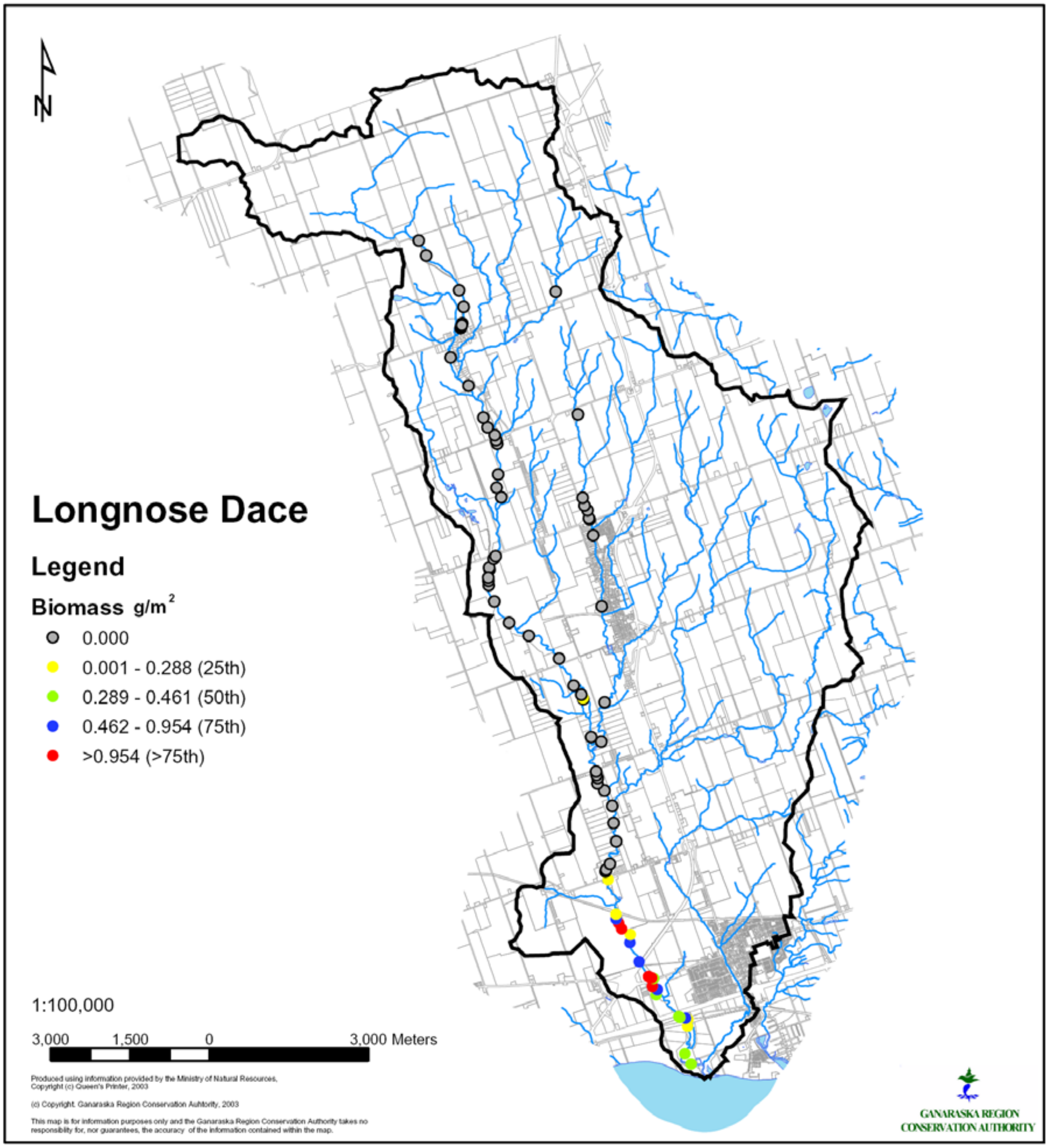


Figure 4.8: Longnose Dace July/August distribution

White Sucker (Catostomus commersonii)

Native to only North America, this widely distributed species spawn in early spring, utilizing streams, shoals and beaches. Spawning in streams occurs in low-velocity reaches or fast-moving riffle runs (Scott and Crossman 1998). White Suckers do not construct nests, however the eggs adhere to stream substrate. Atlantic Salmon and Brook Trout are known to consume juvenile White Suckers. Adults return to their native stream two to four years later to spawn (Scott and Crossman 1998). White Suckers are tolerant to warmer water, however they are commonly found in coldwater systems.

The distribution of White Sucker in Wilmot Creek is similar to that of the Mottled Sculpin. They are prevalent mostly in the middle to lower portions of Wilmot Creek with no recorded catches occurring north of Concession Road 6 (Figure 4.9; Desjardins and Stanfield 2005).

Sculpin Species (Cottidae)

Mottled Sculpin (*Cottus bairdii*) and Slimy Sculpin (*Cottus cognatus*) were observed in Wilmot Creek and were analyzed together. Both scuplin species are native and inhabit cool water streams in Eastern Ontario. Sculpins spawn in the spring, nesting under a rock or ledge, where females deposit a mass of eggs on the cover ceiling (Scott and Crossman 1998).

The two species of sculpin have very different distributions within the watershed. Slimy Sculpins are almost entirely captured upstream of Concession 6 (Figure 4.10) whereas, Mottled Sculpins are widely distributed in areas downstream (Figure 4.11). The differentiation between these two species in the field has been a persisting problem. The potential for incorrect identifications is high (Desjardins and Stanfield 2005).

Species More Prevalent in the Lower Portions of the Watershed

In addition to a few of the species previously discussed (Rainbow Darter, Longnose Dace, and Blacknose Dace), several species were more prevalent in the lower reaches of the watershed. Species such as Brook Stickleback (*Culaea inconstans*), Johnny Darter (*Etheostoma nigrum*), Iowa Darter (*Etheostoma exile*), Bluntnose Minnow (*Pimephales notatus*), Creek Chub (*Semotilus atromaculatus*), Spottail Shiner (*Notropis hudsonius*), Pumpkinseed (*Lepomis gibbosus*), and Rock Bass (*Ambloplites rupestris*) were almost exclusively captured below the CNR railway bridge. It appears as though the railway bridge may be acting, or has acted in the past, as an upstream dispersal barrier for non-jumping species (Desjardins and Stanfield 2005).

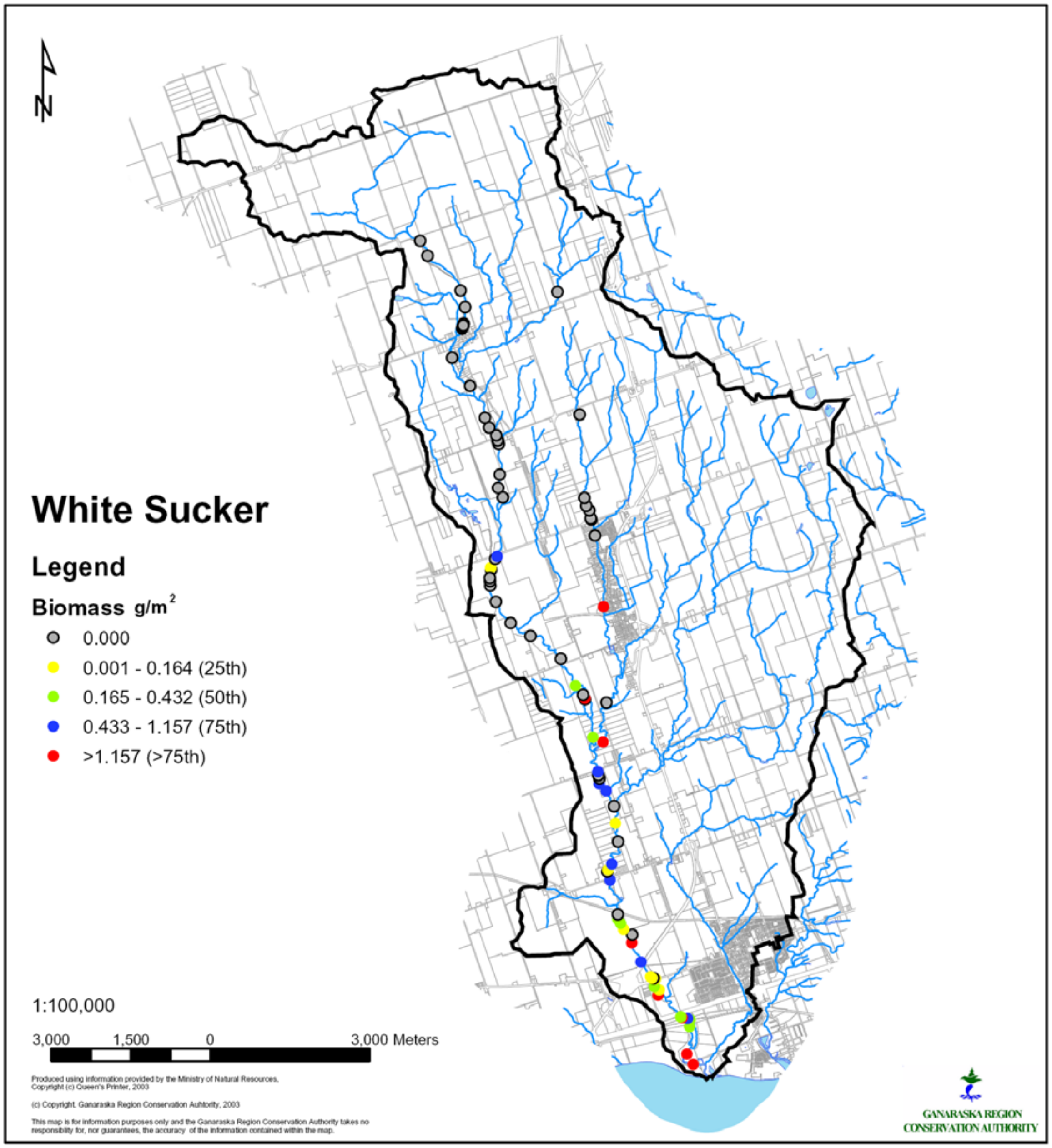


Figure 4.9: White Sucker July/August distribution

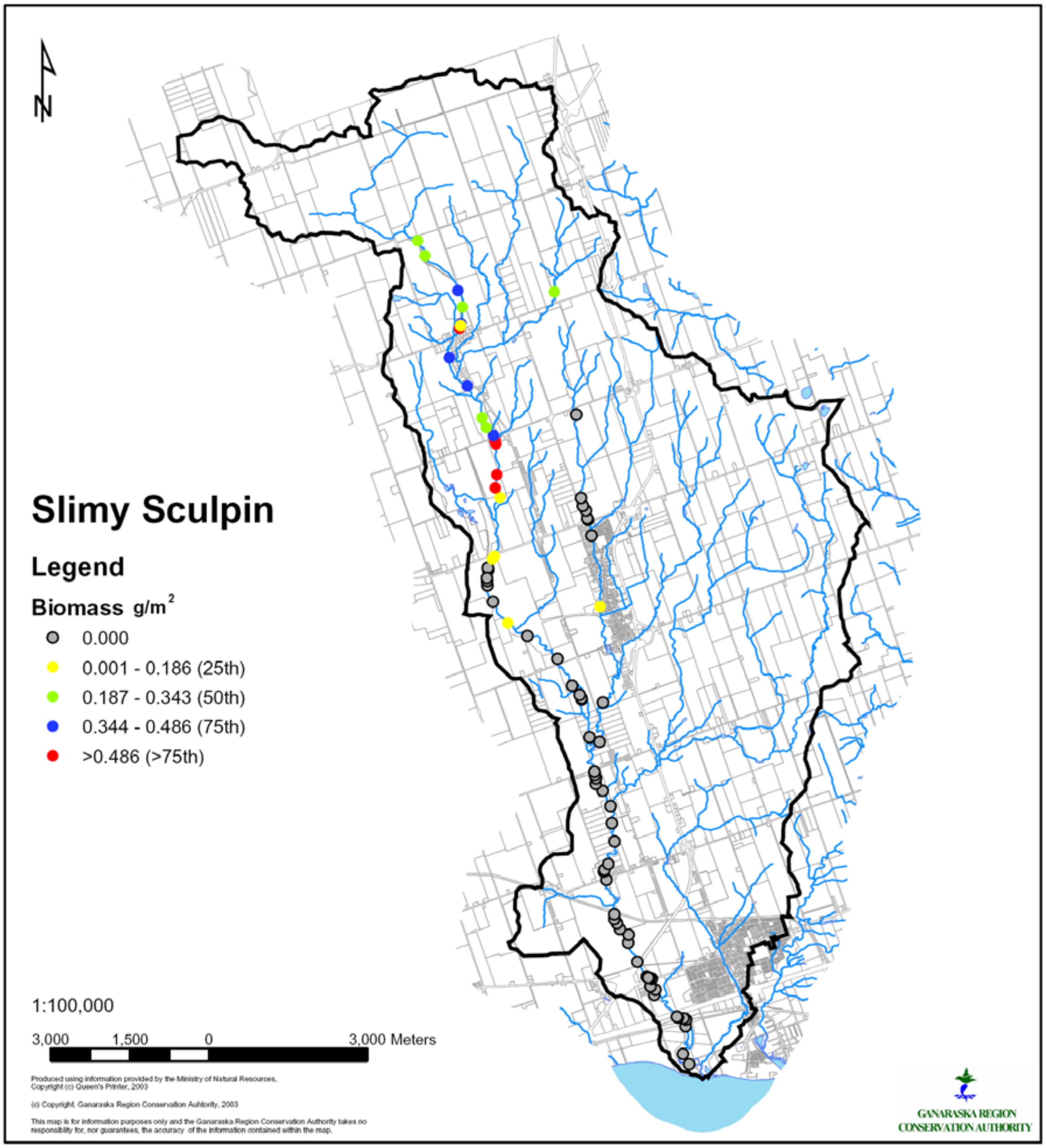


Figure 4.10: Slimy Sculpin July/August distribution

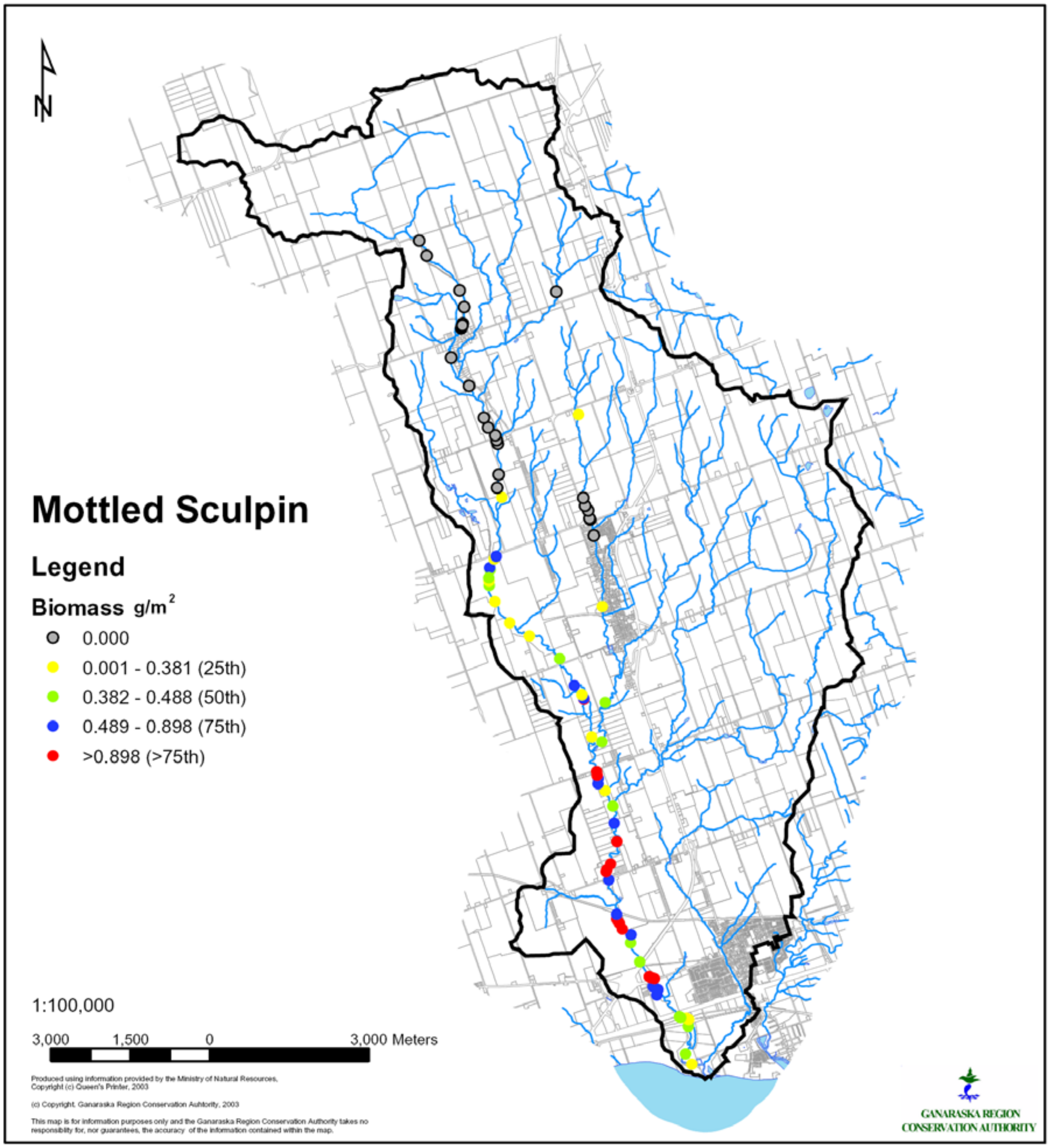


Figure 4.11: Mottled Sculpin July/August distribution

Fish Communities
Four fish communities were identified in the Wilmot Creek watershed (Figure 4.12. Communities were identified at each sample site, in which abundance and densities of fish caught were used to classify that individual community.

Group 1: Darters and Cyprinids
Warm water fish communities (Dace and Darters) dominate fish community group 1, located on the lower portions of Wilmot Creek. This zone is accentuated by a potential migration barrier caused by sediment down cutting at the CNR bridge.

Group 2: Mottled Sculpin and Rainbow Trout
Group 2 contains higher densities of Rainbow Trout, and appears to be a transition area between Groups 1 and 4 in fish community, habitat, and position in the basin. The lower boundary of this mixed community is closely associated with the same barrier previously mentioned.

Group 3: Brook Trout
Fish community group 3, located in headwater regions of both Wilmot and Orono Creeks, contains higher numbers of Brook Trout. Instream habitat variables did not distinguish this group, and the influence of surficial geology is unclear. This fish community may also be influenced by the relatively low abundance of inter-specific competitors perhaps due to the presence of downstream migration barriers.

Group 4: Slimy Sculpin and Brown Trout
Fish community group 4, located in the headwater regions of the mainstem of Wilmot Creek, contains higher numbers of Slimy Sculpin, Brown Trout and lamprey species and is further distinguished by the relatively high amounts of wood cover and colder water temperatures. At the landscape level, this group is found in an area marked by a transition for well drained to moderately well drained soils.

Foster Creek was not sampled during the creation of the *Wilmot Creek Fisheries Management Plan*; however, fisheries data is available through the development of the *Foster Creek Subwatershed Planning Study* (Gartner Lee Limited and Greenlands International 2001). Rainbow Trout, Blacknose Dace, Creek Chub, Fathead Minnow, Carp, White Sucker, Brook Stickleback, Mottled Scuplin and Johnny Darter have all been found within Foster Creek. It was concluded that the fish communities in Foster Creek represent a typical, small, southern Ontario stream dominated by Cyprinids (Creek Chub) and White Suckers. The presence of cool water indicator species such as Mottled Sculpin and Rainbow Trout suggest that Foster Creek does have the ability to support these species but the low water levels and heavy silt deposition in several locations reduces this potential (Gartner Lee Limited and Greenlands International 2001).

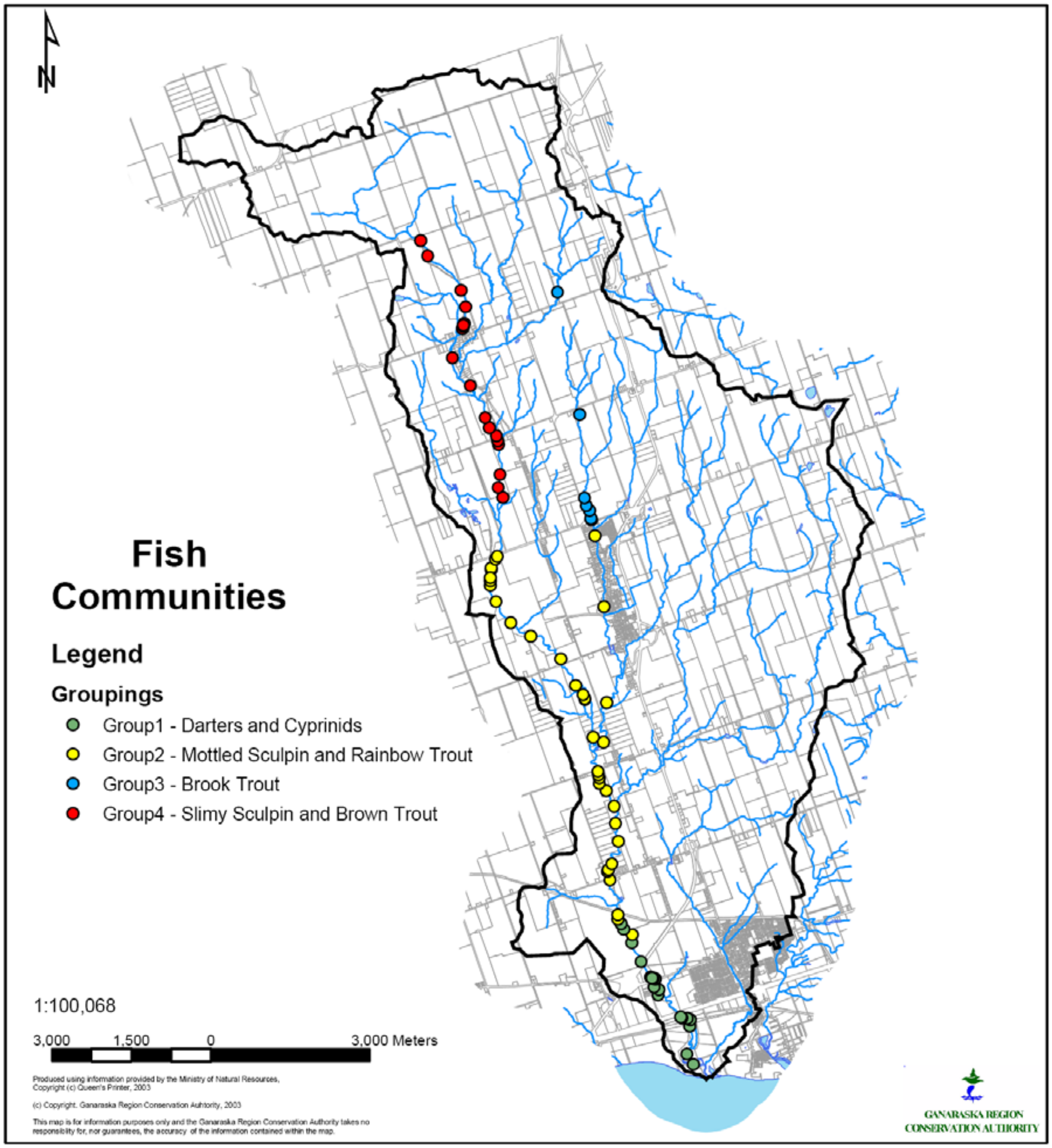


Figure 4.12: Fish communities

Index of Biotic Integrity

An Index of Biotic Integrity (IBI) is a tool that measures fish community associations that is used to identify the general health of the broader stream ecosystem. Steedman (1986) utilized this method for streams in southern Ontario. Steedman employed ten measures of fish community composition, grouped into four general categories: species richness, local indicator species, trophic composition and fish abundance (Table 4.2). These ten categories were summed to determine an IBI on a scale from ten (poor) to 50 (very good). Two of these metrics were not utilized for this study, the percent of sample as piscivorous species (>20cm), and the percent of sample with blackspot disease since the latter was not collected, and may not necessarily reflect unhealthy aquatic habitat conditions. One metric was adjusted to include all salmonid species (Chinook Salmon, Coho Salmon, Rainbow Trout, Brown Trout, Atlantic Salmon, and Brook Trout) instead of just Brook Trout to reflect ecological health the Wilmot Creek watershed. The IBI health scores were adjusted to reflect this, with the scale shifting to eight (poor) to 40 (excellent) (Table 4.3). The stream health score hierarchy was modified to reflect this change. Each metric was scored a 1, 3, or 5, with 5 being the highest health rating (Table 4.4).

Table 4.2: Eight sub-indices used in calculating the Index of Biotic Integrity

Species Richness

- number of native species
- number of darter and/or sculpin species
- number of sunfish and/or trout species
- number of sucker and/or catfish species

Local Indicator Species

- presence or absence of salmonid species, including Chinook Salmon, Coho Salmon, Rainbow Trout, Brown Trout, Atlantic Salmon, and Brook Trout (only in streams designated as current or historical coldwater)
- percent of sample as dace species

Trophic Composition

- percent of sample as omnivorous species

Fish Abundance

- catch-per-minute of sampling

Table 4.3: Conversion of IBI scores to qualitative health categories

Health Category	IBI Score (out of 40)	Percent of Maximum IBI	Numerical Code
Excellent	33 or greater	83 or greater	4
Good	24-32	61-82	3
Fair	18-23	45-60	2
Poor	8-17	20-44	1
Very Poor	no fish	0	0

(adapted from Steedman 1986)

Table 4.4: Configuration and scoring criteria for IBI

Category	Metric	Scoring Criteria 5 (best)	3	1 (worst)
Species Richness and Composition	Number of native fish species Number of darter or sculpin species Number of sunfish or trout species Number of sucker or catfish species	0.67 MSRL* or higher	0.33 to 0.67 MSRL	Less than 0.33 MSRL
	Presence/absence of Salmonid species	Present		Absent
	Percent of sample as dace species	<50%		>50%
Trophic Composition	Percent of sample as omnivores	<20%	20-40%	>40%
Fish Abundance	Catch per minute of sampling	4.4-25.3	>25.3	<4.4

*Maximum Species Richness Line

Fisheries Data

Fisheries data consisted of six sites monitored by the Ministry of Natural Resources from 1987 to 2008. Each fisheries site after 1992 was sampled following the Ministry of Natural Resources stream electrofishing protocol (Stanfield 2005). Electrofishing stations prior to 1992 were sampled using the three-pass methodology, where the cumulative species abundance was used in the IBI calculations. Only data collected during the month of August was utilized, or when not available, the closest date. Stream health was calculated for each year data was available at each site. The average stream health score for this time period is shown in Table 4.5 and Figure 4.13.

Stream quality based on Steedman's IBI (Table 4.5) showed two sites being good (33%), four fair (67%), and zero excellent or poor sites. The four 'fair' sites did not score higher primarily due to the low overall species diversity. Sites BM02, BM03 and BM04 were dominated by a salmonid community along with mottled and/or slimy sculpin. Table 4.6 shows the importance of Lake Ontario in regards to the abundance of native species; with the site closer to Lake Ontario having the highest number of native species.

Table 4.5: Temporal trends in IBI stream health

Site	1987 to 2009 Average	IBI Ranking	Years of Data	Standard Deviation	r^2	Slope
BM01	29.44	Good	18	3.4848	0.2075	0.2455
BM02	22.10	Fair	20	3.2102	0.0001	-0.0049
BM03	21.73	Fair	22	3.1042	0.0011	0.0151
BM04	22.86	Fair	21	2.7980	0.0055	0.0294
BM05	23.00	Good	20	2.7145	0.0014	-0.0142
OR01	22.00	Fair	4	1.6330	0.4000	-0.8000

Table 4.6: Proportion of native species at each site

Site	1987 to 2008 Average number of native species	Native species range	1987 to 2008 Average number of introduced species	Introduced species range
BM01	8.1	3-16	1.4	1-2
BM02	1.5	1-4	1.5	1-4
BM03	1.6	1-3	2	1-5
BM04	2.7	1-7	2.2	0-5
BM05	1	1	1.5	0-3
OR01	0.33	0-1	2.3	2-3

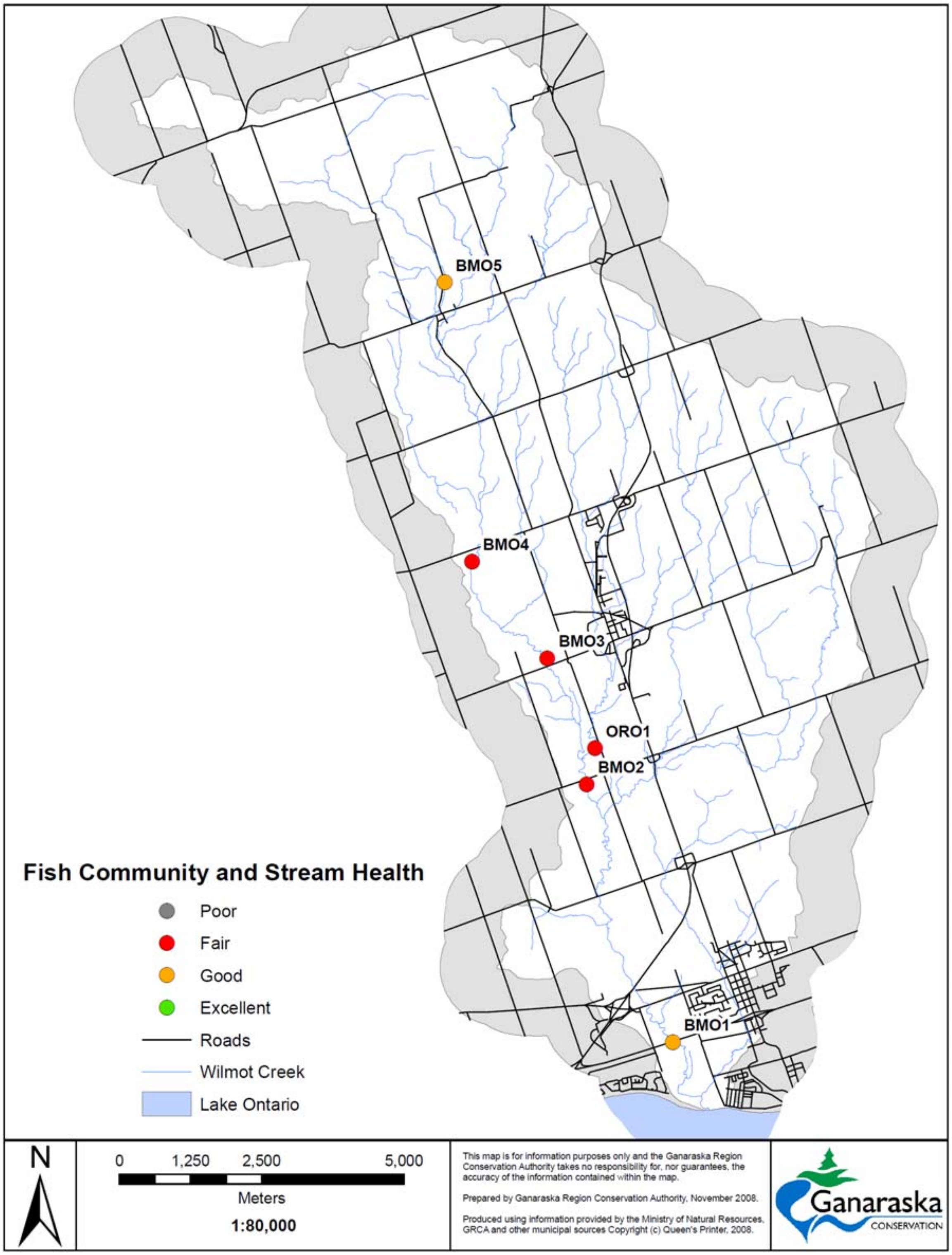


Figure 4.13: Stream health based on Steedman's Index of Biotic Integrity

4.0.2 Instream Habitat

A stream's ability to support a diverse and sustainable aquatic community depends on the instream habitat characteristics that include stream temperature, dissolved oxygen, food types, cover, stream bottom type and spawning areas (Cushing and Allan 2001). Stream temperature needs to be stable and within a range necessary for specific species' health and survival. Dissolved oxygen in streams is usually abundant, however concentrations vary in relation to temperature, water aeration (e.g., water flowing over rocks), primary production and water quality (Cushing and Allan 2001). Food sources of aquatic species include vegetation (e.g., periphyton), particulate organic matter, aquatic macroinvertebrates, fish and terrestrial organisms. A range of food types needs to be present in a stream to support a dynamic food web. These instream habitat requirements are discussed in further detail in Section 4.0.3 (stream temperature), 3.7 (dissolved oxygen) and 4.0.4 (benthic macroinvertebrates) of this document.

Cover in a stream is vital to aquatic organism survival. Cover consists of riparian vegetation, boulders, overhanging banks, logs, root wads and shade from overhanging objects (Cushing and Allan 2001). Instream cover primarily provides shelter from predators and strong currents. Streams that support trout and salmon have a range of stream morphologies ranging from cascade (8 to 30% slope) to dune-ripple regime (<0.1% slope). Typically, local streams with a step-pool (4 to 8% slope) or pool-riffle (0.1 to 2% slope) are the most productive. Stream reaches of > 4% slope are generally not utilized by salmon for spawning because of the reaches' high bed load transport rate, deep scour, and course substrate (Roni et al. 1999). Desired stream bottom composition for trout and salmon life cycles (e.g., spawning bed) includes a combination of large rocks, rubble, gravel and smaller amounts of sand. Other cover and substrate compositions are required for many different aquatic organisms. The following section discusses instream habitat in terms of cover and substrate composition, which among other life cycles, are necessary for spawning habitats.

Methods

Habitat data was collected at 54 sties using the Ontario Stream Assessment Protocol (OSAP) Channel Morphology method or the Rapid Assessment Method (RAM). Habitat attributes were measured in relation to percent rock as cover; percent wood as cover (materials > 100 mm on their median axis); and percent of substrate characterized as fine (<2 mm), gravel (2-100 mm), and cobble (>100 mm). Further information can be found in Desjardins and Stanfield (2005).

Instream Habitat Results

Adapted from Desjardins and Stanfield (2005)

Wilmot Creek historically had excellent salmonid spawning habitat with an abundance of gravel substrates. Analysis confirms that this habitat still exists in sections of the mainstem, with gravel generally occurring in 40% to 90% of the substrate. However, there are areas that differ considerably with regard to substrate size. For example, upper reaches have mixed substrates, with near equal proportions of fines (sands) and gravel with smaller proportions of cobbles. Fines (mainly sand) dominate in the region from about midway through Concession 5 upstream into Concession 7.

Although cobble never dominates the substrate in any area of the stream, they do tend to be more common in downstream areas as indicated by the proportion of rock as cover. The higher abundance of exposed rock in downstream areas is likely a result of sediment downcutting through this portion of the creek. This section of creek has large exposures of clay and comparatively low amounts of sediment. Lower sections of Wilmot Creek are said to be sediment starved (Les Stanfield, personal communication). Conversely, the absence of cobble higher in the watershed likely results from sedimentation of finer materials, a significant implication to both the fisheries and processes of sediment movement. For example, cobbles are absent from several areas where fines and gravel are very abundant.

Habitat analysis conducted at nine sites on Foster Creek (Gartner Lee Limited and Greenlands International 2001) indicates that this tributary contains an abundance of silt and sand, with certain areas containing gravel and cobble. Instream cover consisted of grasses, woody debris, aquatic vegetation and debris such as concrete. In addition, canopy cover over the creek ranged from 0% to 95%, but consisted mainly of non-native Manitoba maple (*Acer negundo*) and crack willow (*Salix fragilis*).

A high amount of wood cover in these areas also likely contributes to the high proportion of fine sediments in mid to upstream locations (e.g., upstream of Concession 5). Wood increases the complexity of the channel, influences morphology and slows sediment transport. It is clear that substrate may offer one indicator of habitat change that is responsive to changes in the system. By understanding the various instream habitat types based on substrate and cover, fisheries habitat can be managed to ensure proper restoration is applied to appropriate stream reaches. It is also important to remember that different aquatic organisms require different habitat types. Therefore by having variability in habitat types, a healthy sustainable aquatic habitat is achievable.

4.0.3 Surface Water Temperature

Surface water temperature is spatially and temporally variable and is influenced by air temperature, precipitation, stream flow, geology, topography, land use, watershed vegetation, channel and floodplain morphology, and riparian vegetation (Poole and Berman 2001). Out of all these controlling factors a strong linear relationship often exists between air temperature and river water temperature (Wetzel 2001), with a time lag by the water temperature to reflect air temperature (Stoneman and Jones 1996). As a result, air temperature is commonly used to help characterize stream temperature.

In addition to air temperature, groundwater inputs into surface water are also a dominant controlling factor of stream temperature (Power et al. 1999). Areas of groundwater discharge to a stream cause stream temperatures to be cooler than areas that do not experience discharge. Groundwater discharge areas provide places of refuge from warm temperatures, and coldwater fish tend to take advantage of these locations (Power et al. 1999). Water temperature and the presence or absence of groundwater discharge into a stream is important factors in determining the presence or absence of fish species in a particular area of the stream (Power et al. 1999). For example, Brook Trout are generally found in the coldest reaches of a stream and utilize groundwater inputs for spawning.

As described above, stream temperature dictates the types of biota that are found in a particular reach or area of the stream. Coldwater fish species require a stream temperature below 19^{o}C, cool water fish species between 19^{o}C and 25^{o}C and warm water species above 25^{o}C. However, different life stages often require different temperatures. Although fish species can tolerate stream temperatures outside of their required range, the longer the stream temperature remains in an extreme stage, the more stress is applied to the individual fish or a particular fish species (Cushing and Allan 2001).

Stream water temperatures were analyzed and reported in Desjardins and Stanfield (2005). There is a strong general warming trend in the mainstem of Wilmot Creek, with coldwater common in headwaters, and summer maximum temperatures exceeding 28°C near the outlet to Lake Ontario (Figure 4.14). Within this pattern there are local warming and cooling trends that need further investigation. Areas with unusually warmer temperatures (e.g., sites in the middle portions of the 6th Concession and lower portions of Orono Creek) may reflect local compounded impacts influenced by forest removal, pond construction, or water extractions. Areas with colder temperatures may indicate groundwater upwelling. Foster Creek is observed to be a warm water system and is managed as such under the *Fisheries Act*. However, cool water species are present in the creek.

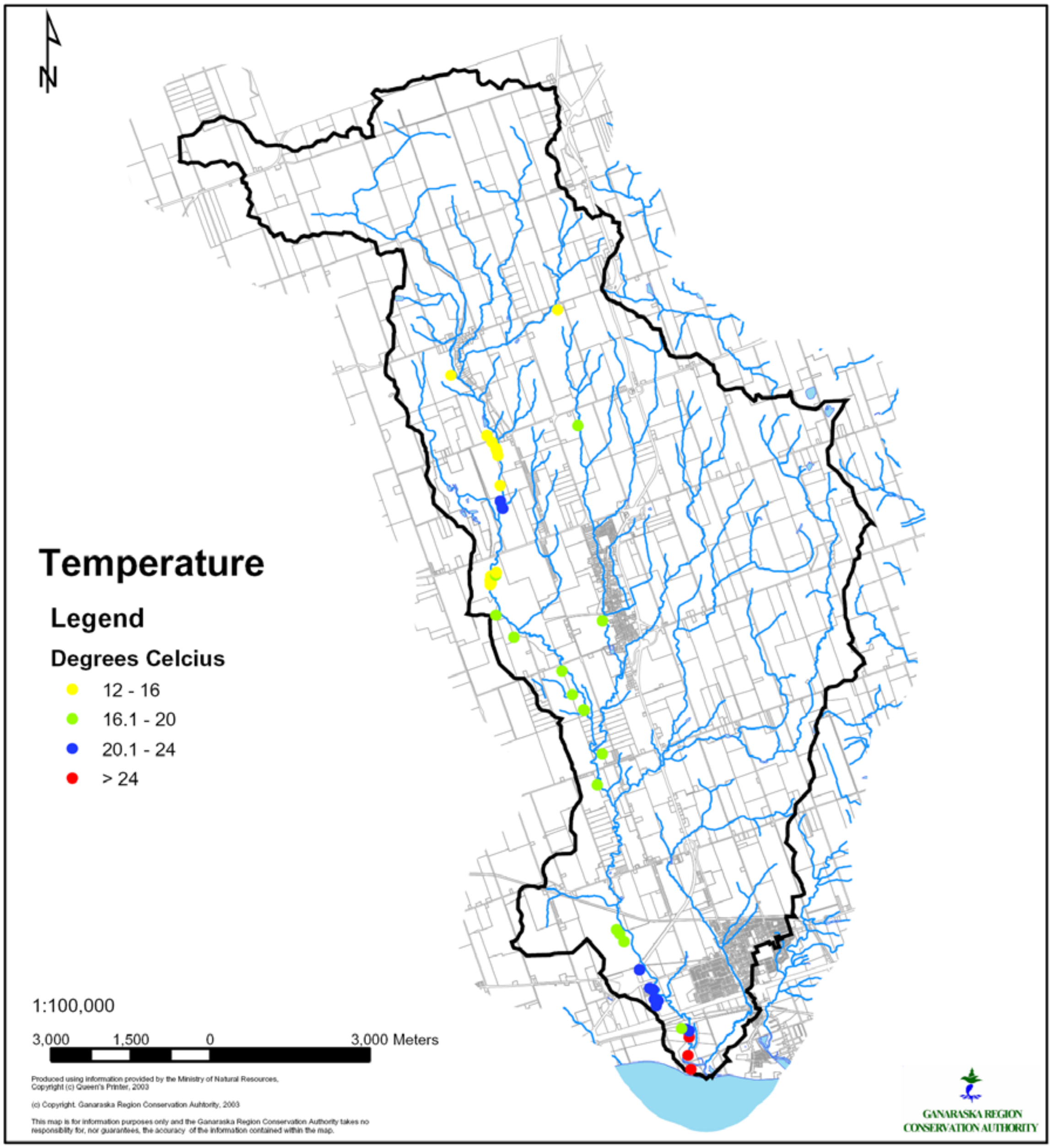


Figure 4.14: Summer stream thermal classification

Another explanation for sites experiencing differing water temperatures is the effect of shading from the riparian area. Solar radiation accessing a stream is a major variable associated with summertime stream heating (Teti 1998). Where solar radiation has access to surface water, stream temperatures will rise accordingly. If groundwater discharge is not present in those same reaches that experience solar radiation, stream water will rise as a result of heat input and no cooler water inputs from groundwater contributions. This is why riparian vegetation is an important component to reducing the variability in stream temperature changes.

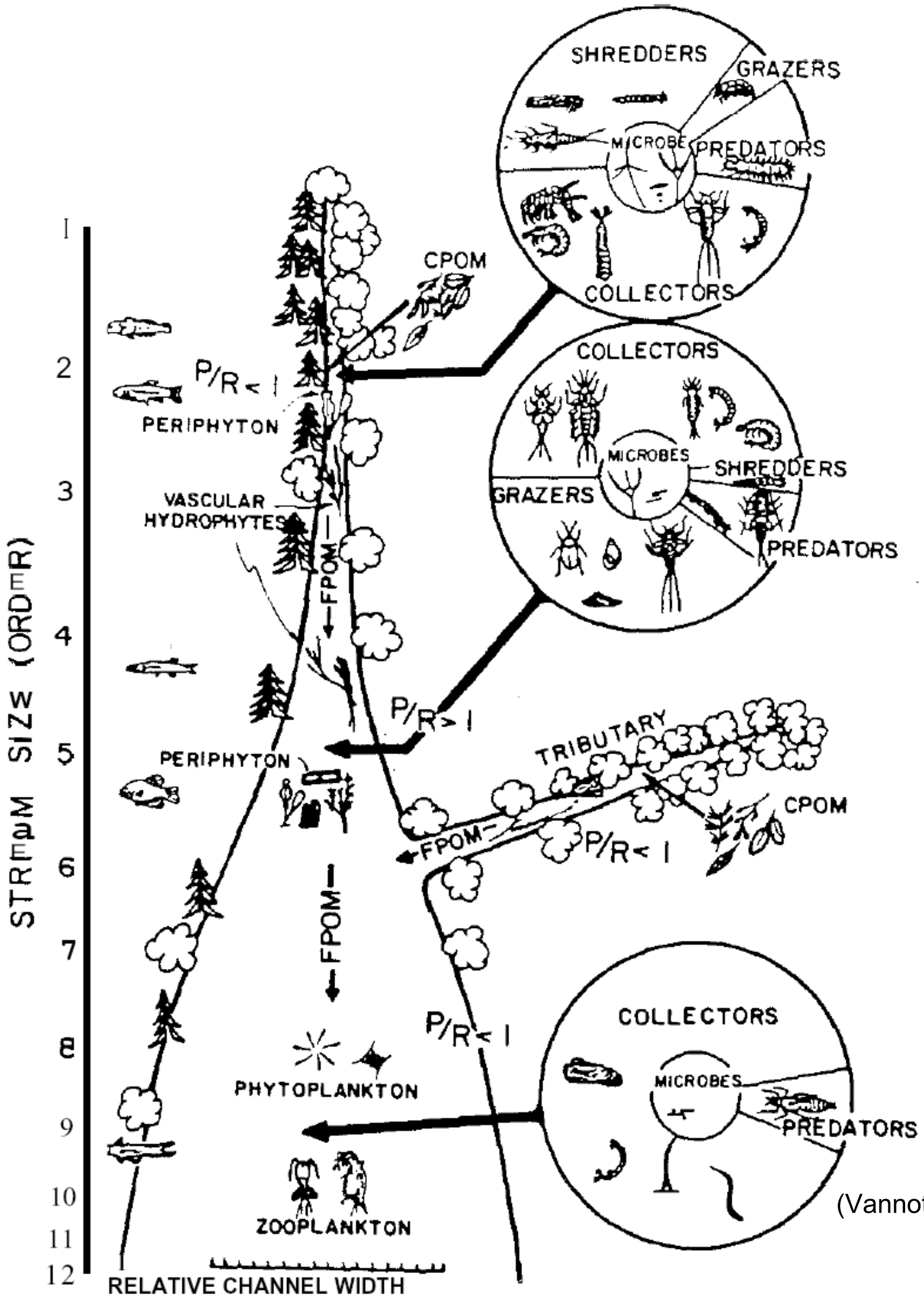
Channel structure and riparian areas can play a role in providing shade to stream. Narrow channels can be shaded more easily by stream banks (Moore et al. 2005) and tree shading can help minimize temperature variability in streams. Conversely, wide channels tend to be less shaded because they have a canopy gap over the stream (Moore et al. 2005). Stream channel morphology also contributes to the temperature regime of a stream. The channel morphology may promote hyporheic (surface and groundwater interface) water flow. As warm stream water moves through the hyporheic zone, it dissipates heat, mixes with colder groundwater, and may return to the stream cooler than the stream it returns to. Stream bank armouring discourages this mixing, and in combination with other urban impacts in the lower reaches of Wilmot Creek may explain why the sample sites are classified as warm water.

4.0.4 Benthic Macroinvertebrates

Benthic macroinvertebrates represent aquatic organisms that are visible to the naked eye and live on the bottom of a water body or in the subsurface (hyporheic zone) of a stream. The families of benthic macroinvertebrates include alderflies and fishflies, beetles, bugs, caddisflies, dragonflies and damselflies, mayflies, moths, true flies, stoneflies, crustaceans, molluscs, segmented worms, horsehair works, flatworks and mites (Jones et al 2005). All of these organisms require water for their entire life stage, or for a portion of it (e.g., reproduction and early life stages).

Benthic invertebrates carry out necessary functions in a river or stream. Grouped into functional feeding groups, benthos can be shredders, grazers, collectors or predators (Cushing and Allan 2001). As such, each functional feeding group has specialized morphologic adaptations needed to carry out necessary functions. As a result, each functional feeding group plays a role in breaking down and assimilating organic matter in a stream, and this is required in a healthy stream.

The role of benthos in a stream is recognized in the River Continuum Concept. This concept views the entire river ecosystem as longitudinally changing physical templates overlain by biologic adaptations along these gradients (Vannote et al. 1980). Seasonal variations of organic matter supply along with structure and feeding types of the invertebrate community play a large role in all biological communities found within the stream (Wetzel 2001) and their ability to adapt to current conditions and future changes. Figure 4.15 depicts the generalized model of the River Continuum Concept.



(Vannote et al. 1980)

Figure 4.15: River continuum concept

Benthic macroinvertebrates are also indicators of stream health. Certain taxonomic groupings (families, genus and species) are tolerant of organic pollution, while others are very intolerant. One index used in assessing stream health is the Hilsenoff Biotic Index, which categorizes taxa based on their tolerance to organic pollution. Indices of stream health based on benthos are useful in assessing water quality, since benthos can represent changes over a long period of time, as their presence or absence is related to current and past land use as well as local adaptation.

Benthic Macroinvertebrate Sampling Methods

Benthic macroinvertebrates are sampled using a kick and sweep method as defined in the Ontario Stream Assessment Protocol (Stanfield 2005). Benthic macroinvertebrate were sampled at 76 sites from 1990 to 2003. Identification of 27 taxa groups was performed on a mixture of classes, orders, sub-orders and families. Sampling occurred primarily during the summer months (July and August); pros and cons exist for this sampling time. A benefit of this sampling time is that invertebrates are most likely to show a response to habitat and stream impacts, since this is the most stressful season for biotic orgamisms given the high water temperature and low oxygen levels. However there is a low richness of species in relation to life history patterns (e.g., many aquatic insects have emerged to winged adults) (Jones et al. 2005).

Benthos diversity information was calculated with the Simpson's Diversity Index, where zero represents low diversity and one represents high diversity. Percent EPT (Ephemeroptera, Trichoptera and Plecoptera) was calculated as well as percent Chironomidae. These two metrics describe the proportion of intolerant and tolerant taxa respectively. Benthos was also used to rank water quality using the Hilsenhoff Biotic Index.

Benthic Macroinvertebrates as Indicators

Benthos diversity ranges from a low Simpson's diversity of 0.15 to a high diversity of 0.74 in the Wilmot Creek watershed (Figure 4.16). However, this reflects the diversity at coarser taxonomic levels, rather than species. In addition, the Ganaraska Region Conservation Authority does not sample during the spring and fall when benthic diversity is at its greatest in relation to the life stages of macroinvertebrates. By sampling in the summer, diversity may be low due to the absence of the macroinvertebrates that have left the aquatic environment for the terrestrial environment (Jones et al. 2005) or are within the aquatic environment as eggs. Percent EPT ranged from 12 to 96% and percent Chironomidae ranged from 0 to 58%.

Benthic macroinvertebrates can describe water quality based on the Hilsenhoff index, which gauges the degree of water quality impairment as it relates to nutrients. Using this index, most of the sample sites rank as "fair" and "good" water quality (Table 4.7; Figure 4.17). It should be noted however, that habitat conditions unrelated to the amount of nutrients could affect the presence or absence of certain benthic species. Low gradient, soft bottom stream segments will contain higher numbers of tolerant species. Their presence likely reflects the substrate as opposed to the quality of the water. Similarly, certain species may not be present during summertime sampling due to life stage cycles. Within Foster Creek and based on 1999 data water quality defined by the Hilsenhoff Index ranged from fair to very good (Gartner Lee Limited and Greenlands International 2001).

The influence of past land use, particularly agriculture, on present day diversity of stream invertebrates may result in long-term modifications to and reductions in aquatic diversity, regardless of reforestation of riparian zones (Harding et al. 1998). A lag of greater than 40 years may be needed before historic invertebrate diversity and composition are present. Also, benthic particulate organic matter, diatom density, percent of diatoms in *Eunotia* species, fish density in runs, and whole-stream gross primary productivity correlated with the amount of disturbed land in catchments in 1944 (Maloney et al. 2008). A more representative nutrient level analysis in watersheds should be presented through water chemistry analysis, described in Section 3.7 of this document.

Table 4.7: Hilsenhoff index of benthic macroinvertebrates

Hilsenhoff Index	Water Quality	Degree of Organic Pollution	Number of Sample Sites
0.00-3.75	Excellent	Organic pollution unlikely	0
3.76-4.25	Very Good	Possible slight organic pollution	2
4.26-5.00	Good	Some organic pollution probable	46
5.01-5.75	Fair	Fairly substantial organic pollution likely	10
5.76-6.50	Fairly Poor	Substantial organic pollution likely	3
6.51-7.25	Poor	Very substantial organic pollution likely	0
7.26 - 10.00	Very Poor	Severe organic pollution likely	0

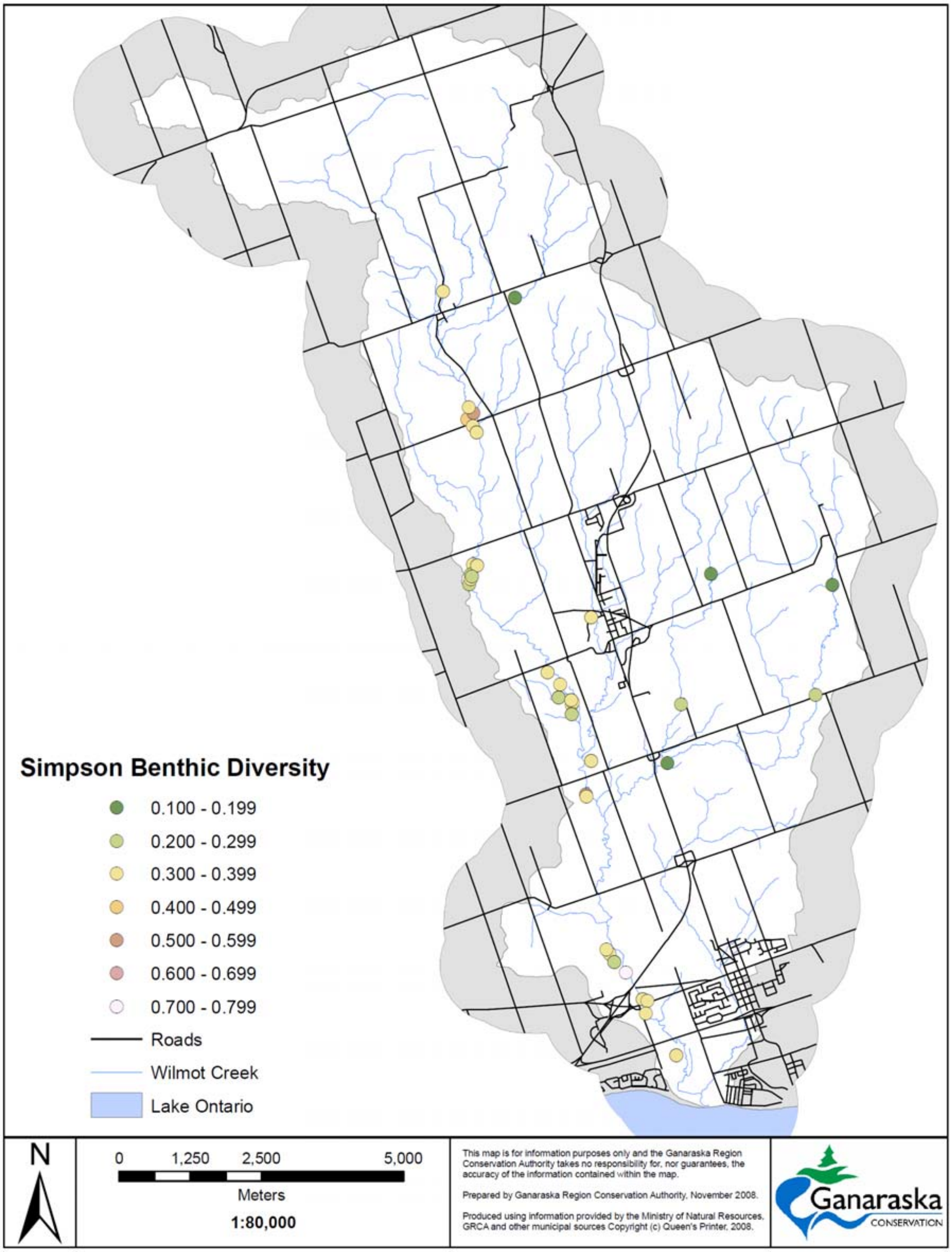


Figure 4.16: Simpsons Benthic Diversity

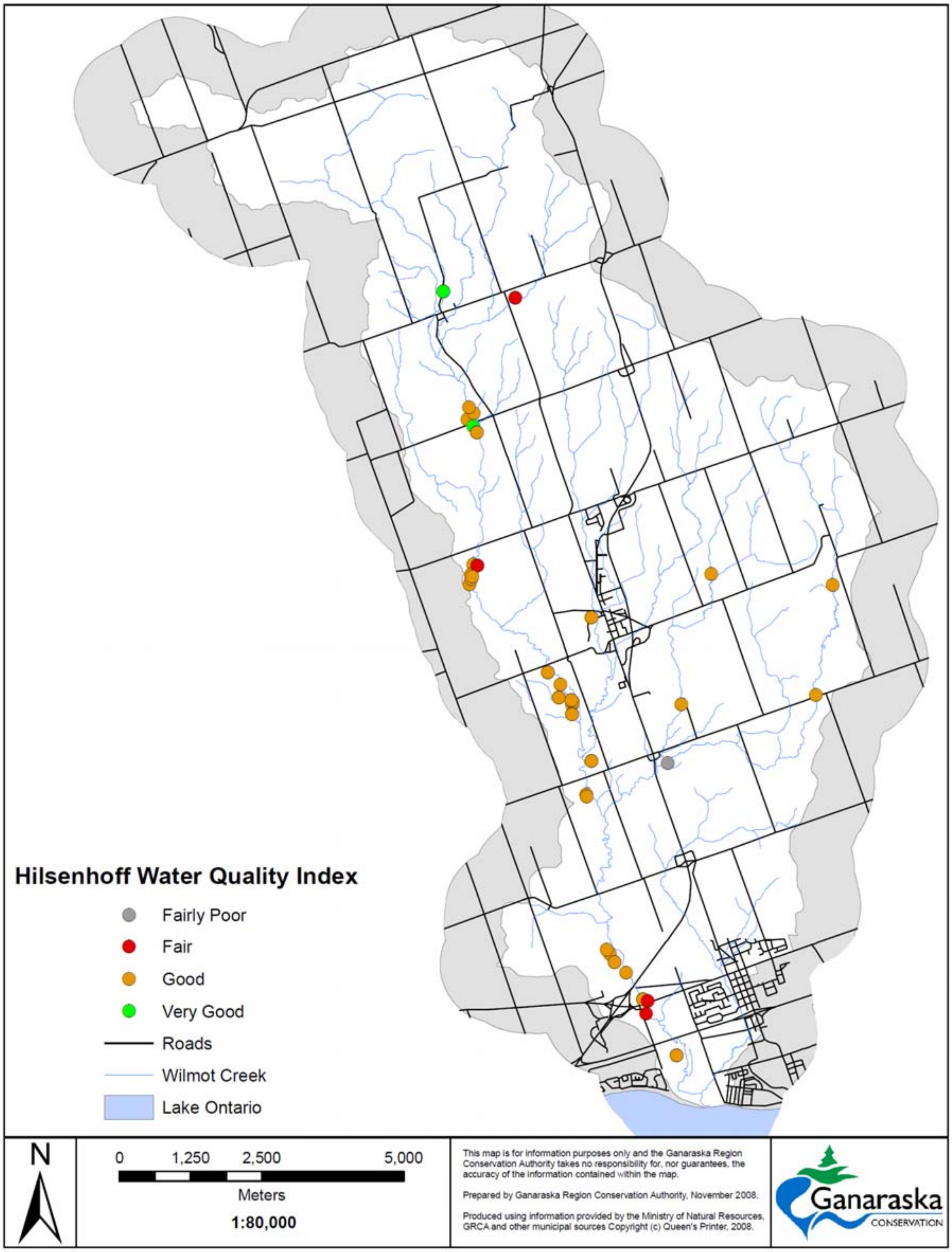
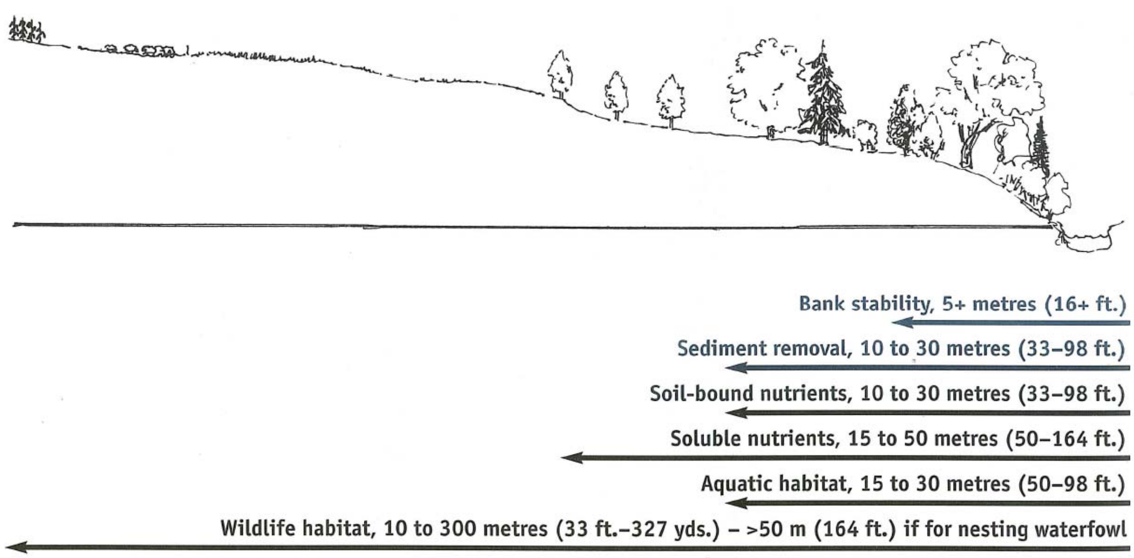


Figure 4.17: Hilsenhoff index

4.0.5 Riparian Areas

Riparian areas occur as transitional areas between aquatic and terrestrial habitats. Although not always well defined, they generally can be described as long, linear strips of vegetation adjacent to streams, rivers, lakes, reservoirs and other inland aquatic systems that affect or are affected by the presence of water (Fischer and Fischenich 2000). Riparian buffer, riparian zone, buffer strip and filter strip are terms often used and interchanged to define the extent and the functions of riparian areas. The role of riparian areas varies greatly and includes sediment retention, nutrient removal before entry into the waterbody, streambank stabilization, contribution to aquatic and riparian area biodiversity and habitats, and the regulation of stream temperature (Fischer and Fischenich 2000).

From a stewardship and management perspective riparian areas are defined as terms of the benefit provided in relation to the width and functional contribution of the riparian area (Figure 4.18). The following describes the role and composition of a 50-metre riparian area along Wilmot Creek. A 50-metre buffer provides bank stability, sediment removal, soil-bound and soluble nutrient retention, protection and contribution to aquatic habitat, and provision of certain wildlife habitat (Figure 4.18). The role of riparian areas and their effectiveness on benefiting the adjacent waterbody depends on soil type, slope, watershed size, function and cover type (Fischer and Fischenich 2000).



(Agriculture and Agri-Food Canada and Ontario Ministry of Agriculture and Food Unknown Date)

Figure 4.18: Riparian area functions

Classifying riparian area cover types using Ecological Land Classification data from 2002 shows that natural cover (forest, meadows and wetlands) dominate the amount of land cover within 50 metres from the stream banks of Wilmot Creek (Figure 4.19). Agricultural land use occurs within 30% of the 50-metre riparian area and within 10% of the developed land cover (Table 4.8).

Table 4.8: Land cover within 50-metre buffers of Wilmot Creek

Land Cover	Percentage within 50-metre buffer
Forest	42
Agriculture	30
Meadows, savannah and thickets	13
Developed	10
Wetlands	5

Riparian areas mitigate surface water quality by reducing surface runoff into Wilmot Creek, thereby reducing sedimentation and nutrient inputs. Where nutrients are a concern, riparian areas may not be adequate enough to hold back surface runoff, especially during heavy rainfall events (Carpenter et al. 1998). Retention of surface runoff is also dependent on the vegetative composition of the riparian area, and varies greatly between wetland, forested and grassed land cover (Mayer et al. 2006). Subsurface removal of nitrogen through plant uptake and conversion occurs in a riparian area, but efficiency is not related to buffer width, rather to microbial denitrification and plant types that are conducive to the uptake of nutrients (Mayer et al. 2006). As a result the composition and structure of a riparian area are necessary in maintaining or improving water quality.

Riparian areas contribute to instream habitat through bank stabilization, cover creation from undercut banks, root wads and wood cover (Section 4.0.2). The location of wood cover seen through instream habitat sampling (section 4.0.2) relates to the amount and location of forested riparian areas in the Wilmot Creek watershed. In addition, the woody debris may not be allowed to enter the stream as a result of public and private land management in the urban areas of Wilmot Creek.

Stream temperature is maintained at a cold to cool water regime as a result of riparian areas providing shade to Wilmot Creek. Along with groundwater inputs, riparian vegetation can regulate stream temperature (Moore et al. 2005). Stream temperatures presented in Section 4.0.3 can also be seen in relation to riparian area composition, with cold and cool water temperatures occurring in areas with forested riparian cover, and warm water temperatures occurring in urban areas where the channel is wider and where limited forests or shading are present.

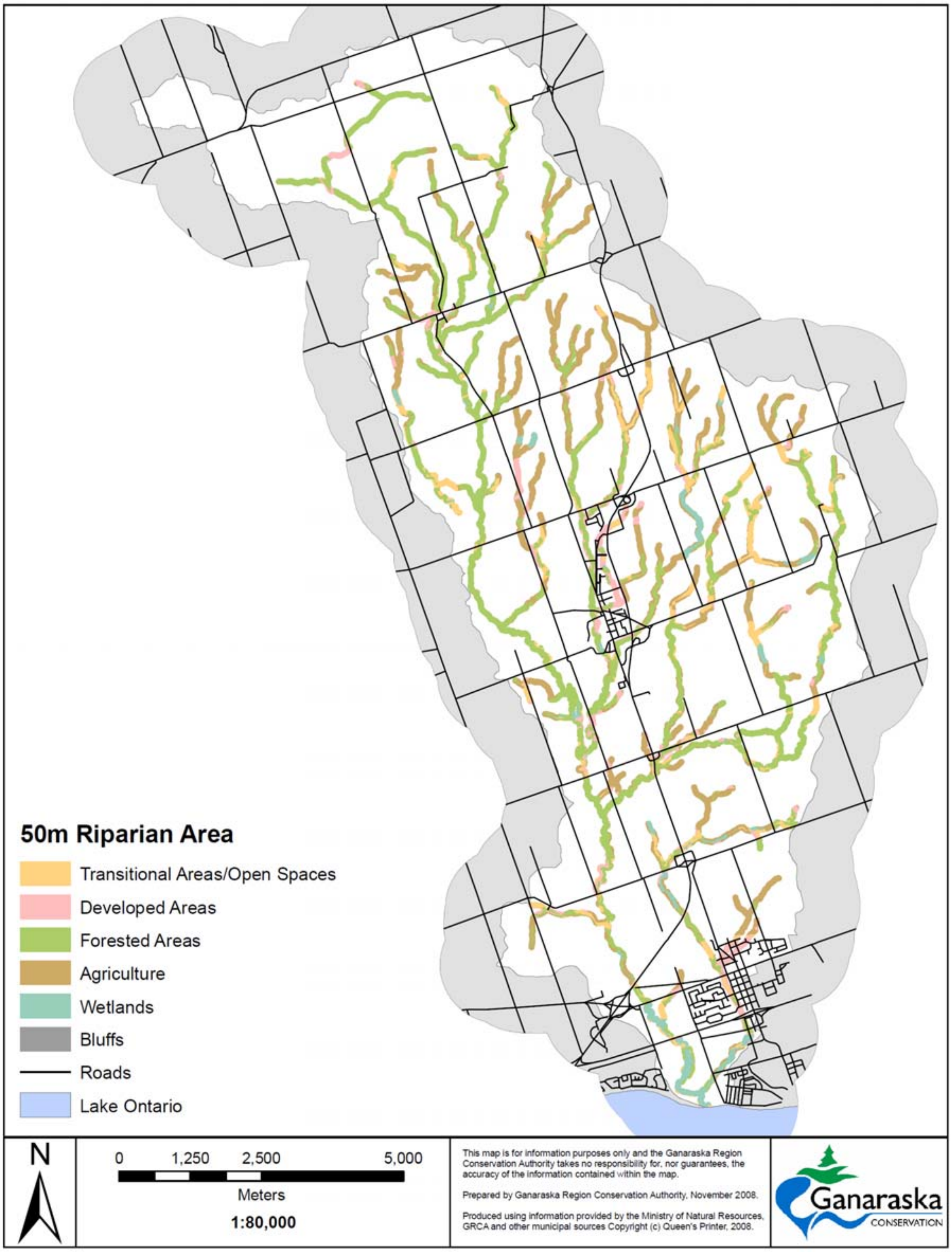


Figure 4.19: Fifty meter riparian area

4.1 TERRESTRIAL NATURAL HERITAGE

Terrestrial natural heritage includes natural areas such as forests, wetlands and meadows, as well as their associated species. These natural features are integral components of a watershed, and are entwined with human land uses. Natural heritage features contribute to healthy watersheds in part by providing habitat for diverse aquatic and terrestrial species and communities. These areas provide food, shelter and life stage requirements, including breeding areas and migratory corridors. Natural areas also provide erosion control, flood attenuation and clean water. Land cover composition in the Wilmot Creek watershed is presented in Figure 4.20, and natural areas found in the Wilmot Creek watershed are described in Table 4.9.

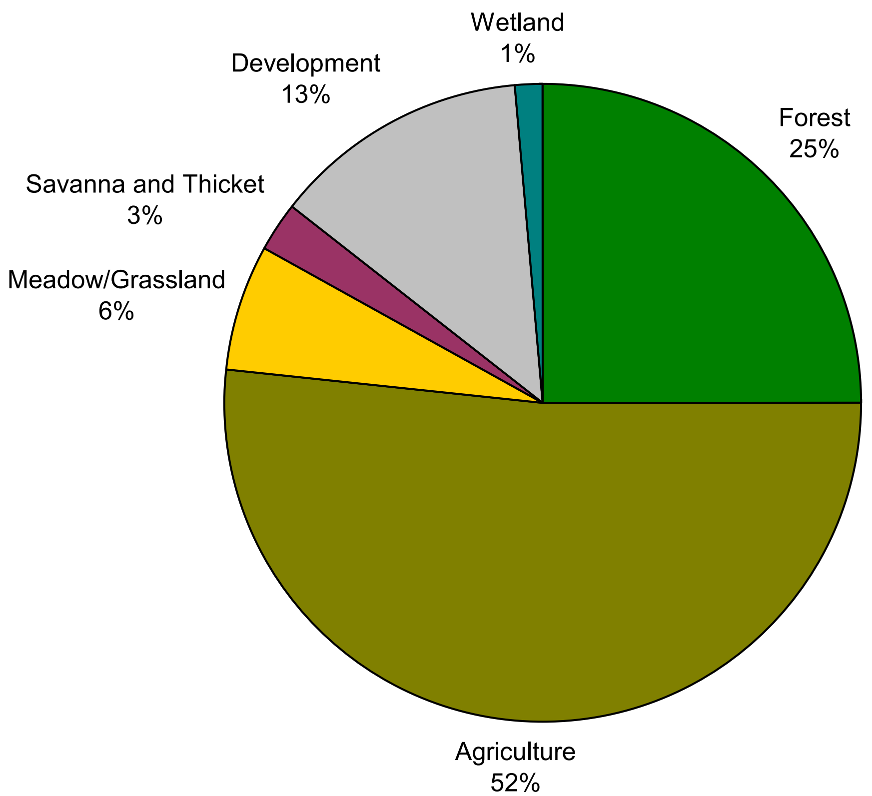


Figure 4.20: Land cover based on ecological land classification

Table 4.9: Natural areas in the Wilmot Creek watershed

Natural Feature	Area (km^2)*	Percentage of Wilmot Creek watershed*
Forests	24	25
Meadows/Grasslands	6	6
Savanna and thickets	2	3
Wetlands	1	1

* based on 2002 ELC Data.

4.1.1 Terrestrial Natural Heritage Study Methods

Terrestrial natural heritage can be assessed at three main scales: landscape, vegetation community or land use type, and species. The landscape level essentially follows principles of landscape ecology in which the entire landscape can be divided into three components: patches, corridors and the matrix (Forman 1996). In the heavily settled landscape of southern Ontario, including the Wilmot Creek watershed, the original dominant landscape cover was forest. These and other associated natural areas have since become fragmented and are represented by patches. In the surrounding landscape, the matrix—the dominant land use—is agricultural and urban. Corridors in this landscape are made up of both natural and man-made features such as riparian areas or roads For the purpose of this background study, the landscape level is evaluated primarily for forest cover by looking at total cover, distribution and habitat patch characteristics.

Vegetation communities are mapped and evaluated using the Ecological Land Classification System for Southern Ontario (Lee et al. 1998), commonly referred to as ELC. This system categorizes community types at several levels of detail. The Ganaraska Region Conservation Authority has remotely mapped vegetation communities at the community series level of the ELC using 2002 colour ortho-corrected aerial photography. The more detailed ecosite and vegetation type levels of the ELC require field assessment, which is expensive and impractical over large areas where most land is in private ownership. The Natural Heritage Information Centre housed at the Ministry of Natural Resources has identified rare vegetation community types for Ontario at the vegetation type level. Without this level of mapping, this report combines the vegetation community reporting with the landscape level reporting, and an overall summary of conditions for major vegetation communities, specifically forest, grassland and wetland. Within these categories rare communities, such as tallgrass prairie, are recognized.

There are many ways of evaluating terrestrial species, but it is a challenge to do so in a way that is relevant to the watershed context since individuals of many species can freely move between watersheds. What is needed is a way to use species as indicators of ecological health. As such, the Ganaraska Region Conservation Authority uses birds as indicators of forest health and frogs as indicators of wetland health. Theoretically, the more sensitive the species present and the more individuals, the healthier the ecosystem is likely to be. Roadside bird and frog surveys were undertaken as a rapid assessment approach to learning what can be found where. In this case ELC mapping was used to select a representative variety of forest patch sizes and landscape matrices for bird surveys and areas where a variety of wetland types could be found adjacent to roads.

Marsh Monitoring protocols were adapted for the roadside surveys, with 10-minute point counts used to record all birds seen and heard, and 3-minute point counts used to record singing frogs. Surveys were conducted to coincide with peak breeding for all species. In addition to indicator species, species of conservation concern are relevant to watershed management. In the future the Ganaraska Region Conservation Authority would like to develop an evaluation approach to identify species of local concern. In the meantime, reporting on this topic will be limited to an overview of species at risk known to occur in the watershed.

4.1.2 Forests

A forest ecosystem is a community of plants, animals, microorganisms, and the physical environment they inhabit, in which trees are the dominant life form (Hunter 1990). Prior to European settlement, forests covered more than 90% of southern Ontario (Larson et al. 1999). Widespread clearing for agriculture has resulted in a landscape of different successional stages and fragmented forest patches of varying sizes. The size, shape and connectivity of patches, as well as the types of land use in the surrounding landscape matrix have much to do with the species composition, and therefore the ecological integrity of the forest. The process of evolution and changes that occur to a forest ecosystem, either naturally or as a result of disturbance, is called forest succession. Succession can be defined as the process of change by which biotic communities replace each other and in which the physical environment becomes altered over a period of time (Kimmins 1996).

For the purpose of this report, forests are defined through ELC (Lee et al. 1998) and include coniferous, deciduous and mixed forests, and cultural plantations and woodlots. Treed swamps must be counted twice when calculating the area covered by forest and wetland separately, because a swamp is often only seasonally flooded and the ecosystem therefore functions as both wetland and forest. Swamp area must then be subtracted when the combined area forest and wetlands are calculated.

Coniferous and deciduous forests are classified as areas of land that contain more that 60% tree cover with a canopy cover of more than 75% coniferous or deciduous trees respectively. Mixed forests are also made up of more than 60% tree cover, but contain a canopy cover of at least 25% of both conifer and deciduous tree species (Lee et al. 1998). Cultural plantations and woodlands are defined as an ecological community resulting from or maintained by cultural or anthropogenic activity. A cultural plantation has more than 60% tree cover, while cultural woodlands contain between 35% and 60% tree cover (Lee et al. 1998). Swamps contain more than 25% tree or shrub cover and are dominated by hydrophytic shrub and tree species. Table 4.10 describes the proportion of forest types in the Wilmot Creek watershed and Figure 4.21 shows the locations.

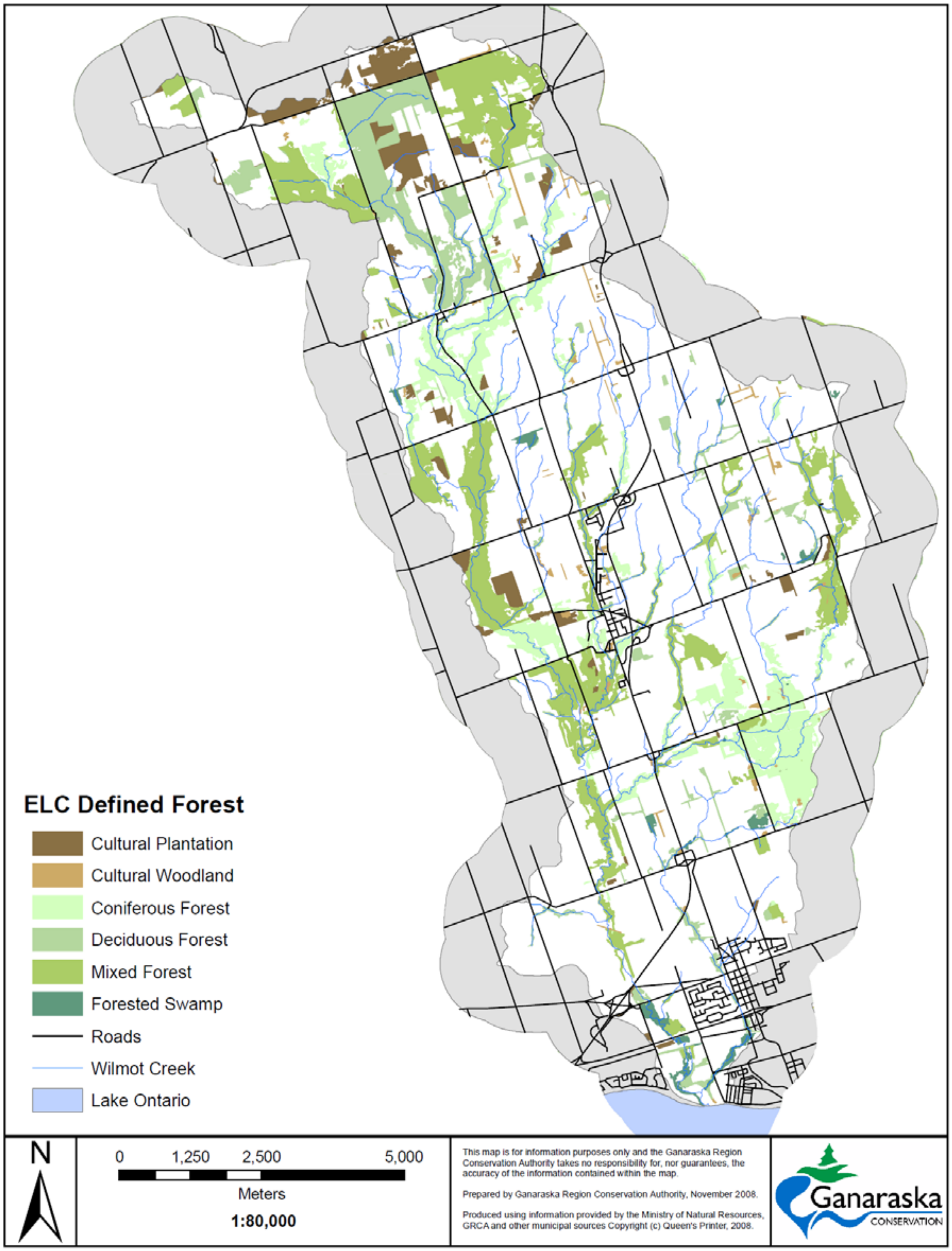


Figure 4.21: Forests

Table 4.10: Forest types

ELC Defined Forest Type	Percentage
Coniferous forest	6.5
Deciduous forest	4.9
Mixed forest	10.2
Cultural plantation	2.8
Cultural woodland	0.5
Thicket swamp	0.03
Coniferous swamp	0.03
Deciduous swamp	0.5
Mixed swamp	0.1

Different successional stages support different communities of plant and animal species. Although succession is often portrayed as progress terminated by disturbance, it can also be viewed as a cycle in which a series of plants and animals come and go (Hunter 1990). In order to maintain all plant and animals species in a landscape, it is necessary to maintain representation of all stages of ecological succession, however not necessarily in equal amounts. Ideally natural disturbances such as fire would dictate the relative abundance of different successional stages. During pre-settlement times old growth forest was likely dominant. Now this community type is rare and vastly under-represented. It has therefore become a conservation concern, and some mature woodlands should be managed to replace what was lost.

Patch (woodlot) size is an important consideration for forest management. Small isolated patches have limited capacity to sustain populations of many animal species. In contrast, large connected patches can support more species and more individuals of each species. They are also more likely to cover a variety of topography supporting more forest vegetation types, as well as natural disturbance regimes. A basic principle of conservation biology is that bigger patches are generally better for supporting biodiversity. Tables 4.11 and 4.12 depict the relationship between forest patch size and the types of species of wildlife that utilize particular patch sizes.

Forest patches that are compact in shape rather than convoluted are also generally better for many species, particularly those that require damp, dark, forest interior habitat. A number of birds experiencing population declines that require forest interior have been noted in the *Atlas of the Breeding Birds of Ontario, 2001-2005* (Cadman et al. 2007). Interior is generally considered to be forest area that is beyond 100 metres from the outside edge of the patch. The first one hundred metres is considered to be prone to negative edge effects originating in the surrounding landscape, including higher temperatures, exposure to wind resulting in desiccation or storm damage, increases in predation and parasitism, and invasions by exotic plants. Currently only 12% of the total forest cover in the Wilmot Creek watershed is forest interior (Figure 4.22). Of this 1% is deep interior forest, considered to be the area beyond 200 metres from the inner forest edge.

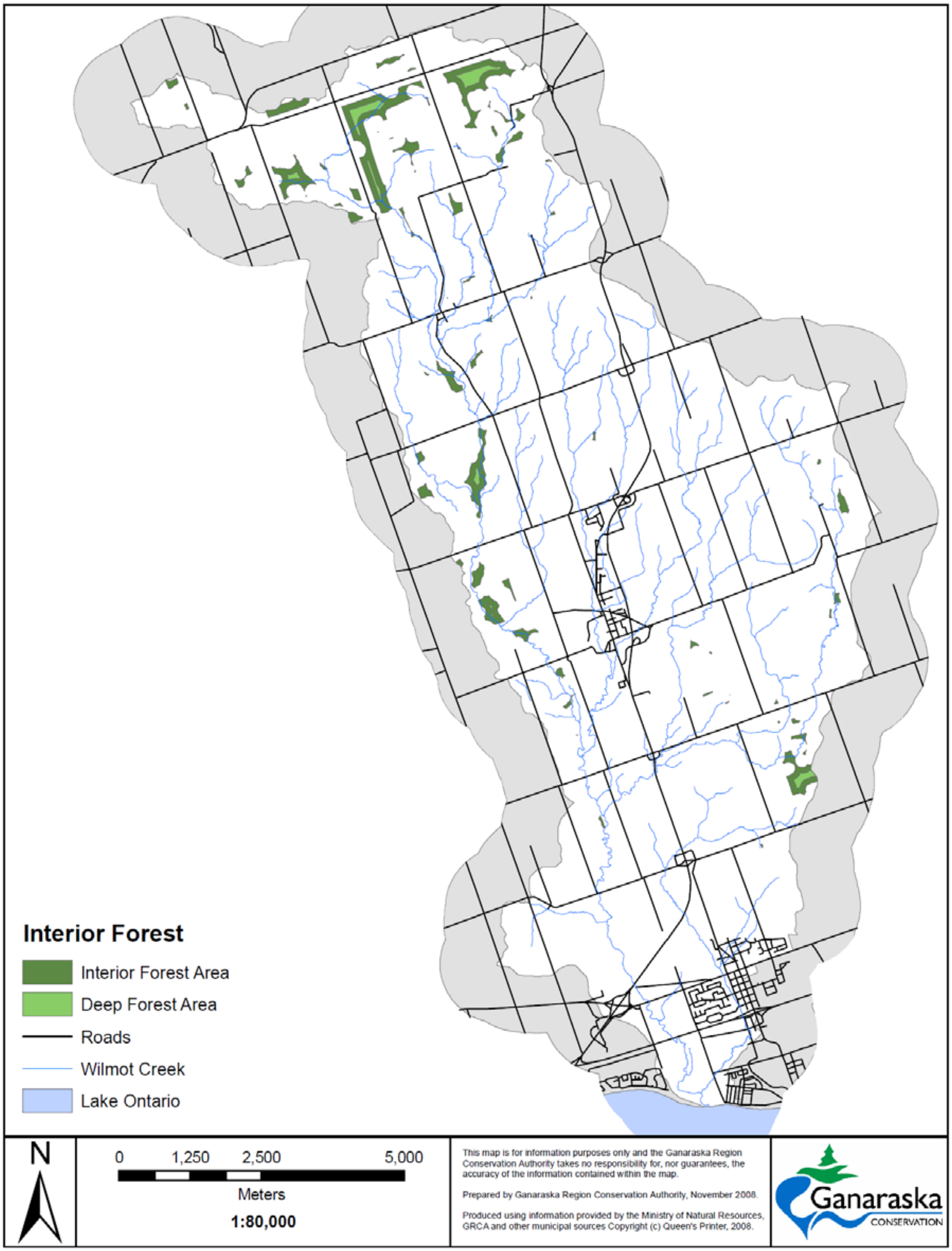


Figure 4.22: Forest interior

Table 4.11: Wildlife use of various forest patch sizes

Area	Forest/Treed Swamp
1 ha	■ Edge tolerant mammals (Gray Squirrel) ■ Common edge-tolerant birds (Blue Jay, American Crow) ■ A few birds may be associated with mature trees (Black-capped Chickadee, Eastern Wood-Pewee)
4 ha	■ A very few common edge-tolerant birds (Downy Woodpecker, Great Crested Flycatcher) ■ Eastern Chipmunk may be present
10 ha	■ Still dominated by edge-tolerant species may have very small areas of interior habitat supporting low numbers of modestly area-sensitive species (Hairy Woodpecker, White-breasted Nuthatch)
30 ha	■ May be large enough to support some species of salamander ■ Small populations of edge-intolerant species (Winter Wren, Brown Creeper, Black-and-White Warbler)
50 to 75 ha	■ A variety of area-sensitive species may be present; some will be absent if there is no nearby suitable habitat ■ Still predominantly edge influenced, but will support small populations of most forest bird species ■ Some will be absent if there is no nearby suitable habitat
100 to 400 ha	■ All forest-dependent bird species ■ Many will still be in low numbers and may be absent if there is no nearby suitable habitat ■ Woodland Jumping Mouse may be present
1,000 ha	■ Suitable for almost all forest birds ■ Some forest-dependent mammals present, but most still absent
10 000 ha	■ Almost fully functional ecosystem, but may be inadequate for a few mammals such as Gray Wolf and Bobcat (100 000 ha has been suggested as a minimum)

(Environment Canada 2005c)

Table 4.12: Anticipated response by forest birds to size of largest forest patch

Size of Largest Forest Patch	Response by Forest Associated
200 ha	Will support 80 percent of edge-intolerant species including most area-sensitive species.
100 ha	Will support approximately 60 percent of edge-intolerant species including most area-sensitive species.
50 - 75 ha	Will support some edge-intolerant species, but several will be absent and edge-tolerant species will dominate.
20 - 50 ha	May support a few area-sensitive species but few that are intolerant of edge habitat.
<20 ha	Dominated by edge-tolerant species only.

(Environment Canada 2005c)

Given that much of the remaining forest cover in the watershed occurs in valleylands, there are a large number of convoluted patches relative to compact ones that tend to be on tablelands. This means an overall high edge-to-area ratio and therefore more exposure to negative edge effects. Natural heritage system modeling can identify opportunities to improve patch shape, and these can help set priorities for private land stewardship.

In a fragmented landscape, connectivity is a key issue for all habitat types, including forest. In landscape ecology there are two types of connectivity. Structural connectivity refers to the physical layout of habitat patches on the landscape. Functional connectivity refers to the degree to which certain species are capable of moving through this structure. As an example, the American Crow (*Corvus brachyrhynchos*), a habitat generalist, has unlimited mobility through any habitat or land use type. In contrast, habitat specialists with limited mobility require contiguous specific habitats for food and cover. It is the latter that tend to be a conservation concern. Without connectivity, isolated populations of these species are at risk of inbreeding and loss of fitness. This can lead to small populations disappearing incrementally across the landscape, contributing to the regional loss of the species.

There are metrics for measuring connectivity with Geographic Information Services (GIS), however many of these merely measure the proximity of forest or other habitat patches (using GIS polygons or pixels). A more accurate method would be to model the potential movements of species or groups of species of conservation concern, although this would be time consuming. This could be done before and after GIS modeling to identify improved natural heritage systems. It could further be combined with a measure of road density as roads are barriers to wildlife movement through the natural heritage system.

Related to both connectivity and patch size is the total amount and distribution of forest cover in the landscape or watershed. The question “how much habitat is enough?” is frequently asked when attempting to protect natural heritage features or systems. In fact, this is a very difficult question to answer because of complex issues related to species population dynamics and interacting components of ecosystems, not to mention our limited understanding of these. Nevertheless, the amount of 30% forest cover has been widely advocated (Environment Canada 2005c). This is based largely on studies in northeastern North America (including Ontario), demonstrating that landscapes with 20 to 30% forest cover tend to support the majority of bird species known in a given area. However, caution must be exercised when applying such generic cover recommendations. First, because they can fly, birds may not be good surrogates for other species that have limited mobility. Secondly, supporting the majority of species means that some species may not be supported. Finally, if a landscape supports more than 30% forest cover, does this mean we can afford to *lose* cover?

In short, conservation goals that set targets of 30 to 40% cover will not be adequate to conserve all species (Groves 2003), and there is no single threshold of habitat cover for species persistence (Fahrig 2001). When one factors in other concerns such as water quality and quantity and ecological functions that work at landscape scales the amount of cover required for integrity is likely to be higher, not lower. Therefore, use of the precautionary principle is recommended.

There are other considerations. If all of the 30% forest cover is concentrated in one part of a watershed, does this mean the amount is adequate? In the Wilmot Creek, like most watersheds originating on the Oak Ridges Moraine, the majority of forest cover is in the headwater area. This is a good thing hydrologically because the forest helps to retain water. It is also a good thing in that these forest patches tend to be larger and better connected, and therefore have greater integrity in terms of species composition and ecological function. However, it also means that forest patches in other parts of the watershed are smaller, more isolated, and have less ecological integrity. Clearly there is always room for improvement in habitat cover, even if there is already more than the minimum standard. More cover and more even distribution of cover are both important. In short, although Wilmot Creek watershed has a good amount of forest relative to the 30% guideline, there is need for improvement in patch size, shape, connectivity and overall distribution of forest cover. The use of GIS to undertake natural heritage system modeling is recommended to identify priority areas for natural cover improvement.

4.1.3 Grasslands and Thickets

Grasslands include cultural meadows, cultural savannas and cultural thickets as well as natural tallgrass prairie and savanna. The "cultural" communities are essentially stages of ecological succession as a disturbed landscape gradually reverts to forest. In many cases this amounts to abandoned agricultural fields, although cultural meadows may be fields that have simply been left fallow. These habitats play a role in overall watershed functions. They allow for reduced runoff, by slowing surface water runoff, filtering out sediments and reducing erosion.

Many species rely specifically on grassland habitats and some are of conservation concern. A decline in bird species associated with grassland and shrubland habitats across Ontario has been noted in the *Atlas of the Breeding Birds of Ontario, 2001-2005*. There are also declines in the Lake Simcoe-Rideau atlas study region, which includes the Wilmot Creek watershed (Cadman et al. 2007). This is part of a disturbing trend across eastern North America. These birds include Bobolink (*Dolichonyx oryzivorus*), Eastern Meadowlark (*Sturnella magna*), Upland Sandpiper (*Bartramia longicauda*), and a number of sparrow species. This change in grassland bird species abundance has been related to temporal landscape changes. Grassland bird species expanded with the clearing of forests in the 19^{th} and early 20^{th} centuries, however today, bird species associated with grassland habitat in Ontario appear to be declining (Cadman et al. 2007). This decline could be related to grassland and shrubland habitats becoming reforested, intensification of agricultural practices (e.g., improved pastures and increased cropping), and urban development (McCracken 2005).

Currently, cultural meadows make up 6% of the landscape in the Wilmot Creek watershed. As defined by ELC cultural meadows contain less than 25% tree cover and less than 25% shrub cover, have a large portion of non-native plant species, and result from or are maintained through anthropogenic actions (Lee et al. 1998). Most of these are old fields have occurred from retired agricultural lands and others land that has been left fallow.

Cultural savanna and thickets make up 3% (0.8% and 1.7% respectively) of the watershed. Cultural savannas, as defined by ELC, contain between 25% and 35% tree cover, have a large portion of non-native plant species, and result from or are maintained through anthropogenic actions (Lee et al. 1998). Cultural thickets contain less than 25% tree cover and more than 25% shrub cover (Lee et al. 1998).

It is difficult to set cover targets for grasslands and shrublands. First, despite the conservation concerns associated with them, grasslands, in particular the cultural varieties may actually be over-represented in southern Ontario relative to the historical amount of forest cover. Second, because they are stages in ecological succession, maintaining an area as grassland would require active management, and to do this on a large scale would be impractical. Actually, the need for more forest cover means that it is a good thing that grassland and shrublands are undergoing succession. Indeed, cultural meadows may be prime areas for tree planting. Perhaps the best bet is to track habitat and land use changes, with the ultimate goal being to ensure that some form of each successional stage is well represented in the watershed or regional landscape.

4.1.4 Wetlands

Wetlands make up 1% of the Wilmot Creek watershed. Based on the ELC wetlands include meadow marsh, shallow marsh, deciduous swamps, coniferous swamps, mixed swamps, thicket swamps and bogs. There are no bogs known in the Wilmot Creek watershed. Treed swamps must be counted twice when calculating the area covered by forest and wetland separately, because a swamp is often only seasonally flooded and the ecosystem therefore functions as both wetland and forest. Swamp area must then be subtracted when the combined area forest and wetlands is calculated. One large wetland complex exists in the Wilmot Creek watershed and is recognized by the province as significant (see Section 4.1.7 for more detail).

Marshes are classified as having water depth less than 2 m, containing less than 25% tree and shrub cover, and dominated by emergent hydrophytic macrophytes (Lee et al. 1998). A meadow marsh contains plant species that are less tolerant to prolonged flooding, since soils become moist to dry in the summer. Meadow marshes are typically found in riparian zones and may form the transition point between shallow marsh and upland habitat. In shallow marshes, by contrast, standing or flowing water tends to remain all year. Dominant vegetation is typically cattail, although the invasive Common Reed (*Phragmites australis*) may take its place, especially in roadside marshes.

Swamps contain more than 25% tree or shrub cover and are dominated by hydrophytic shrub and tree species. Water depths are less than 2 m with standing water or vernal pooling on more than 20% of the land base (Lee et al. 1998). Differences between swamp communities are based on tree canopy cover, tree species and the amount of tree cover. Table 4.13 describes the proportion of wetland types in the Wilmot Creek watershed, and locations are shown in Figure 4.23.

Table 4.13: Wetland types

ELC Defined Wetland Type	Percentage
Meadow Marsh	0.3
Shallow Marsh	0.1
Coniferous Swamp	0.03
Deciduous Swamp	0.5
Mixed Swamp	0.1
Thicket Swamp	0.03

Swamps are the most abundant wetland type in southern Ontario, and in the Wilmot Creek watershed. Like other wetlands, many species rely on swamps for habitat. For example, they provide critical breeding areas for salamanders and frogs, and the cool, moist conditions required by birds such as the Northern Waterthrush (*Seiurus noveboracensis*) and Winter Wren (*Troglodytes troglodytes*). Some swamp species, such as Mallard (*Anas platyrhynchos*) and Wood Duck (*Aix sponsa*), are economically important (i.e., hunting opportunities). The diversity, species, and abundance of flora and fauna that swamps as well as marshes provide is dependant on the size of the ecosystem (Table 4.14).

Depending on the terrain and geology, swamps contribute to aquatic habitats as well. Swamps provide groundwater discharge areas, providing an instream temperature regime required by native Brook Trout and other coldwater fish species. Swamps also contribute nutrients, food and habitat to aquatic organisms in nearby streams. Similar to marshes, swamps also mitigate floodwaters and improve water quality.

Thicket swamps are low wet areas dominated by shrubs such as Red Osier Dogwood (*Cornus strolonifera*) and Speckled Alder (*Alnus rugosa*). These wetlands deserve special mention because they are the principle habitat of the Western Chorus Frog (*Pseudacris triseriata*), a tiny species that has been experiencing population declines throughout its range. In many cases thicket swamps are too small to pick up when interpreting aerial photographs, therefore the total cover for this wetland type may be deceiving. Even tiny thicket swamps can support an entire local breeding population of chorus frogs.

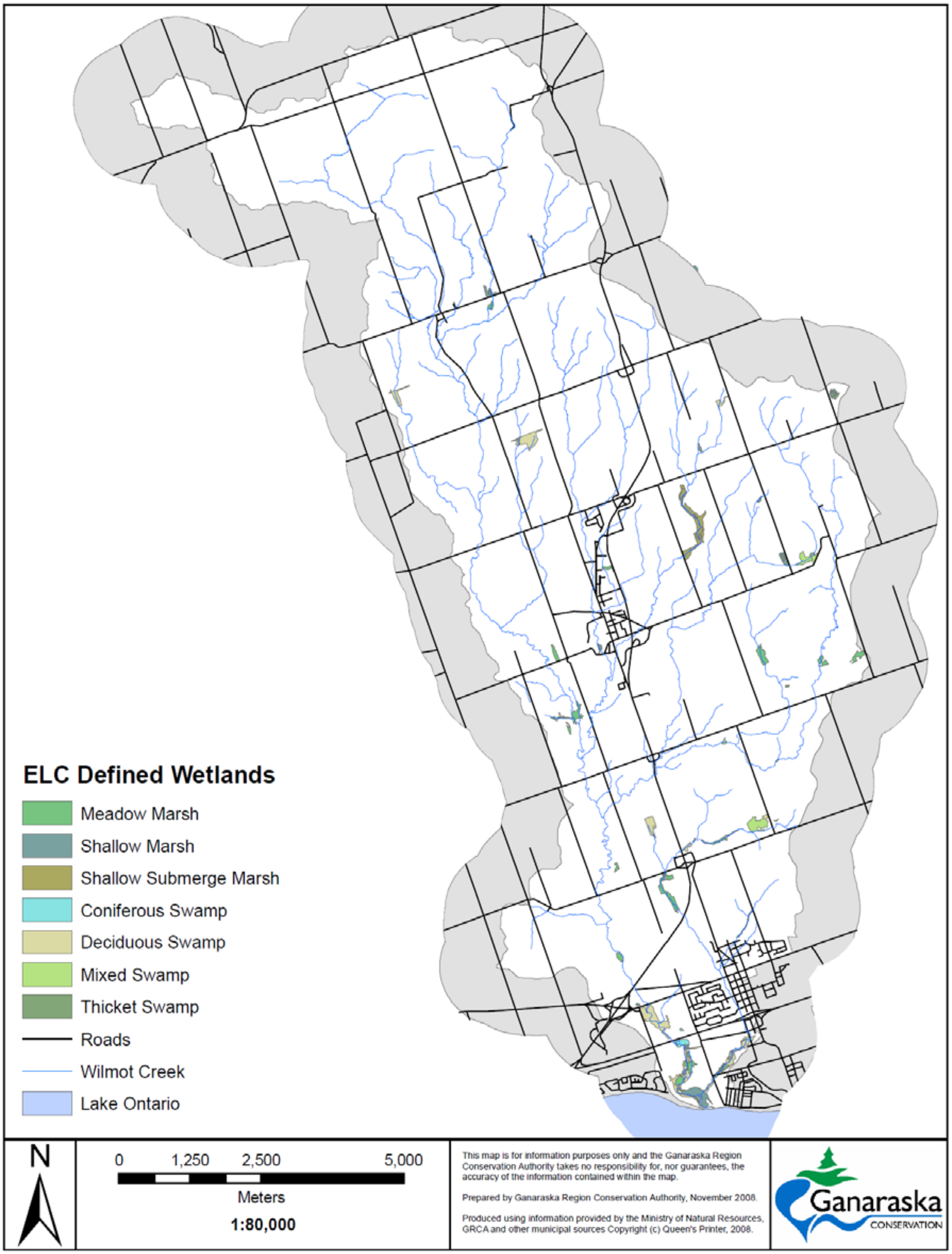


Figure 4.23: Wetlands

Vernal pools can have a similar function to swamps, but on a smaller scale. These are ponds that are formed in depressions as a result of snowmelt and rain. Typically they dry up by mid to late summer. This means they are unsuitable for fish, which in turn makes them ideal breeding habitats for many species that would otherwise be subject to fish predation. Salamanders in particular rely on these habitats, and entire populations from surrounding woodlands may go to a single pond to breed in early spring.

Frogs such as Spring Peeper (*Pseudacris crucifer*) and Wood Frog (*Rana sylvatica*) may rely on vernal pools and forest swamps for breeding. These amphibians are important elements of the food chain. Maintaining vernal pools and connectivity between these and upland forests is vital for the survival of populations. Vernal pools are increasingly being recognized as a conservation concern (Colburn 2005). However, because of their small size and the fact that they frequently occur in forests, they are difficult to map accurately. More work is needed to inventory and map these critical habitats.

Wetlands play an important function in any temperate watershed, and each wetland type contributes differently to the processes that are carried out. Marshes are very efficient in improving water quality, however efficiency depends on the location of marshes relative to overland flow, the substrate type within the marshes, dominant plant species, climate, and the retention time of the water within the marsh (Environment Canada 2005c). Marshes are also important in mitigating floods by storing flood waters and reducing flow velocity and ultimately peak flows in a water system (Environment Canada 2005c).

Table 4.14: Wildlife use of various swamp and marsh sizes

Area	Forest/Treed Swamp	Marsh
1 ha	■ Edge tolerant mammals (Gray Squirrel) ■ Common edge-tolerant birds (Blue Jay, American Crow) ■ A few birds may be associated with mature trees (Black-capped Chickadee, Eastern Wood-Pewee)	■ Small populations of Muskrat ■ Edge-tolerant birds (Red-winged Blackbird, Canada Goose, Mallard) ■ Persistent and common herpetofauna (such as Green Frog and Midland Painted Turtle)
4 ha	■ A very few common edge-tolerant birds (Downy Woodpecker, Great Crested Flycatcher) ■ Eastern Chipmunk may be present	■ Similar species as above, but may also support Bullfrog
10 ha	■ Still dominated by edge-tolerant species may have very small areas of interior habitat supporting low numbers of modestly area-sensitive species (Hairy Woodpecker, White-breasted Nuthatch)	■ May support Marsh Wren, other waterfowl species
30 ha	■ May be large enough to support some species of salamander ■ Small populations of edge-intolerant species (Winter Wren, Brown Creeper, Black-and-White Warbler)	■ Similar marsh bird species as above, plus possibly Black Tern
50 to 75 ha	■ A variety of area-sensitive species may be present; some will be absent if there is no nearby suitable habitat ■ Still predominantly edge influenced, but will support small populations of most forest bird species ■ Some will be absent if there is no nearby suitable habitat	■ Least Bittern may be present in marshes of this size
100 to 400 ha	■ All forest-dependent bird species ■ Many will still be in low numbers and may be absent if there is no nearby suitable habitat ■ Woodland Jumping Mouse may be present	■ Small numbers of diving ducks possible (e.g., Redhead, Canvasback, Ruddy Duck)
1,000 ha	■ Suitable for almost all forest birds ■ Some forest-dependent mammals present, but most still absent	■ All marsh species, although some may still have small populations
10 000 ha	■ Almost fully functional ecosystem, but may be inadequate for a few mammals such as Gray Wolf and Bobcat (100 000 ha has been suggested as a minimum)	■ Fully-functional ecosystem

(Environment Canada 2005c)

Environment Canada's framework for guiding habitat rehabilitation (Environment Canada 2005c) recommends that watersheds should contain more than 10% wetland cover, however, historically watershed may have ha more or less. The capacity for natural wetlands is based largely on topography and soils. Much of the soil in the headwater area of Wilmot Creek is sand, which is highly permeable and therefore not conducive to water retention. In short, rather than see an increase in wetland cover of 9%, it may be possible to undertake a soil and slope analysis and combine this with what we know about hydrology to determine the capacity for an increase in wetland cover in the Wilmot Creek watershed.

4.1.5 Species at Risk and Species of Concern

Provincial legislation has provided for the identification and protection of Species at Risk in Ontario. The legislated purposes of the *Endangered Species Act, 2007* are:

- To identify Species at Risk based on the best available scientific information, including information obtained from community knowledge and aboriginal traditional knowledge
- To protect species that are at risk and their habitats, and to promote the recovery of species that are at risk
- To promote stewardship activities to assist in the protection and recovery of species that are at risk.

A number of Species at Risk have been identified in the Ganaraska Region Conservation Authority jurisdiction (Table 4.15). These species have been designated by the Committee on the Status of Species at Risk in Ontario (COSSARO), an independent body that assesses and classifies species at risk, and/or by the federal Committee on the Status of Endangered Wildlife in Canada (COSEWIC). A list of these species if found in Table 4.15.

Table 4.15: Provincially listed Species at Risk within the GRCA

Scientific Name	Common Name	COSSARO Status	COSEWIC Status
Colinus virginianus	Northern Bobwhite	END	END
Rallus elegans	King Rail	END	END
Coturnicops noveboracensis	Yellow Rail	SC	SC
Lanius ludovicianus	Loggerhead Shrike	END	END
Ammodramus henslowii	Henslow's Sparrow	END	END
Ixobrychus exilis	Least Bittern	THR	THR
Chlidonias niger	Black Tern	SC	
Haliaeetus leucocephalus	Bald Eagle	SC	
Melanerpes erythrocephalus	Red-headed Woodpecker	SC	THR
Dendroica cerulean	Cerulean Warbler	SC	SC
Vermivora chrysoptera	Golden-winged Warbler	SC	THR
Icteria virens	Yellow-breasted Chat	SC	SC
Wilsonia citrina	Hooded Warbler	THR	THR
Emydoidea blandingii	Blanding's Turtle	THR	THR
St\ernotherus odoratus	Stinkpot Turtle	THR	THR
Graptemys geographica	Northern Map Turtle	SC	SC
Heterodon platyrhinos	Eastern Hog-nosed Snake	THR	THR
Tamnophis sauritus	Eastern Ribbonsnake	SC	SC
Lampropeltis triangulum	Eastern Milksnake	SC	SC
Danaus plexippus	Monarch Butterfly	SC	SC
Panax quinquefolius	American Ginseng	END	END
Juglans cinerea	Butternut	END	END
Platanthera leucophaea	Eastern Prairie Fringed Orchid	END	END

SC = Special Concern, THR = Threatened, END = Endangered

Many of the records for these species are historical, and there is a need to revisit some areas to determine if any individuals are still present. Should this be the case, the responsibility falls into the hands of the provincial or federal government, although local organizations including the GRCA, can work with government authorities and landowners on stewardship measures to enhance protection for these species.

Species at Risk are designated based on their national or provincial status, however population declines frequently begin at the local level. There is a real need to gain a better understanding of the local status of sensitive species, and to develop a list of locally rare species. Such a list can help inform planning decisions such that populations of species are retained as components of healthy ecosystems.

4.1.6 Invasive Species

In terrestrial habitats of the Wilmot Creek watershed the invasive species that are currently of greatest concern are plants, especially Dog-strangling Vine (*Cynanchum rossicum*), European Buckthorn (*Rhamnus cathartica*), Garlic Mustard (*Alliaria petiolata*) and Common Reed (*Phragmites australis*). All of these have a negative impact on biodiversity by colonizing natural areas and gaining a competitive edge over native species.

Dog-strangling Vine is of particular concern on the Oak Ridges Moraine, where it is spreading rapidly. It can be found in habitats ranging from old fields to mixed and riparian forests. As is demonstrated at the Orono Crown Forest, it does particularly well in pine plantations where it can prevent understory growth and tree regeneration as well as hamper harvesting efforts. Garlic Mustard prefers moister, less acidic conditions and is a threat to riparian and hardwood forests. European Buckthorn is ubiquitous in much of southern Ontario because it was widely used in hedgerows and is spread as fruits eaten by birds. Control of all three of these and other invasive plants is difficult once they become well-established. Early detection and rapid response is the key. Infestations should be mapped, rate of spread monitored, and response prioritized. Control efforts should be coordinated between organizations with an interest in invasive plant control.

Two other invasive plants are particularly noteworthy in the Wilmot Creek watershed. One of these is Common Reed (Phragmites australis) a large infestation of which can be seen along the side of Highway 115 in the Orono area. This plant, while primarily found in roadside ditches, has the capacity to completely displace cattails and other plants in natural marshes. The second plant of note is Himalayan Balsam (*Impatiens glandulifera*), which is spreading into the Wilmot Creek Marsh and the Port of Newcastle Wetland.

Recent exotic insects of concern in Ontario are the Asian Long-horned Beetle (*Anoplophora glabripennis*) and the Emerald Ash Borer (*Agrilus planipennis)*. So far neither of these has been found in this part of the province, but either could have devastating impacts on forests. Sightings of insects thought to be these species should be reported immediately to the Canadian Food Inspection Agency.

4.1.7 Areas of Natural and Scientific Interest and Coastal Wetlands

The Ministry of Natural Resources is responsible for determining Areas of Natural and Scientific Interest (ANSI) and Provincially Significant Wetlands (PSW). At present, the Ontario Wetland Evaluation System is used in conjunction with provincial scoring criteria to identify provincially significant wetlands and wetland complexes.

Environmentally Sensitive Areas (ESA) in the Wilmot Creek watershed was identified by the Ganaraska Region Conservation Authority during preparation of the 1983 Watershed Plan Resource Inventory. Lands were determined to be sensitive to disturbances from intensive land use such as urban development. A classification scheme was developed to determine the sensitivity based on soil erosion potential, presence of wetlands or recharge areas and wildlife production capability (Ganaraska Region Conservation Authority 1983). The ESA identified in Figure 4.25 was classified as a medium environmental sensitive area based on the defined classification.

Coastal Wetland

This section, including the Figure, has been taken with some adaptations from Environment Canada – Ontario Region (Canadian Wildlife Service) and Central Lake Ontario Conservation Authority 2004.

The Wilmot Creek Marsh, also known as the Wilmot Rivermouth Wetlands is defined as a drowned river mouth and barrier beach. Drowned river mouth wetlands form where a river enters a lake, representing a zone of transition from stream to lake. These wetlands are characterized by meandering stream channels that are back-flooded during high lake levels. Barrier beach wetlands form behind a sand or dune barrier, reducing lake and river water mixing, and isolating the river hydrologically.

The wetland is partially surrounded by natural landscapes (Figure 4.24), including the Samuel Wilmot Nature Area, however residential development is occurring on east side. At 26 hectares in size the Wilmot Creek Marsh is also designated as a Provincially Significant Wetland and an Area of Natural and Scientific Interest (Figure 4.25). Wilmot Creek and the Foster Creek tributary flow into the wetland, supplying water that carries moderate amounts of excess nutrients. Many crustaceans and molluscs are common. Sediments are generally of good quality overall, despite slightly elevated pesticide residue. Turbidity within the wetland can be quite high and results in a patchy submerged plant community. The submerged plants were absent in many open-water parts of the wetland but thick in the secluded back bays that are not exposed to turbid water.

The marsh offers fair amphibian habitat, however human disturbances cause a lack of amphibian populations from being present in the marsh. Wilmot Creek Marsh is abundant in birds that are general marsh users. In addition, area sensitive species such as Virginia Rail (*Rallus limicola*) and Swamp Sparrow (*Melospiza georgiana*) are present. The marsh sustains one of the best coastal wetland fish communities in the Regional Municipality of Durham. Dominated by warm water species, the fish community is characterized by Yellow Perch (*Perca flavescens*) and many sunfish species. This is one of the few coastal wetlands that had an abundance of predatory Northern Pike (*Esox lucius*) and Largemouth Bass (*Micropterus salmoides*).


Figure 4.24: Wilmot Creek marsh

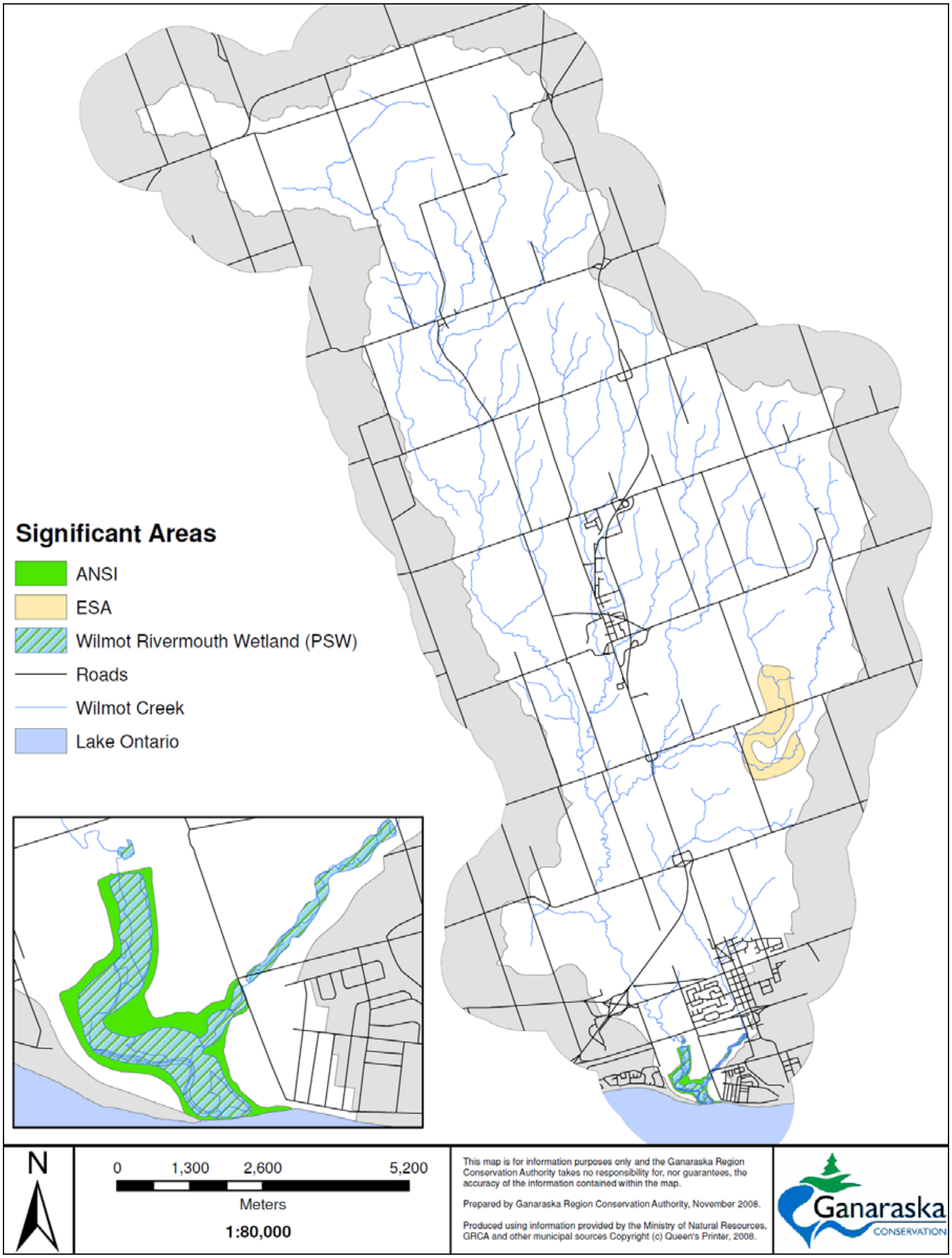


Figure 4.25: Provincially Significant Wetlands and ANSI

Chapter 5 – Cultural Characteristics of Wilmot Creek

5.1 Present Cultural Characteristics

Present settlement patterns, communities and natural resource distribution play an important role shaping surrounding landscapes. This understanding will guide management decisions in the watershed in a localized manner.

5.1.1 Municipal Populations and Growth

Wilmot Creek flows through the Municipality of Clarington with the Regional Municipality of Durham (Figure 5.0). Prior to amalgamation, Clarke Township and Darlington Township contained Wilmot Creek. A small proportion of the headwaters of Wilmot Creek begin in the City of Kawartha Lakes. In the Wilmot Creek watershed, $13km^2$ or 13% of the watershed area has a land use associated with settlement and growth areas (e.g., roads, railways, and urban and rural development), as defined by 2002 Ecological Land Classification mapping. According to the 2006 Statistics Canada Census, there are 8,258 people living in the Wilmot Creek watershed, at a density of 82 $people/km^2$.

Both provincial legislation and municipal official plans have defined areas in the Ganaraska Region Conservation Authority that are expected to experience significant growth. The *Greenbelt Act, 2005*, acknowledges the Oak Ridges Moraine and includes it in the designated Greenbelt area (Figure 5.1). The provincial *Places to Grow Act, 2005* has identified no urban growth centres in the Ganaraska Region Conservation Authority or in the Wilmot Creek watershed. In addition the *Oak Ridges Moraine Conservation Act, 2001* has provided further development directions in the Oak Ridges Moraine in the Wilmot Creek watershed.

Nevertheless, given its proximity to the Greater Toronto Area, the Ganaraska Region Conservation Authority watersheds, including Wilmot Creek watershed are expected to experience an increase in population. As a result, population projections are necessary to ensure that development and infrastructure occur at a sustainable rate for municipalities and the environment. Planning documents such as growth management strategies considers how much population and employment growth is expected to occur over a specific period of time, and then develop specific strategies for where and how this projected growth is to be accommodated. The Regional Municipality of Durham and Municipality of Clarington official plans also directs growth in the watershed.

Regional Municipality of Durham

The Regional Municipality of Durham is the upper tier region that encompasses the Municipality of Clarington in the Ganaraska Region Conservation Authority. Ward 4, of the Municipality of Clarington, is located in the Ganaraska Region Conservation Authority. The Planning Department estimates that the population of the Region of Durham was 531,000 in May 2001. A target of 760,000 people has been estimated for the number of people living in the Region by the year

2011 and a target of 970,000 people by the year 2021 (Regional Municipality of Durham 2005).

Municipality of Clarington

The Municipality of Clarington represents one of the fastest growing communities in Ontario. Ward 4 of the Municipality of Clarington, located in the Ganaraska Region Conservation Authority, includes urban areas (Newcastle and Orono) and surrounding rural areas (Figures 5.2 to 5.4). Clarington's population as a whole grew by 15.2% from 69,834 in 2001 to 77,820 in 2006. This reflects an annual growth rate of approximately 2.3% and a current density of 127.3 people/km^2 (Statistics Canada 2007).

The 2006 population of Ward 4 of the Municipality of Clarington was 13,773 people. Of this, there are 8,258 people living in the Wilmot Creek watershed, at a density of 82 people/km^2. The population is expected to grow in Ward 4 to approximately 19,700 in 2016, an increase of 43% from 2006. Most of this growth will occur in Newcastle Village (Municipality of Clarington, Personal Communications 2007).

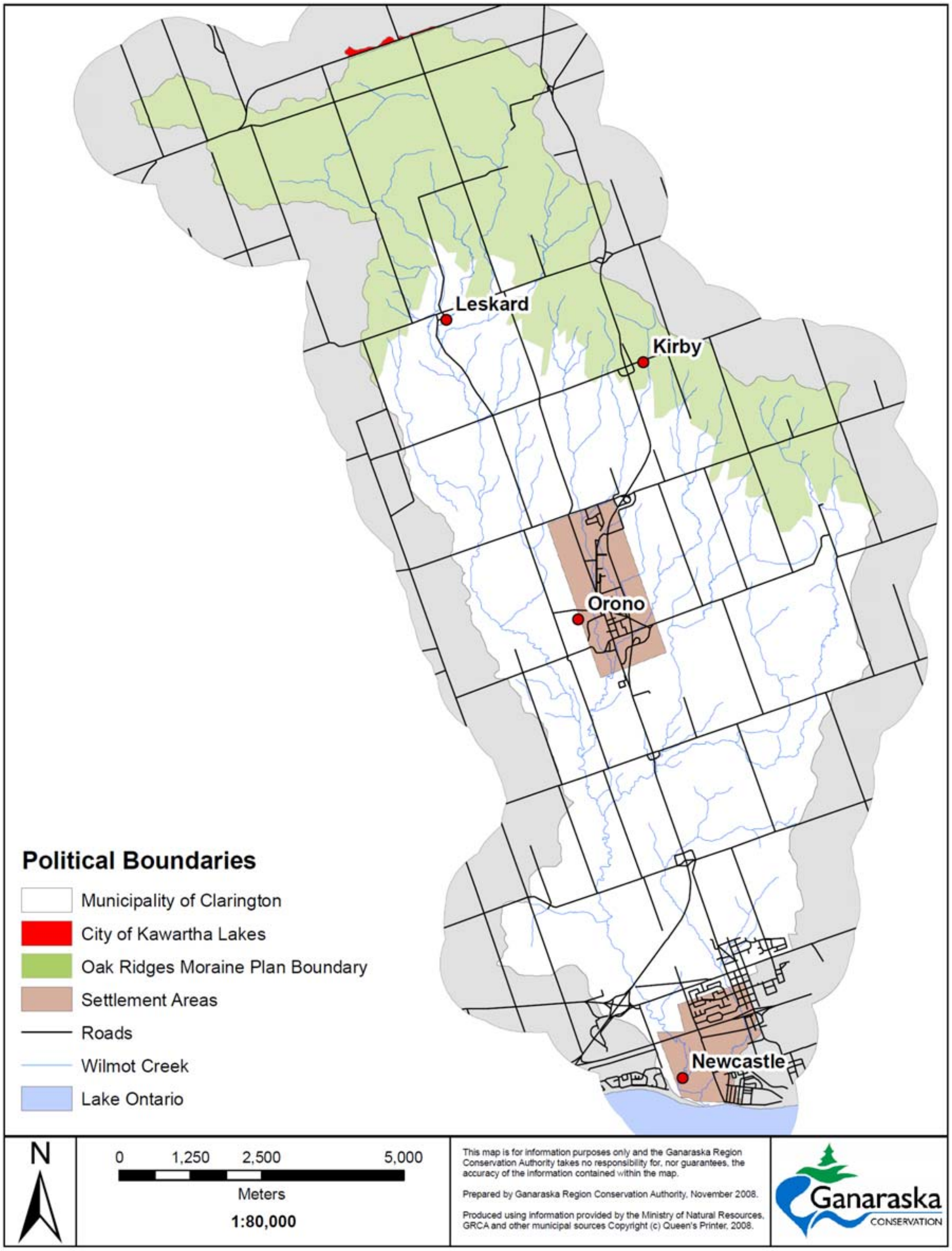


Figure 5.0: Oak ridges moraine planning boundary

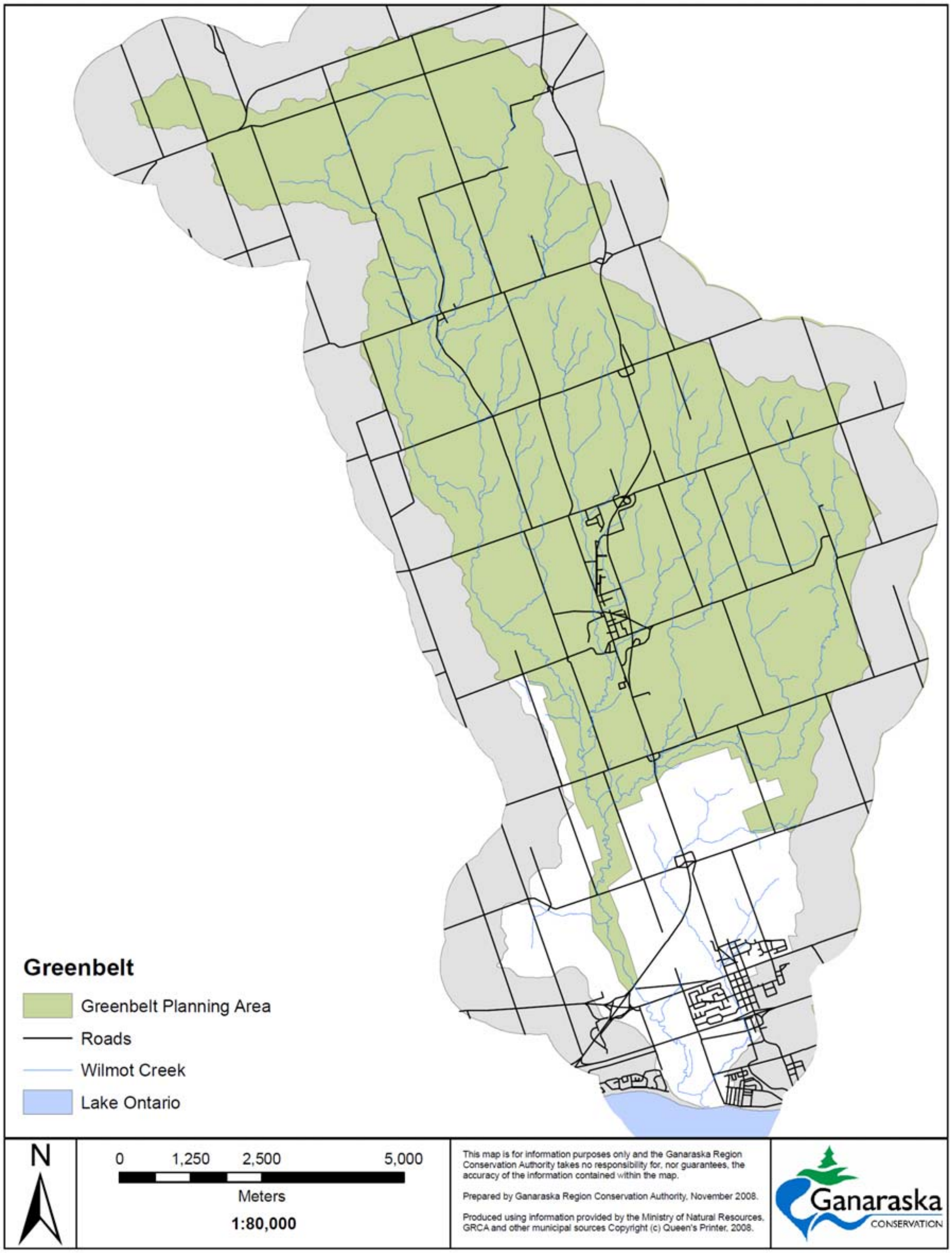


Figure 5.1: Greenbelt planning area

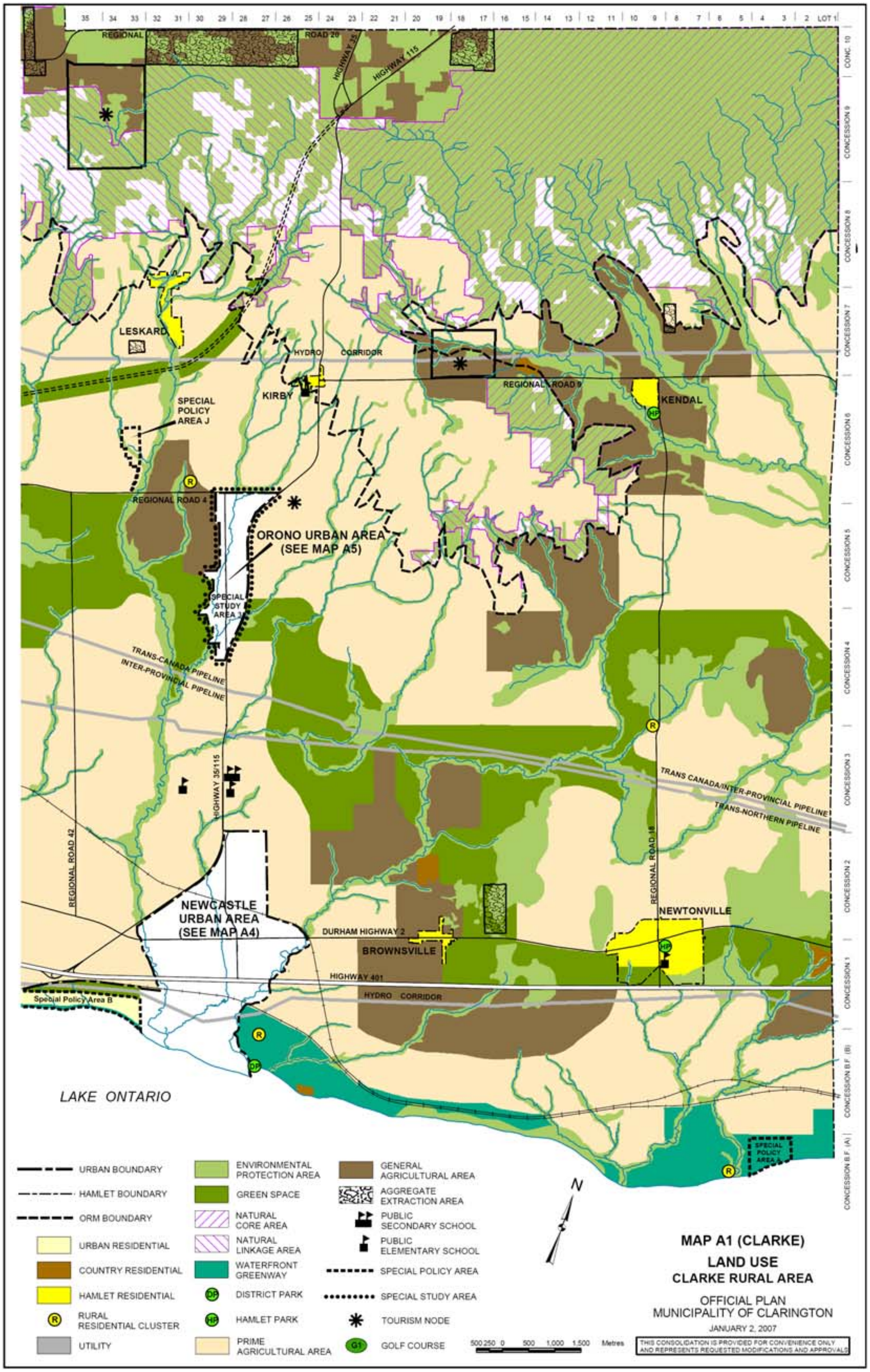


Figure 5.2: Land use in the Municipality of Clarington

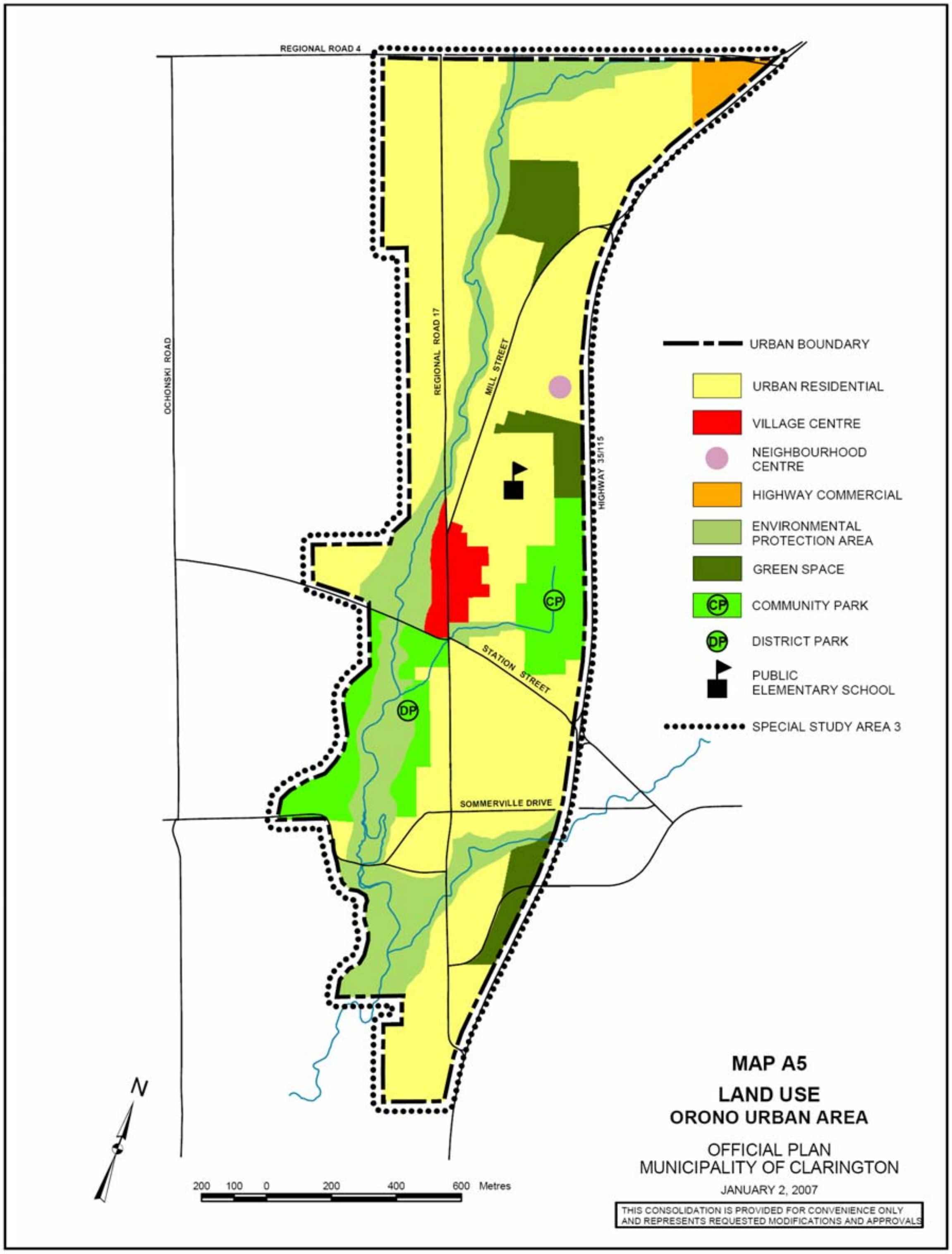


Figure 5.3: Land use in the community of Orono

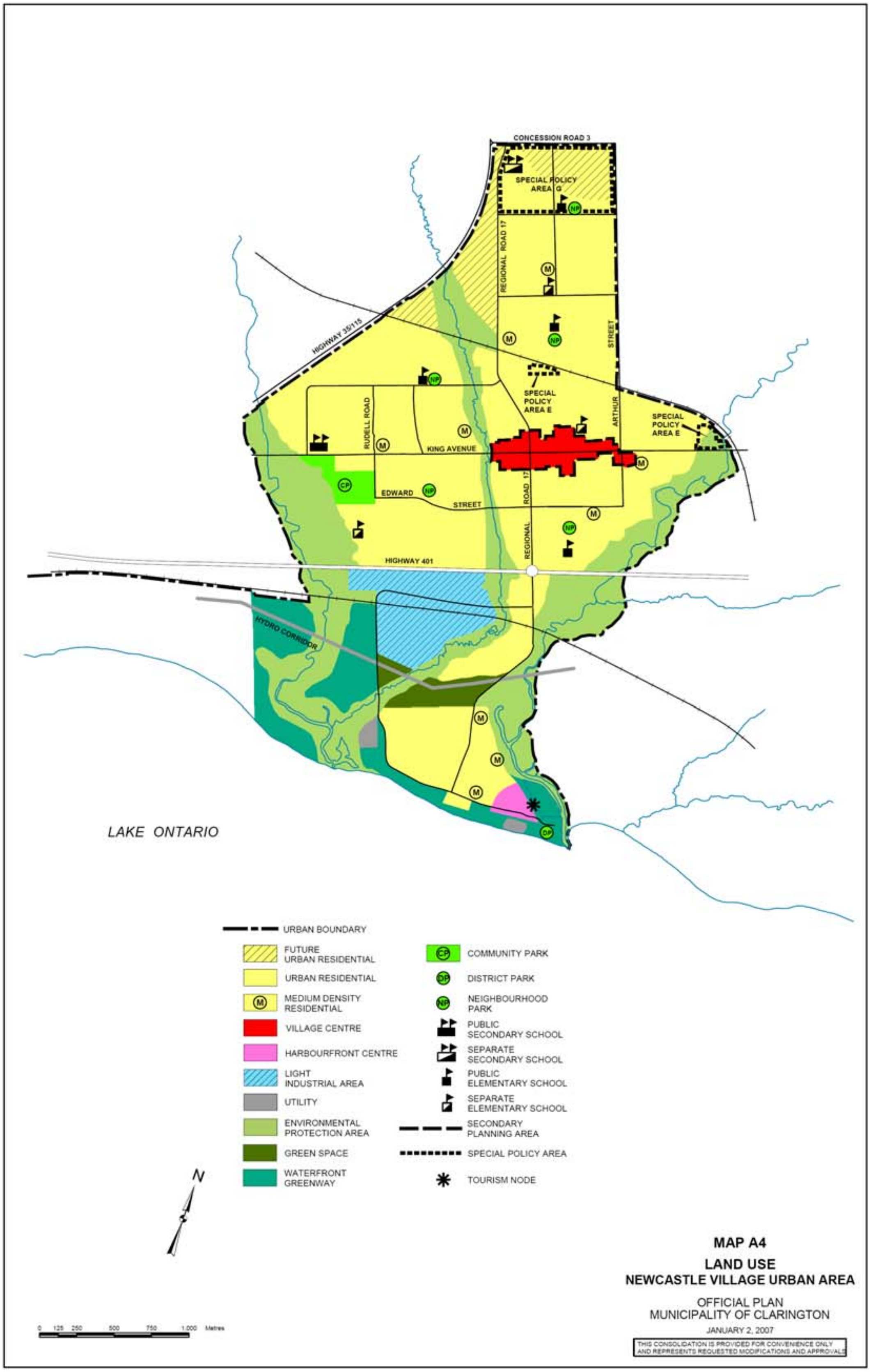


Figure 5.4: Land use in Newcastle

5.1.2 Industrial and Commercial Sector Distribution

Municipal official plans provide information about commercial and industrial developments that are subject to servicing studies and other necessary background information. In rural areas, tourism and agriculture remain the main industries, along with aggregate extraction. Figures 5.2 to 5.4 indicate the locations of employment, commercial and institutional designated areas, identified tourism sites (e.g., parks), agricultural lands and aggregate-licensed areas.

The Municipality of Clarington, in its entirety, has five distinct industrial and business areas. Of these areas, the Newcastle Industrial Area is located in the Ganaraska Region Conservation Authority. The major manufacturing and industrial products produced are steel and metal products, paper products, construction, aggregate excavation, agriculture and agriculture services, wood products and robotics (Regional Municipality of Durham 2006). In addition, many tourist attractions exist throughout the watershed including Mosport International Speedway.

Commercial use of groundwater and surface water exists in the Wilmot Creek watershed. Water use greater than 50,000 litres per day requires a permit from the Ministry of the Environment. Information on the use of water for commercial purposes is found in the Section 3.5.4 of this document.

5.1.3 Agriculture

Agricultural practices are the dominant land use in the Wilmot Creek watershed. Based on 2002 ELC mapping, agricultural land use covers an area of 52% of the Wilmot Creek watershed (Figure 5.5). As indicated by Statistics Canada's 2006 census, agricultural production types and intensities vary throughout the Municipality of Clarington, however crop production prevails over livestock production (Statistics Canada 2008). Table 5.0 contains a breakdown of agricultural land use in the Municipality of Clarington in the Wilmot Creek watershed.

Please note that only portions of the Municipality of Clarington and Regional Municipality of Durham are in the Ganaraska Region Conservation Authority. Statistics related to agriculture will be reported at the regional level as many statistical reports are unavailable on a smaller scale. However, activities are assumed to be constant across the municipality.

Table 5.0: Agricultural land use in 2006 within the major municipalities

Region	Number of Farms	Land Farmed (Hectare)
Regional Municipality of Durham [A]	1,686	132,212
Municipality of Clarington [A]	437	33.074

A – Only a portion of these areas are found within the GRCA Region.
(Statistics Canada 2008)

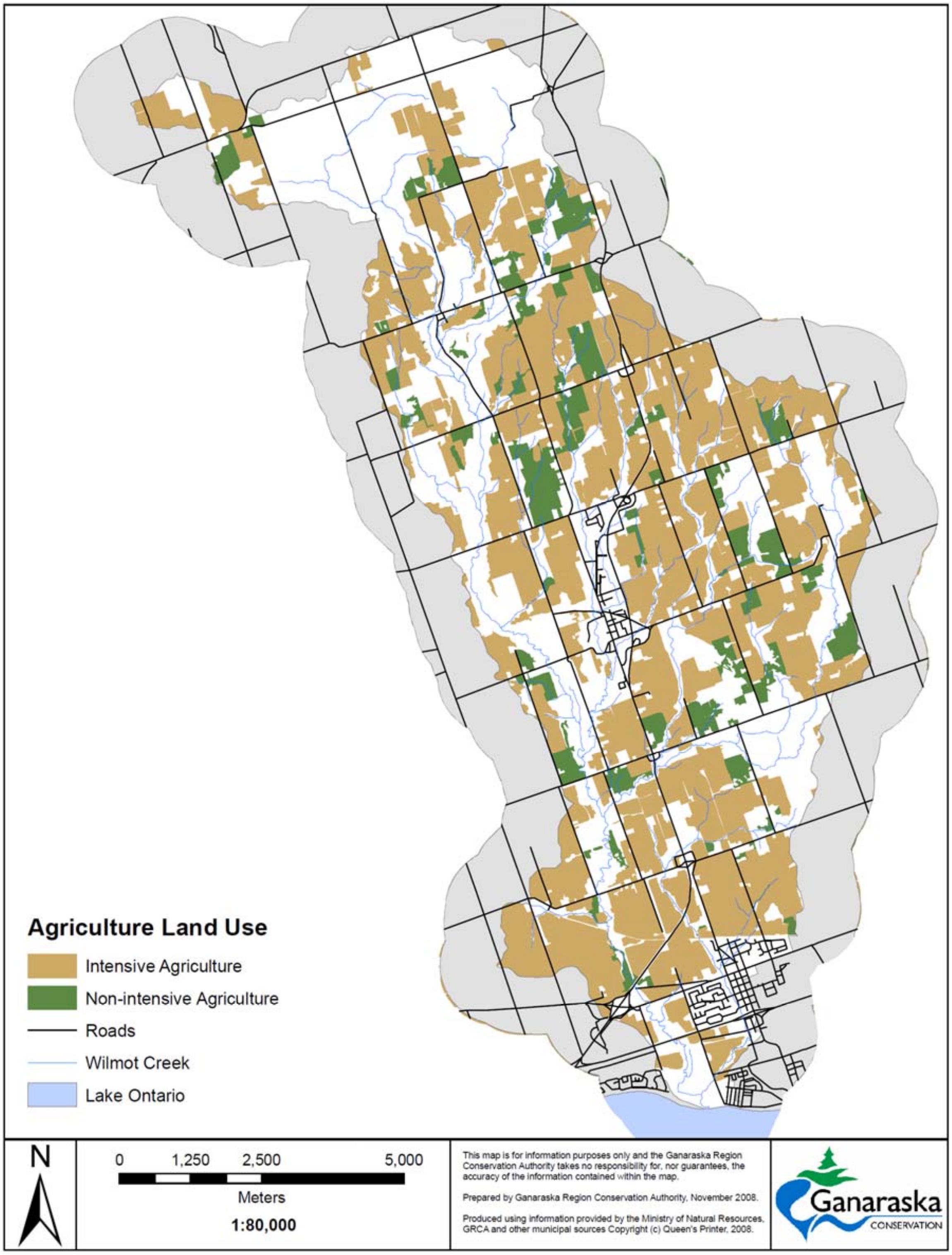


Figure 5.5: Agricultural lands

Agricultural Land
In the Regional Municipality of Durham most farm sizes are less than 53 hectares (1,080 farms): 417 farms are between 53 and 161 hectares, and 189 farms are greater than 162 hectares (Statistics Canada 2008). Of the total land farmed (132,212 hectares), 47,479 hectares of farmland w54 rented or leased in the Regional Municipality of Durham.

Crops and Livestock
Crops, including produce, are grown on 92,454 hectares of land in the Regional Municipality of Durham. The five most predominant field crops grown include alfalfa and alfalfa mixtures, grain corn, soybeans, hay and fodder crops (oats, barley, mixed grains and corn silage) and winter wheat (Statistics Canada 2008). Yet, many other field crops are grown throughout the Wilmot Creek watershed.

Produce is also grown in the Regional Municipality of Durham. A total of 683 hectares of fruit is produced, consisting predominantly of apples, raspberries, strawberries and grapes (Statistics Canada 2008). In 2006, major field vegetable crops grown within the Regional Municipality of Durham included sweet corn, tomatoes, pumpkins, and green or waxed beans. These crops were grown on 848 hectares of land (Statistics Canada 2008). Many other vegetable and fruit varieties are grown throughout the Wilmot Creek watershed; there are also floriculture (flowering plants), nursery and sod production operations.

In 2006 farms in the Regional Municipality of Durham were in production of dairy and beef cattle, pigs, sheep and poultry (chickens and turkeys) (Statistics Canada 2008). However, other livestock are raised and owned in the Wilmot Creek watershed including goats, horses and bees (Statistics Canada 2008). Dairy and beef cattle production are the predominant livestock raised in the Wilmot Creek watershed.

Agricultural Conservation Measures
In 2006, 13 farms in the Regional Municipality of Durham were reported as certified organic producers (Statistics Canada 2008) and additional 128 were reported as uncertified organic producers. Soil conservation is widely practised throughout the area, helping to mitigate soil erosion and surface runoff and to increase soil and crop productivity (Table 5.1). Many farmers in the Wilmot Creek watershed also participate in the Environmental Farm Plan and the corresponding funding programs to learn new best management practices and carry out stewardship projects on their lands.

Table 5.1: Farms in 2006 participating in soil conservation practices

Activity	Number of Farms Reporting
Total number of farms reporting	1,686
Crop rotation	917
Winter cover crops	206
Rotational grazing	554
Buffer zones around riparian areas	385
Windbreaks or shelter belts	511
Green manure crops for plough-down	316

Agricultural production in the Ganaraska Region Conservation Authority and the Wilmot Creek watershed is ever-evolving and shifting. The promise of increased crop prices in relation to ethanol and biodiesel production has seen marginal land being put back into crop production. The recent Bovine Spongiform Encephalopathy (BSE) crisis has seen many cattle producers leave the cattle industry or shift their efforts to cash cropping. Many dairy farmers have sold quota and ceased their dairy operations in the area. Continual shifts in crop markets are causing producers to bring non-marginal, profitable land into production, and trade concerns are causing farmers to question the stability of grain and oil seed productions across Canada. As a result, a trend to larger and fewer operations is evident in all sectors of the agriculture industry, both in Ontario and in the Ganaraska Region Conservation Authority.

5.1.4 Infrastructure

Municipal infrastructure such as roads and bridges, utilities, landfills, water and wastewater services, and stormwater management facilities is all necessary in communities. Each utilizes natural resources or effects the natural environment in a different way. Infrastructure requires proper planning, management and development in order to sustain the local community and natural environment.

Transportation and Transmission Line Corridors

Provincial highways, Regional Roads, as well as local roads in the Wilmot Creek watershed are shown in Figure 5.6. Highway 401 and Regional Roads 2 and 9, and Regional Road/Concession Road 4 are the east-west transportation roads. Major north-south transportation corridors include Highway 115/35 and Regional Road 17. The CPR and CNR railroads run west to east along the south half of the Wilmot Creek watershed (Figure 5.6). Many hydro corridors and stations exist in the Wilmot Creek watershed mainly running in a west to east direction and along transportation routes (Figure 5.7). The Enbridge Gas Line runs east-west through the middle of the Wilmot Creek watershed (Figure 5.7).

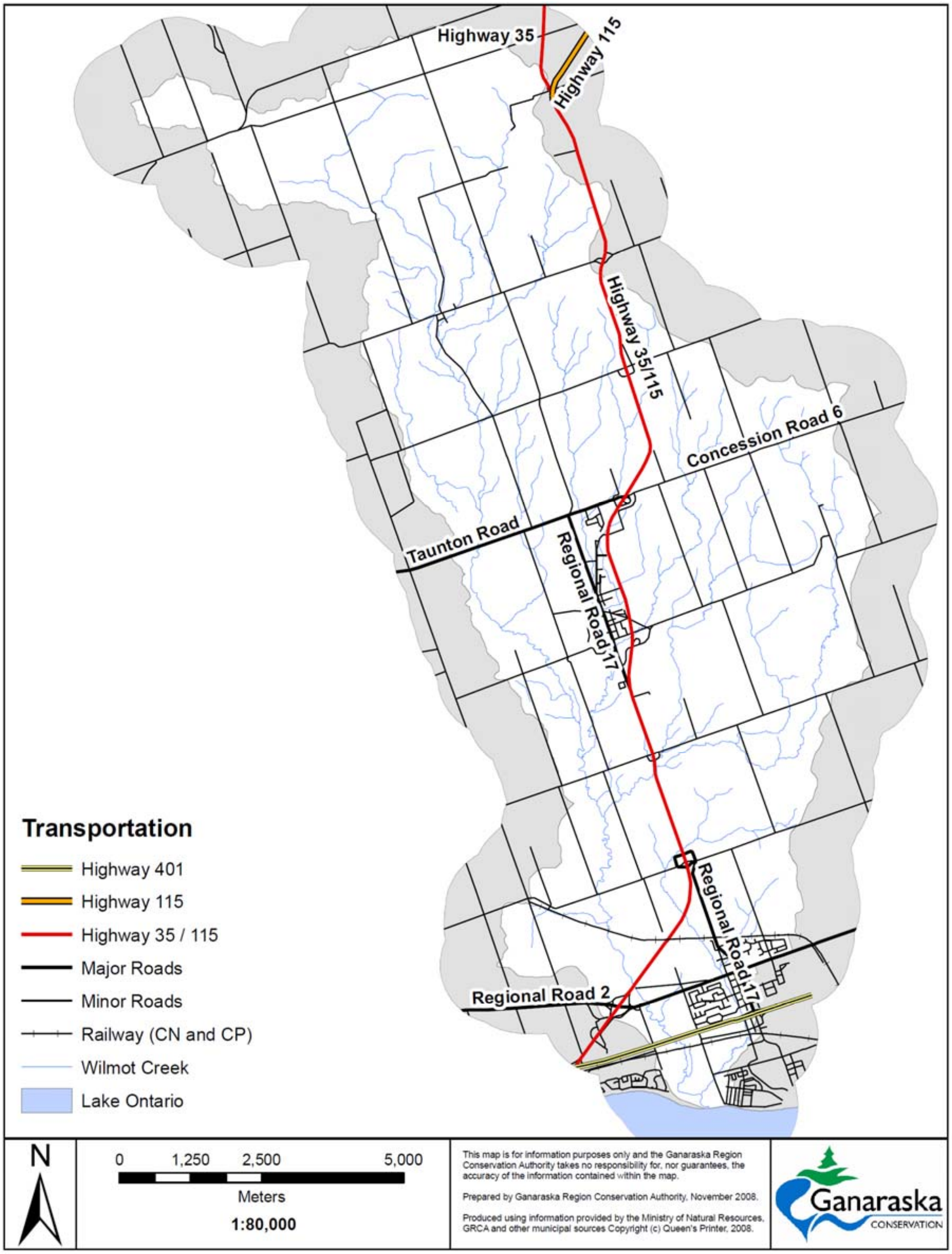


Figure 5.6: Transportation routes

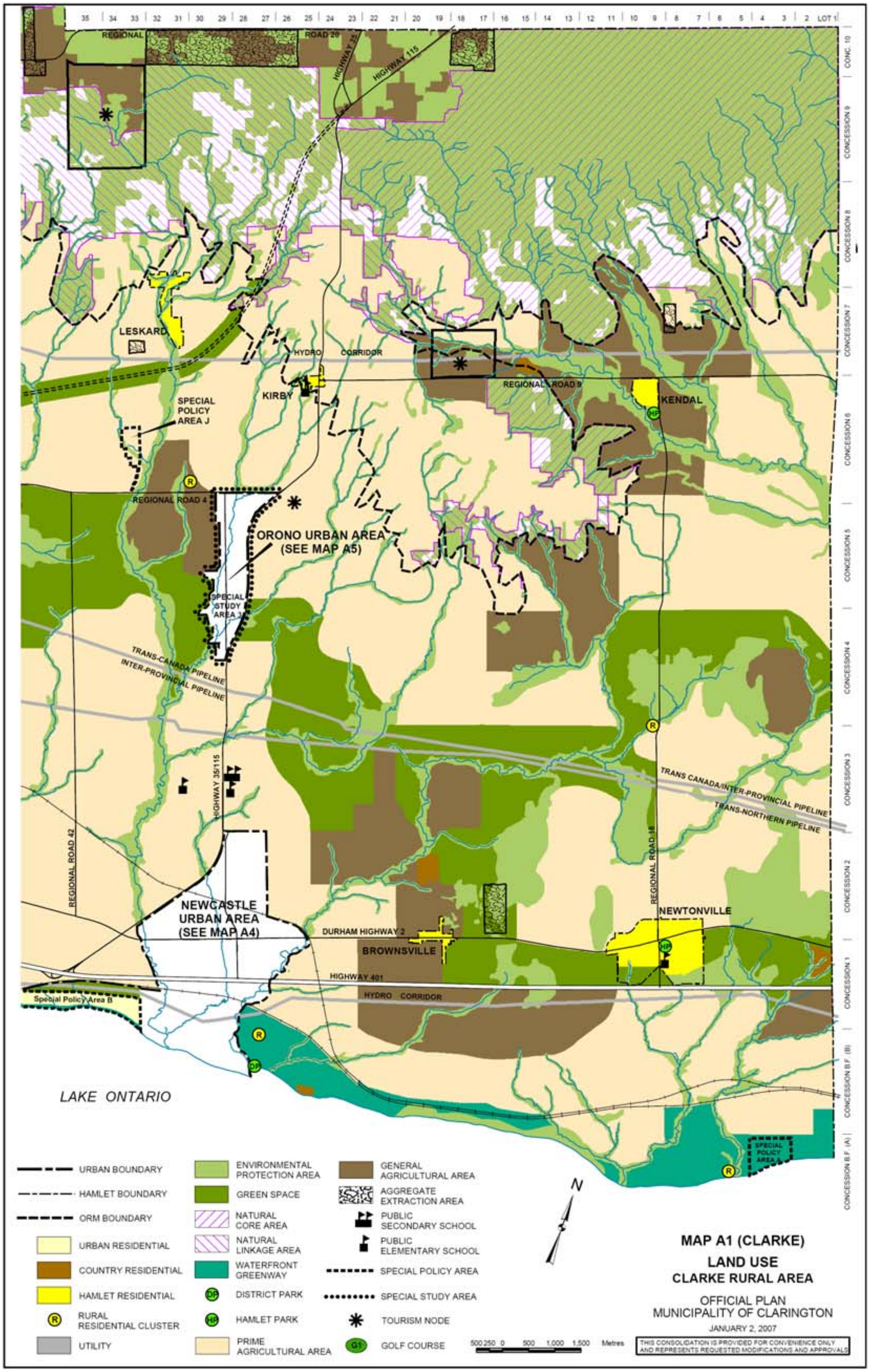


Figure 5.7: Utility corridors

Winter Road Maintenance

Winter maintenance can have negative impacts on surface water and groundwater due to runoff from road salting and material storage locations. The Province of Ontario is responsible for the provincial highways (Highway 401 and Highway 115) in the Wilmot Creek watershed. The Regional Municipality of Durham is responsible for regional roads, and the Municipality of Clarington is responsible for all other roads.

The Province of Ontario manages its highways in the winter using best practices consistent with those used across North America, and employs the latest winter maintenance technologies (Ontario Ministry of Transportation 2005). Current information is not available to determine salting rates or other application methods of de-icing agents on Highway 401 and 115.

The Regional Municipality of Durham is responsible for Regional Road 2, 4, 9 and 17, and follows a salt management plan to ensure that environmental regulations are followed when applying winter material and disposing of snow. One snow and sand dome is located in the Wilmot Creek watershed on Taunton Road (Regional Road 4).

The Municipality of Clarington conducts winter road maintenance using a salt management plan (Municipality of Clarington 2005). The Municipality maintains a sand/salt mixture to between 10 to 15% ratios. Within Orono four snow dumps are used and one site was historically used. The total capacity of the active snow dumps is 37,000 metric tones. The abandoned site had a capacity of 5,000 metric tonnes (Municipality of Clarington 2005). One snow dump exists in Newcastle, with a capacity of 10,000 metric tonnes (Municipality of Clarington 2005).

Landfills

Waste management in the Ganaraska Region Conservation Authority is primarily under the jurisdiction of the upper tier municipalities. There are no active landfills in the Wilmot Creek watershed. There is one known closed landfill in the Wilmot Creek watershed, west of the main branch on Regional Road 4 (Taunton Road). The Orono Village Police Landfill is 4.5 ha in size with a filled area of 3.23. The Certificate of Approval was issued in 1975 (Municipality of Clarington, Personal Communications, 2007 – Data from 1991).

Water Treatment Plants and Private Wells

Figure 5.8 shows the municipal water-serviced areas in the Wilmot Creek watershed. The Newcastle Water Supply System, operated by the Regional Municipality of Durham draws water from Lake Ontario to be treated for drinking water. The communities of Newcastle and Newtonville are serviced by the Newcastle Water Supply System. The Regional Municipality of Durham operates the Orono Water Supply System that provides water to residents in Orono. The Orono Water Supply System draw water from groundwater wells. Information on these wells from a water use perspective is found in the water budget section of this document. Details on these water treatment systems are found in Table 5.2.

The rest of the population in the Wilmot Creek watershed, not serviced by municipal water systems, rely on private water supply wells for drinking water (Figure 5.9). These wells draw water from either overburden or bedrock aquifers.

Table 5.2: Municipal water treatment system information

	Orono Water Supply System	**Newcastle Water Supply System**
Location	Orono	Newcastle
Population served	1,783	7,846
Water source	Groundwater	Lake Ontario
Number of wells	3	--
Number of intake cribs	--	1
Maximum daily permitted water taking (m^3/d)	873 per well	8,180

Wastewater Treatment

The Newcastle Wastewater Treatment Plant services Newcastle in the Wilmot Creek watershed, and outlets into Lake Ontario (Figure 5.10). The rest of the population in the Wilmot Creek watershed rely on private septic systems. Currently, there is limited data available about the number, concentrations, and other information of septic systems in the Wilmot Creek watershed.

A survey was conducted by Jagger Hims Limited (2001) on the existing private services within Orono. The study area included 92 lots, which were comprised of commercial, residential and institutional properties. Through the survey it was determined that one sewage system was malfunctioning, 41 systems were under some degree of stress, 12 properties utilized holding tanks, and 20 systems were noted to be functioning properly.

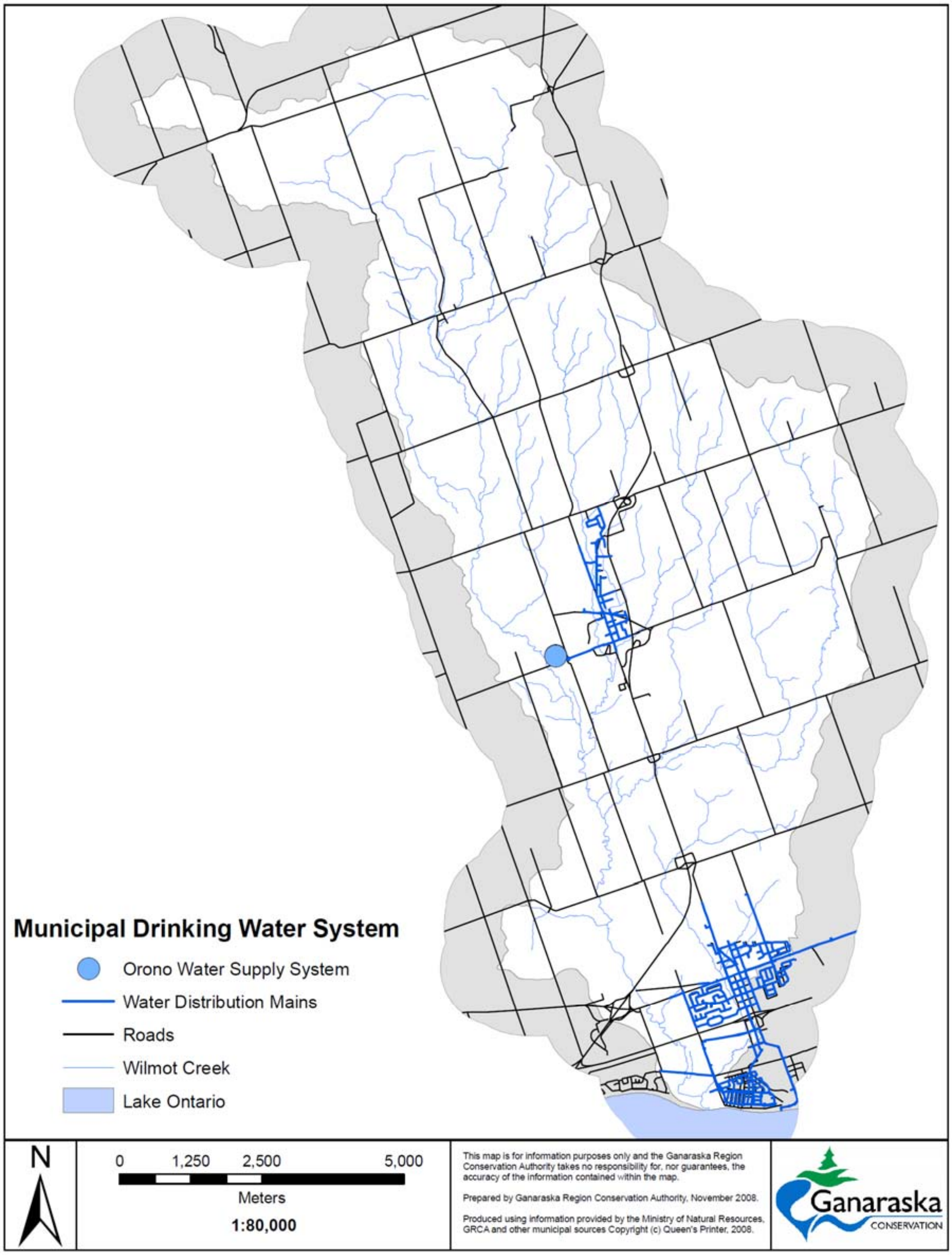


Figure 5.8: Municipal water serviced areas

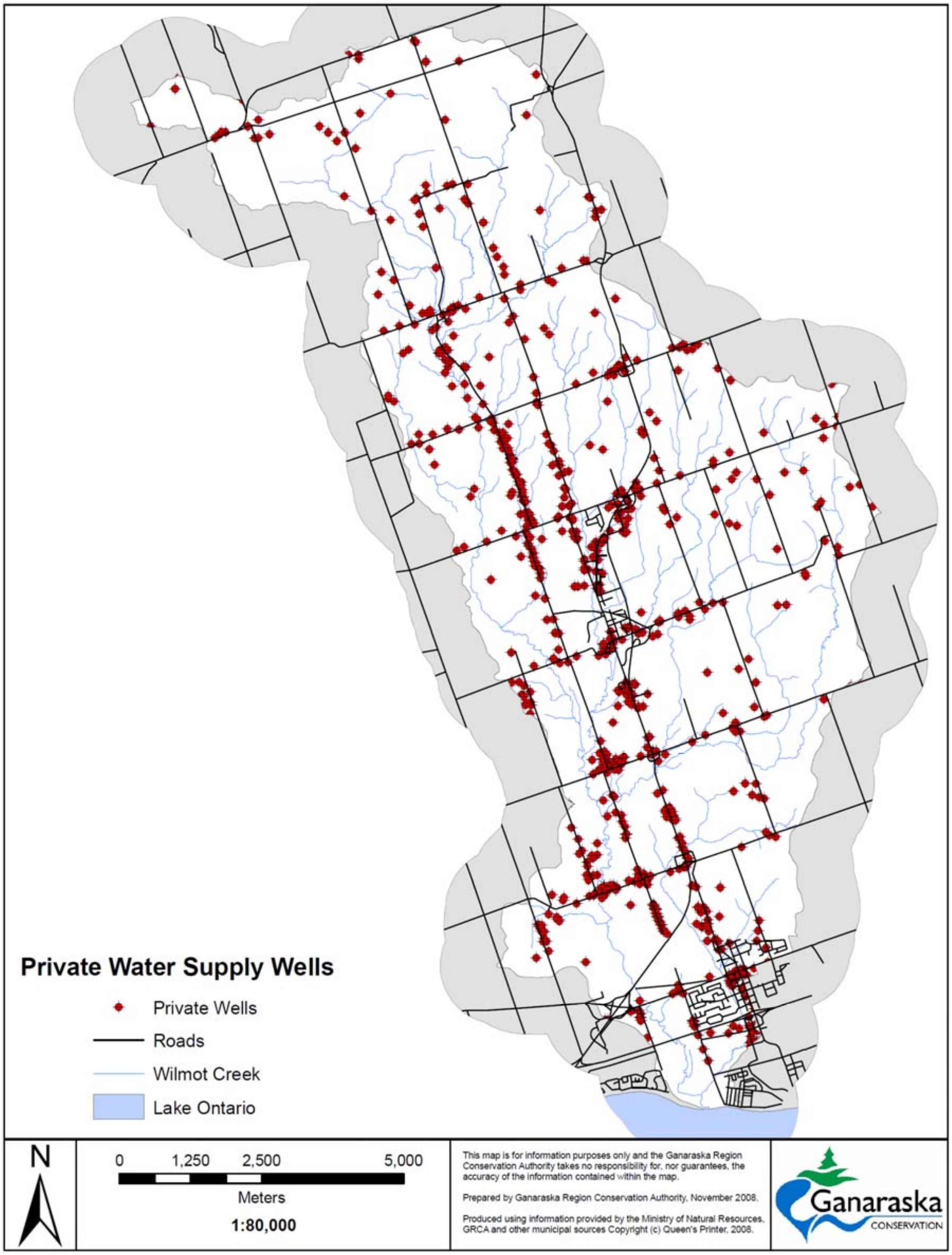


Figure 5.9: Private water supply wells

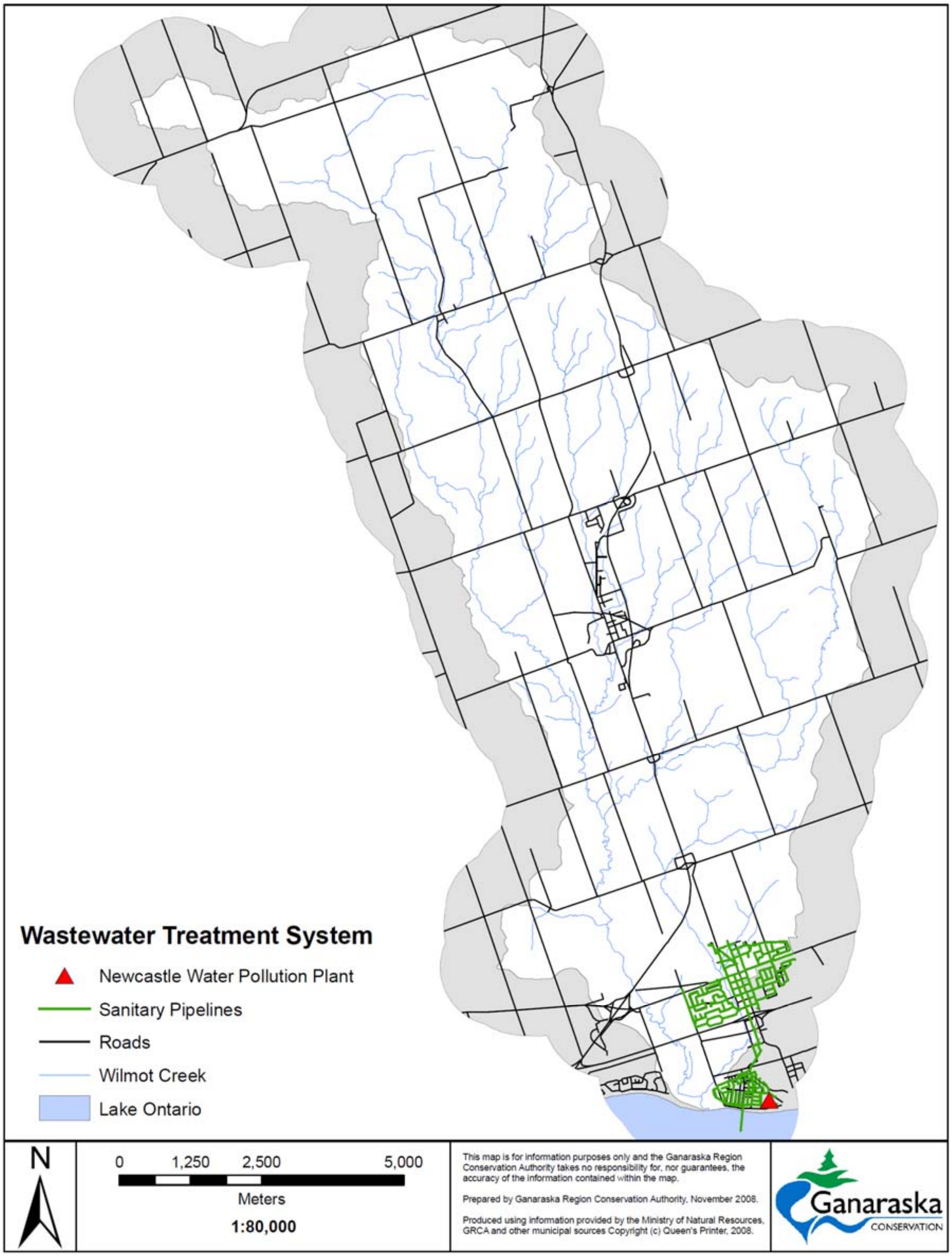


Figure 5.10: Wastewater treatment system

Stormwater Management
Stormwater management facilities are normally associated with urban areas of the Wilmot Creek watershed where runoff is directed toward ponds, creeks and infiltration trenches. In rural areas, most of the runoff from roads and residential areas is directed toward ditches and closed depression areas where higher infiltration rates are anticipated due to high permeability of surficial soils and topography.

Staff at the Ganaraska Region Conservation Authority review all development proposals to ensure they comply with requirements defined locally (through developed plans) and in provincial guidance documents. Both water quantity and quality, which affect aquatic habitats, are considered in any technical review. The general requirements for stormwater management are prescribed by the Ministry of the Environment and are defined as follows:

> *"Stormwater Management is required to mitigate the effects of urbanization on the hydrologic cycle including increased runoff, and decreased infiltration of rain and snowmelt. Without proper stormwater management, reduced baseflow, degradation of water quality, and increased flooding can lead to reduced diversity of aquatic life, fewer opportunities for human use of water resources, and loss of property and human life."* (Ontario Ministry of the Environment 2003b)

Two Stormwater Management Ponds exist in the Wilmot Creek watershed, which treat a total of 47.3ha of land for water quality at 30.7ha of land for water quantity. Neither one of these development areas are fully built out. Limited long term management strategies have been developed for these ponds.

To meet urban development requirements, several Master Drainage Plans and hydrologic models have been developed. The Foster Creek Subwatershed Planning Study provides the hydrologic analysis of 2 to 100 year storm and Hurricane Hazel by calibrated Visual OTTHYMO 2.0 model and hydraulic analysis with HEC-RAS model for Foster Creek. Infiltration targets, discharge targets and proposed facilities are defined. Please refer to the Surface Water Analysis section for more detail.

5.1.5 Natural Resources and Uses

The local environment is used by humans for many uses. Economies and communities are built around the extraction and conversion of natural resources for human use. Natural resources can be renewable (e.g., timber or water) or non-renewable (e.g., aggregates, oil and gas).

Aggregate Extraction, Oil and Gas
In the Wilmot Creek watershed, the Oak Ridges Moraine and the Iroquois Plain provide many aggregate resource opportunities (Figure 5.11). A total of 1.2 km^2

or 1.3% of Wilmot Creek watershed is defined as an aggregate land use by 2002 Ecological Land Classification Mapping (Figure 5.12). The Oak Ridges Moraine is composed of high quality aggregate resources in the form of sand with pockets of sand and gravel. The granular material contained in the Iroquois Plain region grades from fine sand to crushable oversized gravels. The lateral extent and depth of beach deposits are variable. There are no bedrock quarries in the Wilmot Creek watershed due to the thickness of the overburden.

The historical extraction of sand and gravel has left numerous abandoned or unused small pit sites in the northern Oak Ridges Moraine and southern sections of the Wilmot Creek watershed. Other aggregate resource areas have been sterilized by the construction of Highway 401. Due to the nature and depositional history of the area's geological formations, there is no oil and gas production in the Wilmot Creek watershed.

All municipalities have requirements on how new aggregate resource sites are developed. Many conditions are geared toward the protection of the natural environment, agricultural lands, and public health and safety. The Oak Ridges Moraine Plan contains additional requirements as to which Oak Ridges Moraine land use designation aggregate resources can be developed in (i.e., natural linkage area and countryside area). Municipalities also have requirements on how a licensed aggregate is to close. The Ministry of Natural Resources regulates how an aggregate area is to be rehabilitated.

Forestry

Forestry resources in the Wilmot Creek watershed consist of private forestry operations and the harvest operations for personal use (e.g., firewood and lumber). Forest resource is also used for aesthetic purposes and food (e.g., fruit, maple syrup and nuts). There are no large scale harvest operations in the Wilmot Creek watershed.

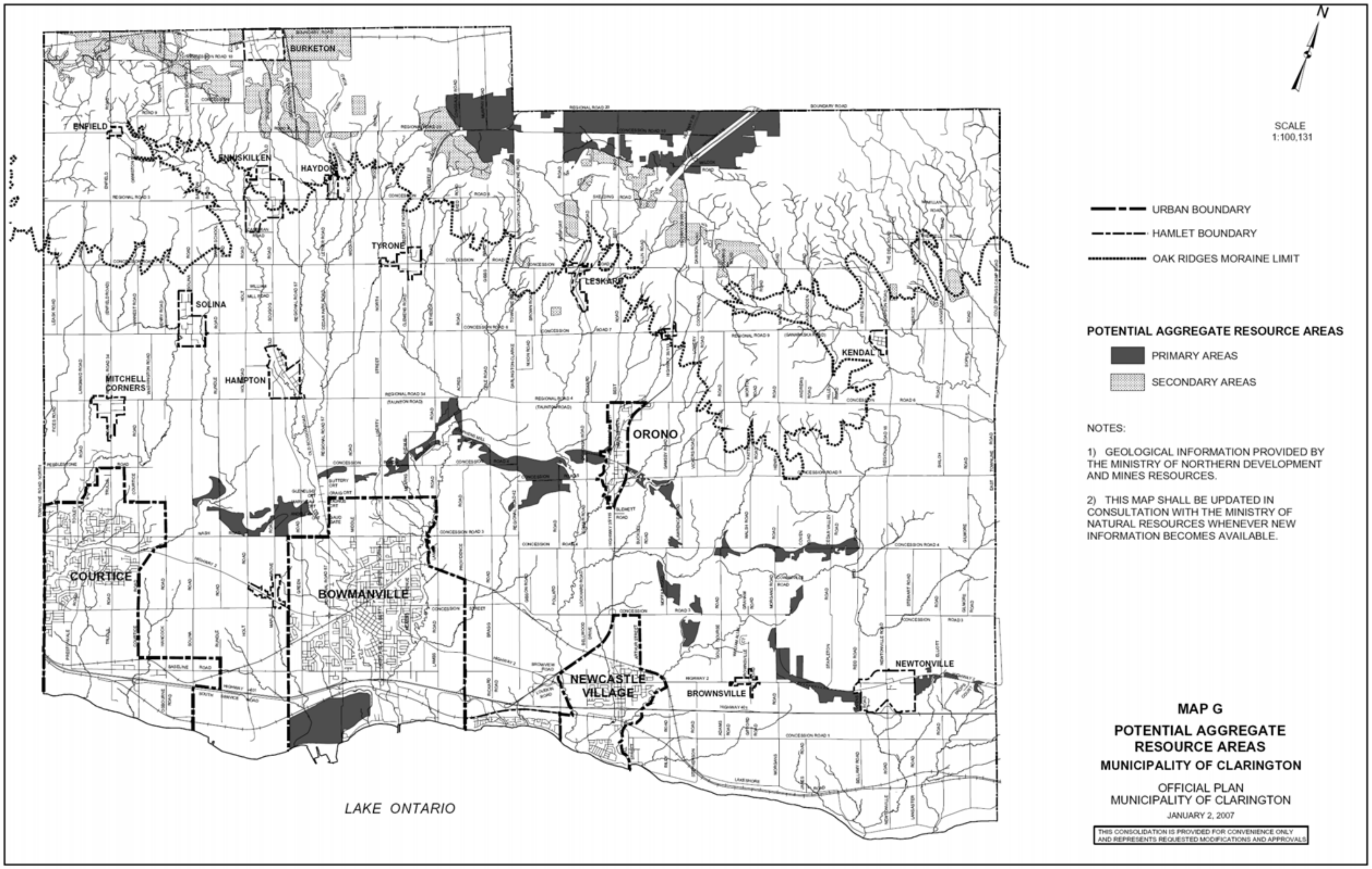


Figure 5.11: Potential aggregate resource areas

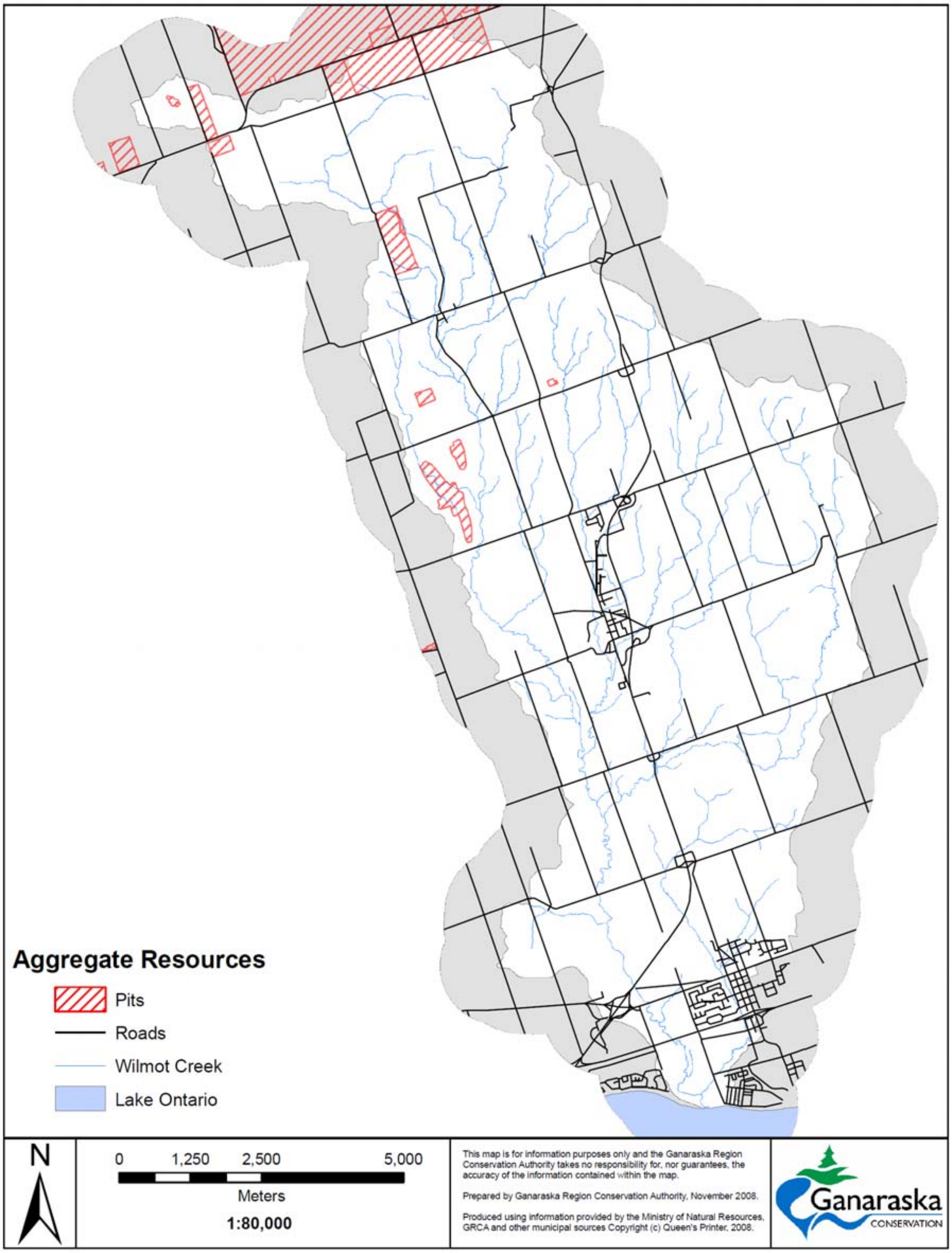


Figure 5.12: Aggregate land use

5.1.6 Protected Lands

Certain lands in the Wilmot Creek watershed are designated as conservation areas that are owned by the Ganaraska Region Conservation Authority. These lands are open to the public and have been created to satisfy many objectives. Other lands are owned by the Conservation Authority, but not open to public use. Lands are also owned by the municipality or the provincial government for public use and environmental protection. The following describes the different protected lands in the Wilmot Creek watershed.

Thurne Parks Valley Land Conservation Area

Thurne Parks Valley Land Conservation Area is 18.5 hectares, and located north of Newcastle (Figure 5.13). Purchased in 1976 by the Ganaraska Region Conservation Authority, the property protects the flood prone valley lands and preserve trout spawning and migration. One of the major features in the conservation area is the presence of a kilometre section of Wilmot Creek. In addition, the Hunter/Stalker Creeks joins the main branch within the conservation area. Current public use of this area includes passive recreation and angling. A master plan exists for the Thurne Parks Valley Land Conservation Area (Grant 1978).

Leskard Land Holdings

The Leskard Land Holdings were first considered for acquisition in the Wilmot Creek Headwaters Management Study (McGregor 1977). The driving force behind the protection of the lands resulted from the highly erodible soils and the environmental sensitivity of the area. The 19 acre property was acquired in 1979 for the purpose of protecting sensitive floodplains of Wilmot Creek.

Orono Crown Lands

The Orono Crown Lands (Figure 5.13) were originally purchased by the province as a tree nursery, to be operated by the Ministry of Natural Resources (Section 2.0). In addition to growing and shipping seedlings, the Ministry used the lands for forest research projects. This facility was closed in 1996.

As a result of community consultation in 2001, the Ministry of Natural Resources partnered with the Orono Crown Lands Trust in the management of the property. The Orono Crown Lands Trust is composed of volunteers from the local community. The Lands Trust assists the Ministry of Natural Resources in the management and maintenance of the property for public use and environmental protection. There is also an outdoor education centre maintained by the Kawartha-Pine Ridge Board of Education. For more information please visit http://www.oronocrownlands.com.

Samuel Wilmot Nature Area

The Samuel Wilmot Nature Area lies between the Canadian National Railway and Lake Ontario, Toronto Street on the east and Cobbledick Road on the west. The Nature Area is 77 hectares in size and is comprised of the creek valley, marsh, forests, old fields, a remnant orchard and hedgerows (Municipality of Clarington 1998). The Nature Area lands provide excellent recreational opportunities for fishing, bird watching, walking and nature enjoyment, as well as the potential for education and interpretation of the area's landscape and settlement history (Municipality of Clarington 1998). The Nature Area provides protection for the provincially significant Wilmot Creek marsh, wildlife habitat and vegetation communities.

An Environmental Management Plan was created for the Samuel Wilmot Nature Area in 1998. The concept of the plan was built on the principle of protecting the ecological integrity of the natural environment, while providing for nature-oriented recreational uses and enjoyment of the site's natural and visual resources (Municipality of Clarington 1998). The Nature Area was divided into six management zones for ease of implementation. These management zones include wetland, valley and stream, buffers, mature forest, tablelands, and the Lake Ontario shoreline.

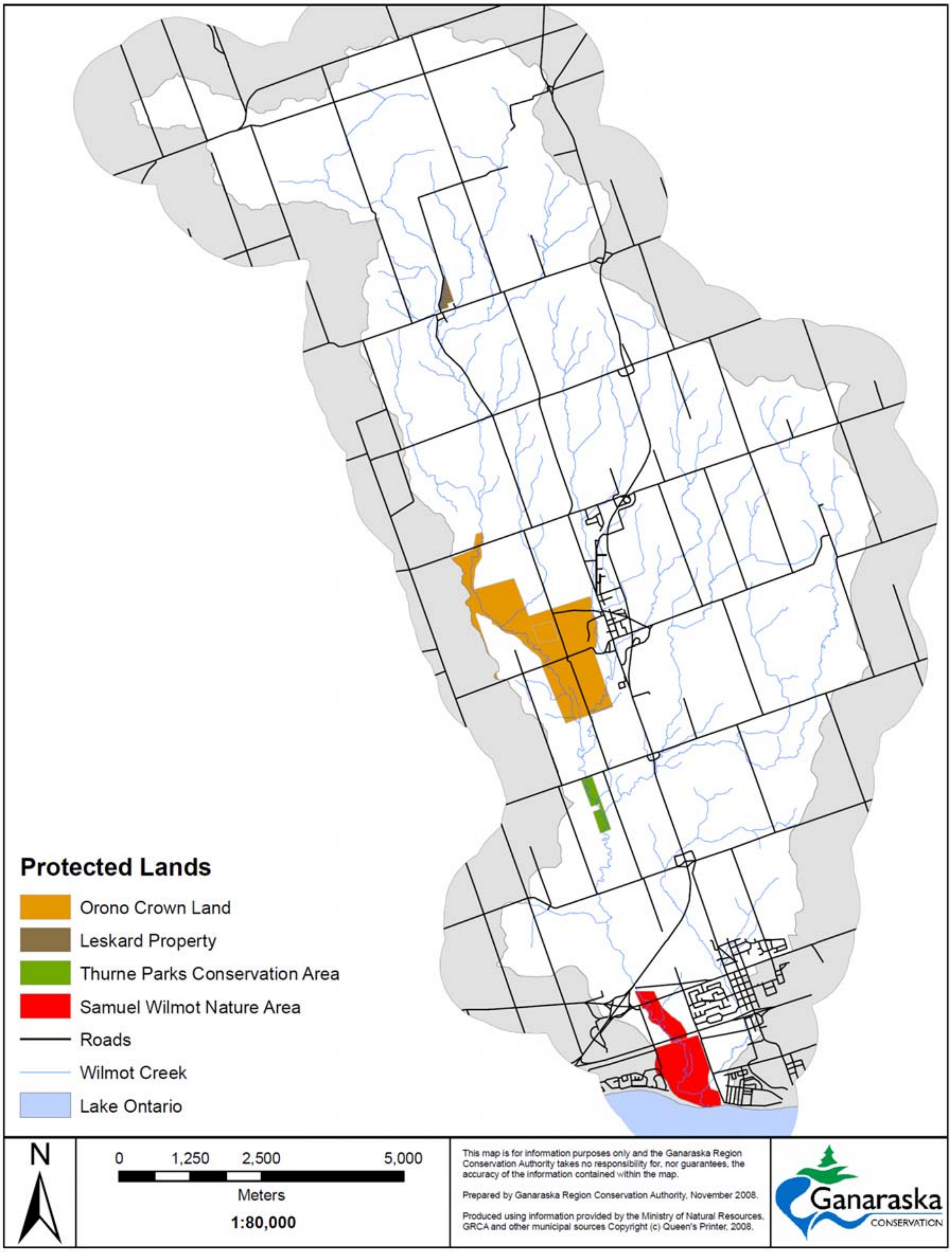


Figure 5.13: Protected lands

5.1.7 Green Spaces

The amount and quality of green space in a watershed directly affects the health of a watershed. Green spaces contain permeable surfaces which can influence the hydrology of the area, especially in urban areas, and can provide habitat suitable to native flora and fauna. However, due to the potential of disturbance in these areas and the continuous use of these areas, invasive and exotic species have a higher potential of becoming established.

The amount and quality of green space available also have a positive relationship with human health and active lifestyles. Having opportunities to enjoy the outdoors is an important component of many people's lives, and can also have an indirect benefit of nature appreciation and increased education in local watersheds and environments. Activities such as hiking, fishing, skiing, cycling, horseback riding, nature appreciation, field sports, golf, and more active activities such as four-wheeling and snowmobiling rely on green space.

For the purposes of this study, green space is defined as parkland and natural areas. Parkland represents areas that have been created for the purpose of providing recreational activities, and include active and passive recreational areas as well as existing and planned/proposed areas. Examples of parkland include municipal parks and playing fields. Natural areas are areas such as forests, wetlands, valleys and stream corridors, which exist or are planned and include naturalized areas. Infrastructure corridors such as hydro, utility and abandoned rail corridors are included in the green space system as these provide passageways (formal or informal) through otherwise impassable areas. A green space system can be created by linking these various areas, providing a continuous green space system that provides opportunities for wildlife movement, increased biodiversity and a connected green space system for the use and enjoyment of citizens. Figure 5.14 and 5.15 shows the locations of municipal parks, conservation areas and crown lands located in the Wilmot Creek watershed.

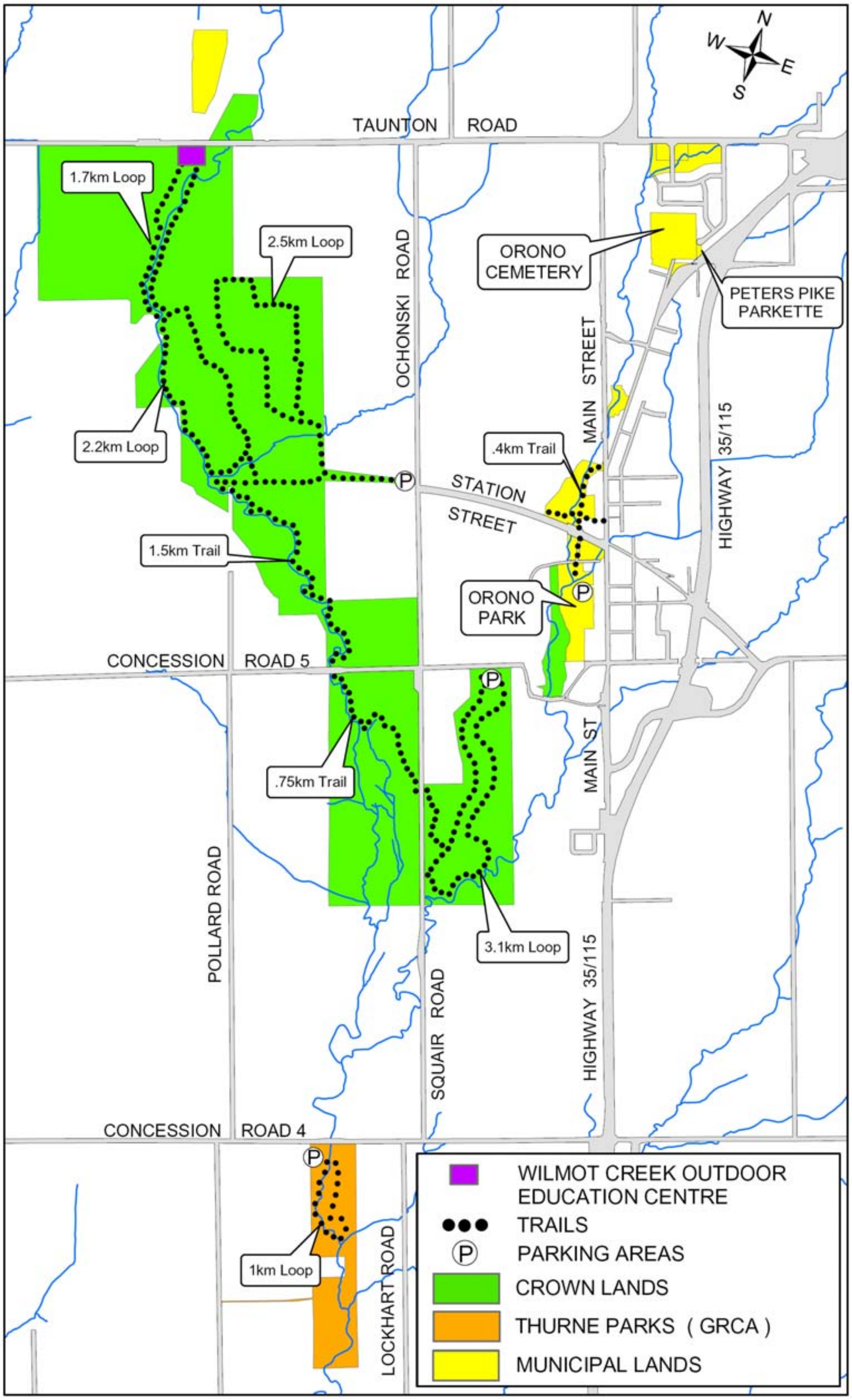


Figure 5.14: Public spaces in Orono

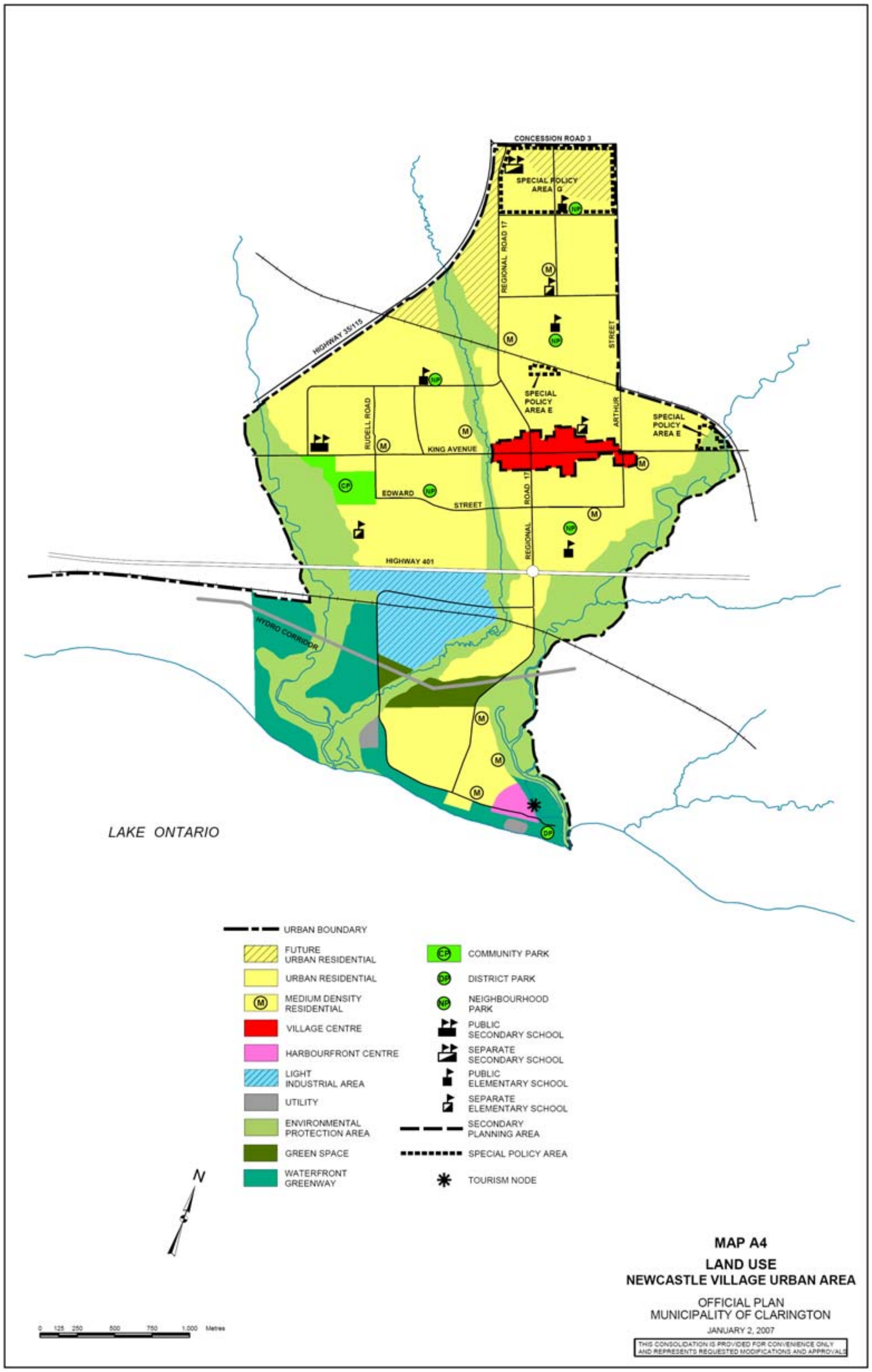


Figure 5.15: Public spaces in Newcastle

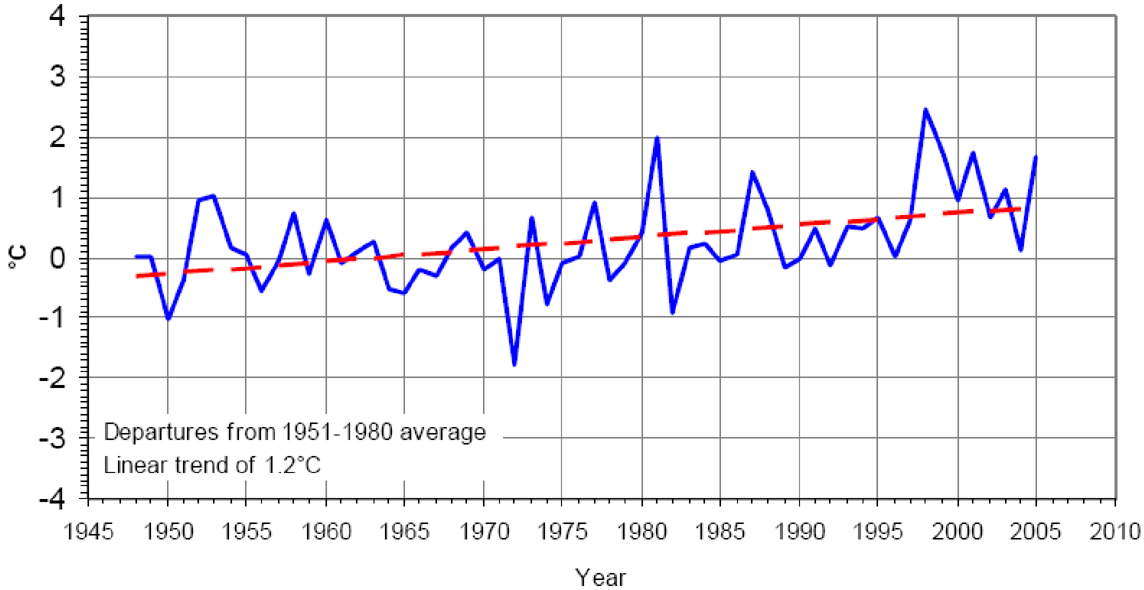
Chapter 6 - WILMOT CREEK IN A PROVINCIAL CONTEXT

6.0 Potential Climate Change Effects

Climate change is defined as a change of climate, which can be attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is, in addition to natural climate variability observed over comparable time periods (Environment Canada 2006). Climate change is not a localized phenomenon. Occurring across the globe, effects have been felt by many different ecosystems and in many different countries. The *United Nations Framework Convention on Climate Change* (2008) summarizes global events that result from climate change.

- The average temperature of the earth's surface has risen by 0.74°C since the late 1800s. It is expected to increase by another 1.8 to 4°C by the year 2100. Even if the minimum predicted increase takes place, it will be larger than any century-long trend in the last 10,000 years.
- The principal reason for the increase in temperature is a century and a half of activities that have increased the amount of greenhouse gases in the atmosphere, especially carbon dioxide, methane, and nitrous oxide. Such gases occur naturally, keeping some of the sun's warmth from reflecting back into space, and without them the world would be a cold and barren place. But in augmented and increasing quantities they are pushing the global temperature to artificially high levels and altering the climate. Eleven of the last 12 years are the warmest on record, and 1998 was the warmest year.
- The current warming trend is expected to cause extinctions. Numerous plant and animal species, already weakened by pollution and loss of habitat, are not expected to survive the next 100 years. Human beings, while not threatened in this way, are likely to face increased difficulties. Recent severe storms, floods, and droughts, for example, appear to show that computer models predicting more frequent "extreme weather events" are on target.
- The average sea level rose by 10 to 20 cm during the 20th century, and an additional increase of 18 to 59 cm is expected by the year 2100. (Higher temperatures cause ocean volume to expand, and melting glaciers and ice caps add more water). If the higher end of that scale is reached, large populations will be displaced, coastal cities will disappear, and freshwater supplies will be destroyed for billions of people.
- Agricultural yields are expected to drop in most tropical and sub-tropical regions and in temperate regions too. This will cause drying of continental interiors, such as central Asia, the African Sahel, and the Great Plains of the United States. These changes could cause, at a minimum, disruptions in land use and food supply. And the range of diseases such as malaria may expand.

Similar climate change effects are seen in Canada. According to Environment Canada (2006), a warming trend of +1.2°C has been identified over the last 58 years in Canada (Figure 6.0). The year 2005 had the fifth highest national temperature departure since 1948, and 1998 was the warmest year (+2.5°C) during that period.



(Environment Canada 2006)

Figure 6.0: Annual Canadian temperature departures and long-term trend, 1948 to 2005

Since 1948, average annual temperatures in Ontario have increased as much as 1.4^{o}C (Chiotti and Lavender 2008). This trend is projected to continue, with the most pronounced temperature increases occurring in winter. Projections also indicate that intense rainfall events, heat waves and smog episodes are likely to become more frequent (Chiotti and Lavender 2008).

Climate change can also be seen through the Cobourg STP Environment Canada climate station. Figure 6.1 shows the maximum and minimum daily temperature average of a year, and an annual mean air temperature from 1973 to 2005. There is a significant increase in mean annual temperature since 1973 (n=31, r=0.53, p = 0.002). Although no study on climate change effects to aquatic and terrestrial ecosystems and habitats has occurred in the Wilmot Creek watershed, predicted changes in Ontario can be used to understand possible changes, outcomes and stressors. A glimpse at effects on water quantity has been gained through the water budget process (Section 3.5.4) by analyzing current water quantity data with Global Climate Change Models.

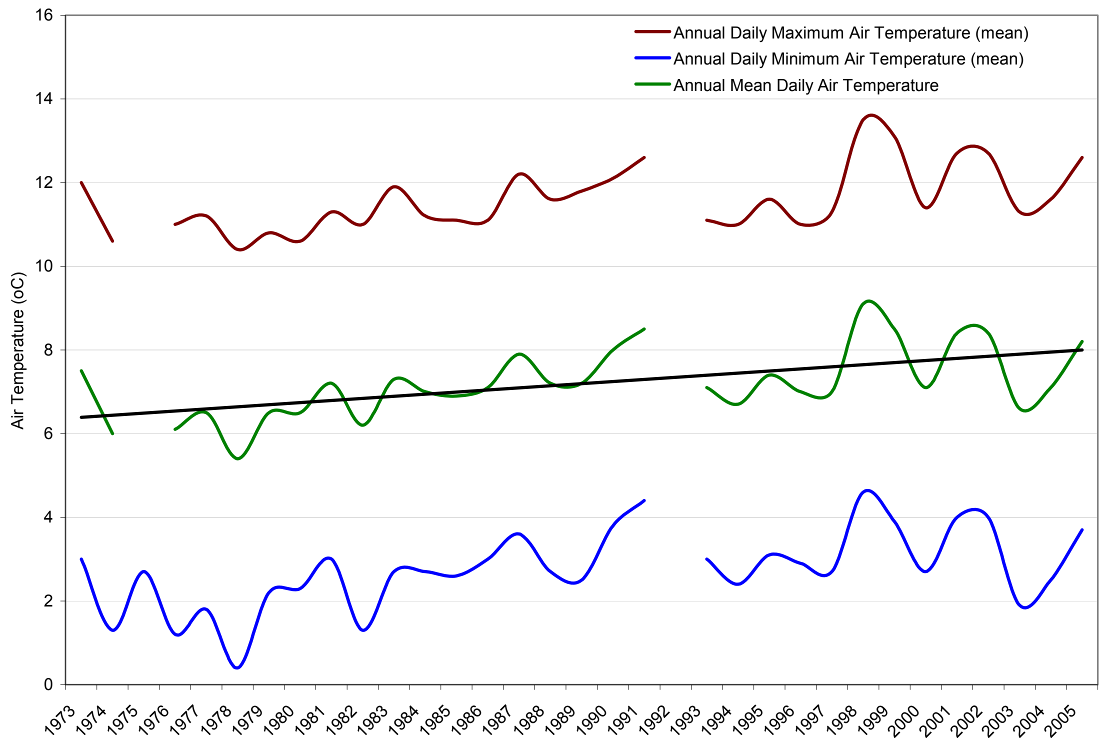


Figure 6.1: Annual average air temperature at the Cobourg STP Environment Canada Station, 1973 to 2005

Within the Great Lakes basin ecosystems change due to climate change has been noted, and is outlined by Chiotti and Lavender (2008).

- The ice cover season on the Great Lakes has been shortened by about 1 to 2 months during the last 100 to 150 years.
- Nearshore lake temperatures have increased at several locations since the 1920s. These increases are likely associated with extensive algae blooms and invasion of non-native species.
- Shifts in fish communities are expected to occur with declines in coldwater species in the Great Lakes. Warm water species such as Bigmouth Buffalo and Flathead Catfish are already being seen more frequently in the Great Lakes basin.
- Additional stressors on already fragile habitats such as coastal wetlands and terrestrial ecosystems may be unable to maintain their functions under increased climate change.

Changes are also expected to occur in water resources in the Great Lakes basin, and will affect both groundwater and all surface water sources (Great Lakes, inland lakes, rivers, streams and ponds). Table 6.0 outlines possible changes to water resources in the Great Lakes basin. Spring freshets and extreme rainfall events will also change the way streams respond under a flood. Increasing winter temperatures will possibly cause the spring freshet to occur earlier and because of more frequent winter thaws the freshet will likely be lower, reducing the risk of spring flooding (Chiotti and Lavender 2008). In addition, projected increases in the frequency and intensity of extreme rainfall events will result in increased summer flood risks.

Table 6.0: Expected changes to water resources in the Great Lakes Basin

Hydrological parameter	Expected changes in the 21st century, Great Lakes basin
Runoff	• Decreased annual runoff, but increased winter runoff • Earlier and lower spring freshet (the flow resulting from melting snow and ice) • Lower summer and fall low flows • Longer duration low flow periods • Increased frequency of high flows due to extreme precipitation events
Lake levels	• Lower net basin supplies and declining levels due to increased evaporation and timing of precipitation • Increased frequency of low water levels
Groundwater recharge	• Decreased groundwater recharge, with shallow aquifers being especially sensitive
Groundwater discharge	• Changes in amount and timing of baseflow to streams, lakes and wetlands
Ice cover	• Ice cover season reduced, or eliminated completely
Snow cover	• Reduced snow cover (depth, areas, and duration)
Water temperature	• Increased water temperatures in surface water bodies
Soil moisture	• Soil moisture may increase by as much as 80 percent during winter in the basin, but decrease by as much as 30 percent in the summer and fall

(Chiotti and Lavender 2008)

Many other negative impacts from climate change are predicted to occur (Chiotti and Lavender 2008). Risks to human health will come from temperature stress, air pollution, extreme weather events, vector and rodent borne disease, water borne diseases and Ultraviolet Radiation. Agriculture may see increases in pests and diseases, lower livestock productivity and changes in crop production in relation to growing seasons. Changes to energy consumption and production will occur, as will a decline in shipping and negative impacts on transportation corridors through increased temperature and extreme weather events. Finally, tourism in southern Ontario is predicted to be effected by milder winters and shifts in warm-weather tourism industries.

Climate change presents challenges to Ontario ecosystems, communities and economic structure. Although these changes and their magnitude will be variable across the province, change will occur. As a result, ecosystems will need to adapt in order to survive increases in temperature, extreme weather and stresses to habitats (i.e., increases in invasive species and disease). The key to local ecosystems, flora and fauna, as well as humans handling changes in climate, is resilience and the ability to adapt. By preserving, enhancing and properly managing the Wilmot Creek watershed, resilient and healthy ecosystems will be able to better adapt to changes presented from a changing climate and many other current and future stressors.

6.1 Drinking Water Source Protection

The Ontario government has given Royal Assent to the *Clean Water Act, 2006,* which is aimed at protecting sources of municipal drinking water as part of the government's overall commitment to human health and the environment. A key focus of the legislation is the production of locally developed, science based assessment reports and protection plans (Ontario Ministry of the Environment 2007b). The need for legislation such as the *Clean Water Act* was spurred by the tragic events that occurred in Walkerton, Ontario in May 2000 when seven people died and thousands became sick from drinking municipal water that was contaminated with *E. coli*.

Assessment reports and protection plans will be written for specific planning regions, known as source protection regions or areas. The local source protection region, which includes the Ganaraska Region Conservation Authority is the Trent Conservation Coalition Source Protection Region (TCC SPR). Under the *Clean Water Act*, the Ganaraska Region Conservation Authority becomes a source protection area within the TCC SPR.

The Trent Conservation Coalition Source Protection Region is a grouping of five Conservation Authorities that primarily consist of the Trent River watershed. The TCC SPR stretches from Algonquin Provincial Park in the north to Lake Ontario and the Bay of Quinte in the south, and includes the Trent River watershed, the Ganaraska River watershed, Wilmot Creek watershed, the Cobourg Creek watershed, and several smaller watersheds that empty into Lake Ontario and the Bay of Quinte. The Source Protection Region is approximately 15,000 km^2.

Five Conservation Authorities comprise the TCC SPR (beginning from the northwest and moving in a general clockwise direction).

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

For the purpose of drinking water source protection planning, the TCC SPR has been enlarged beyond conservation authority jurisdiction to include the entire Trent River watershed. This includes the Gull and Burnt River watersheds, lying mainly within Haliburton County, as well as additional watershed areas draining southward to the Kawartha Lakes in the northern half of Peterborough County. Approximately 4,171km^2 outside of conservation authority jurisdiction is included in the TCC SPR.

Although source protection plans will be created for a source protection region, the planning areas of interest are vulnerable areas. These include municipal surface water intake zones, wellhead protection areas, significant recharge areas, and highly vulnerable aquifers. These areas have been defined using defensible science based methods.

While the Wilmot Creek watershed plan process is taking place, work under the *Clean Water Act* framework will be occurring. A 24-member source protection committee will prepare terms of reference, an assessment report and a source protection plan for the Ganaraska Region Source Protection Area. The committee membership represents municipalities, farmers, small businesses representatives and a range of other stakeholders in the TCC SPR. Through the source protection committee, work will be completed to identify, assess and address risks to drinking water within municipal sources (wellhead and intake protection areas). Stakeholders such as local property owners can also participate through a number of different mechanisms.

Specifically, the Terms of Reference set out who is responsible for carrying out different activities. The Terms of Reference include strategies to consult with potentially affected property owners to involve the public and resolve disputes. While the committee creates an assessment report, the committee will identify threats, issues and concerns in the planning region. This knowledge will be represented as implementation actions within the source protection plan.

As described by the Ontario Ministry of the Environment (2007b), source protection plans will generally be implemented through existing regulatory requirements or approvals, zoning by-laws, official plan amendments, education or voluntary initiatives. Source protection committees may decide that existing programs and activities, voluntary or otherwise, may not be enough to address some significant threats to municipal drinking water supplies.

If a scientific assessment shows that an activity poses a significant risk to a drinking water source, an approved source protection plan may restrict or limit certain activities on properties located in designated wellhead protection areas and intake protection zones. Activities that pose a significant risk to drinking water sources may be prohibited or may require a risk management plan before they can be carried out.

The source protection plan may be very similar to the Wilmot Creek Watershed Plan, but will differ in the fact that the source protection plan addresses issues surrounding municipal water sources, whereas the watershed plan will address watershed-wide ecosystem based concerns and issues. Plan implementation may occur simultaneously in some instances, when the action will protect similar resources or environmental features and achieve similar outcomes. While working with municipalities, the Ganaraska Region Conservation Authority will strive to reduce duplication between the plans and the resultant implementation tools and resources.

6.2 Lake Ontario

Lake Ontario is the final receiving lake in the Great Lake drainage basin, before water flows through the St. Lawrence River to the Atlantic Ocean (Figure 6.2). Lake Ontario is bounded by the Province of Ontario in Canada, and New York State and Pennsylvania State in the United States of America (Figure 6.3). With a total drainage area to Lake Ontario of 64,030 km^2, New York State has the largest drainage area to Lake Ontario (35,000 km^2), followed by Ontario (29,100 km^2) and Pennsylvania State (300 km^2 – upper Genesee River).

Lake Ontario is the smallest of the Great Lakes, with a surface area of 18,960 km^2 (7,340 square miles), but it has the highest ratio of watershed area to lake surface area. It is relatively deep, with an average depth of 86 m and a maximum depth of 244 m second only to Lake Superior (Environment Canada et al. 1998). Approximately 80% of the water flowing into Lake Ontario comes from Lake Erie through the Niagara River. The remaining flow comes from Lake Ontario basin tributaries (14%) and precipitation (7%). About 93% of the water in Lake Ontario flows out to the St. Lawrence River; the remaining 7% leaves through evaporation (Environment Canada et al. 1998).

In 1987, the governments of Canada and the United States made a commitment, as part of the *Great Lakes Water Quality Agreement*, to develop a Lakewide Management Plan for each of the five Great Lakes. The *Lake Ontario Lakewide Management Plan* is a binational, cooperative effort to restore and protect the health of Lake Ontario by reducing chemical pollutants entering the lake and addressing the biological and physical factors impacting the lake (Environment Canada et al. 2008).

(Great Lakes Information Network 2008)

Figure 6.2: Great Lakes drainage basin

(Environment Canada et al. 2008)

Figure 6.3: Lake Ontario drainage basin

Environment Canada et al. (2008) acknowledges the importance of watershed management to the health of Lake Ontario. A binational work plan for 2007 to 2011 recommends working with Conservation Authorities within the Lake Ontario basin to identify and promote watershed management strategies (Environment Canada et al. 2008) that will benefit and enhance Lake Ontario. In addition, many projects are currently being carried out in Wilmot Creek that will benefit the health and sustainability of Lake Ontario.

The Lake Ontario fishery is dependent on its tributaries for spawning and rearing habitat. Despite the trend of resource exploitation in the 1800s, there was a shift is resource management in the mid 1900's when the Great Lakes Water Quality Agreement (between the United States and Canada) was signed in 1972. This agreement sparked a renewed interest in restoring the Lake Ontario ecosystem (Smith 1995). By the mid 1900's little sports fishing opportunities existed and non-native salmonids were introduced in attempt to restore biological balance and promote the creation of a fishery in Lake Ontario. Fish stocking and sea lamprey control conducted since the 1970s resulted in an increased abundance and diversity of fish (Smith 1995).

It is envisioned that the Wilmot Creek watershed background document and management plan, as well as the *Wilmot Creek Fisheries Management Plan* will provide needed information into the *Lake Ontario Lakewide Management Plan*, and management initiatives carried out on a watershed scale will benefit the health and sustainability of Lake Ontario.

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ACRONYMS AND GLOSSARY

ANSI	Area of Natural or Scientific Interest
AVI	Aquifer Vulnerability Index
CEQG	Canadian Environmental Quality Guidelines
CGCM	Canadian Global Climate Model
CN	Curve Number
CNR	Canadian National Railway
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
COSSARO	Committee on the Status of Species at Risk in Ontario
CWQG	Canadian Water Quality Guidelines
DA	Dissemination Area
DEM	Digital Elevation Model
ELC	Ecological Land Classification
EPT	Ephemeroptera, Trichoptera and Plecoptera
GCM	Global Climate Models
GIS	Global Information System
GRCA	Ganaraska Region Conservation Authority
GRWQMN	Ganaraska Water Quality Monitoring Network
GUDI	Groundwater under the Direct Influence of Surface Water
NASHHYD	NASH rural unit hydrograph
NHIC	Natural Heritage Information Center
OFAT	Ontario Flow Assessment Technique
ODWS	Ontario Drinking Water Standard
OMAFRA	Ontario Ministry of Agriculture, Food and Rural Affairs
(O)MNR	Ontario Ministry of Natural Resources
(O)MOE	Ontario Ministry of the Environment
OSAP	Ontario Stream Assessment Protocol
PGMN	Provincial Groundwater Monitoring Network
PPS	Provincial Policy Statement
PTTW	Permit to Take Water
PWQMN	Provincial Water Quality Monitoring Network
PWQO	Provincial Water Quality Objective
RAM	Rapid Assessment Method
TCC SPR	Trent Conservation Coalition Source Protection Region
TSS	Total Suspended Solids
WHPA	Wellhead Protection Area
WWR	Water Well Record
YPDT-CAMC	York, Peel, Durham, Toronto, Conservation Authorities Moraine Coalition

Units

cfu/100ml	colony forming units per 100 milliliters
cms	cubic meters per second
g/L	grams per litre
L/D	litres per day
masl	meters above sea level
mg/L	milligrams/litre
µs/cm	micro siemens per centimetre
µg/L	micrograms per litre

Glossary

Anthropogenic: human induced or caused.[7]
Aquifer: A water bearing formation that is capable of transmitting water in sufficient quantities to serve as a source of water supply.[4]
Aquitard: A low-permeability unit that contains water but does not readily yield water to pumping wells. Aquitards can restrict contaminant movement.[4]
Artesian aquifer: An aquifer that contains water under pressure resulting in a hydrostatic head above ground level.[4]
Baseflow: Streamflow that results from groundwater seeping into a stream.[4] Baseflow represents the discharge of groundwater to streams, supports flow in dry weather. The flow of streams composed solely of groundwater discharge.[5]
Bedrock: A general term for any consolidated rock.[4]
Capture Zone: The area surrounding a well that will supply groundwater to that well when pumped at a specified rate for a specified period of time.[2]
Coldwater Species/Habitat: Species with narrow thermal tolerance levels that are usually restricted to cold, highly oxygenated water. The temperature range for these species is from 10ºC to 18ºC.[9]
Community: An assemblage of interacting populations living in a particular locale.[5]
Confined aquifer: An aquifer that is bound above and below by deposits with significantly lower hydraulic conductivity.[4]
Confluence: The location where one stream flows into another.[5]
Contaminant: An undesirable chemical or biological substance that is not normally present in groundwater, or a naturally occurring substance present in unusually high concentrations. Common contaminants include bacteria and viruses, petroleum products, chlorinated substances, pesticides, nitrates and salt.[2]
Discharge: The volume of water that passes a given location within a given period of time.[1]
Drainage basin: The land area which contributes runoff to streams, rivers and lakes. Also called a watershed or catchment area.[4]
Drawdown: A lowering of groundwater levels caused by pumping. The difference between the static water level and the pumped water level.[4]
Drumlin: Oval hills of glacial till with smooth convex contours. In any areas the drumlins all point in the same direction, which is considered to be the direction of movement of the glacier, which formed them.[3]
Evapo-transpiration: The combined loss of water to the atmosphere from land and water surfaces by evaporation and from plants by transpiration.[4]
Floodlines: Lines on a watershed map depicting regional flow conditions based on a specific historical event (i.e., Hurricane Hazel).[12]
Floodplain: The area, usually low lands adjoining a watercourse, which has been or may be subject to flooding hazards.[12]
Fluvial: Of or belonging to rivers.[12]
Gauging station: The site on a stream, lake or canal where surface water data is collected.[4]

GIS (Geographic Information System): A map based database management system, which uses spatial reference system for analysis and mapping purposes.[4]
Glaciofluvial: Pertaining to glacial meltwater streams and their sedimentary deposits.[4]
Glaciolacustrine: Pertaining to lakes adjacent to glaciers and fed by glacial meltwater.[4]
Gravel: Rock particles between 4 mm and 76 mm in diameter.[4]
Groundwater flow: The movement of water through the pore spaces of overburden material or through faults and fractures in bedrock.[4]
Groundwater model: A computer model in which groundwater flow is characterized by numerical equations.
Groundwater recharge: The inflow to a groundwater reservoir.[4]
Groundwater reservoir: An aquifer or aquifer system in which groundwater is stored.[4]
Groundwater storage: Groundwater stored in aquifers.[4]
Groundwater: Water occurring in the zone of saturation in an aquifer or soil.[4]
Hardness: A measure of the concentration of divalent cations in water, (mainly calcium and magnesium).[4]
Headwaters: The origins of streams and rivers.[12]
Hummocky Topography: Pertaining to an area where the topography is undulatory with a predominance of closed depressions that minimize surface water runoff and enhance groundwater infiltration.[4]
Hydraulic Conductivity: A measure of the ability of groundwater to flow through (the subsurface environment) or (a soil or rock formation).[2]
Hydraulic gradient: The rate of change in total head per unit of distance in the direction of flow. The slope on a water surface such as the watertable or potentiometric surface.[4]
Hydrogeology: The study of water below the ground surface.[12]
Hydrology: The study of surface water flow systems.[12]
Hydrograph: A graph that shows water level as a function of time.[4]
Hydrologic cycle: The circulation of water in and on the earth and through the atmosphere through evaporation, condensation, precipitation, runoff, groundwater storage and seepage, and re-evaporation into the atmosphere.[4]
Hydrostrati-graphic unit: A formation, part of a formation, or group of formations with similar hydrologic characteristics that allow for grouping into aquifers and confining layers.[4]
Infiltration: The flow of water from the land surface into the subsurface.[4]
Irrigation: The controlled application of water through man-made systems to supply water requirements not satisfied by rainfall.[4]
Macroinvertebrates: organisms with no backbone that are greater than 2mm in size. Generally refers to Benthic organisms such as insects and mollusks.[6]
Manure: The fecal and urinary matter produced by livestock and poultry.[4]
Nitrate (NO_3): An important plant nutrient and inorganic fertilizer.In water, the major sources of nitrates are septic tanks, feed lots and fertilizers.[4]

Non-point source contaminant: Contamination, which originates over large areas.[4]
Oak Ridges Moraine: A knobby ridge of sand deposited at the edge of a glacier by escaping meltwater; the Oak Ridges Moraine was formed by the Simcoe and Lake Ontario Ice Lobes meeting.[3]
Ontario Drinking Water Objectives: (ODWO): A set of regulations and guidelines developed by the Ontario government to help protect drinking water sources.[5]
Piezometer: A pipe installed in the ground and used to measure water levels and collect water.[4]
Pool: A section of a stream where the water has a reduced velocity, often with water deeper than the surrounding areas.[6]
Pore space: The open space between mineral grains in a porous material.[4]
Provincial Groundwater Monitoring Network (PGMN): A groundwater monitoring program operated with the Ministry of the Environment to record groundwater level changes over time, record groundwater quality and quantifies groundwater-surface water interactions.[5]
Provincial Water Quality Monitoring Program (PWQMN): A water chemistry monitoring program operated by the Ministry of the Environment in cooperation with municipal governments and agencies.[5]
Provincial Water Quality Objectives (PWQO): numerical criteria that act as chemical and physical indicators for a satisfactory level of surface water quality to protect all forms of aquatic life.[8]
PoTable water: Water that is fit to drink.[4]
Precambrian: The period of geologic time that precedes the Cambrian Period (2,500 to 4,500 million years ago).[4]
Quaternary: Geologic period spanning the last 1.8 million years and characterized by alternating glacial and interglacial climates. It is divided into the Pleistocene and Holocene epochs.[11]
Recharge area: Areas where the water is absorbed into the ground and added to the zone of saturation.[4]
Redd: Trout and salmon nest
Riffle: A section of the stream with turbulent flow, usually with gravel, cobble or boulder bed material. Riffle sections are between pools and have faster moving water.[6]
Riparian Area: the land adjacent to a watercourse that is not normally submerged, which provides an area for vegetation to grown as a buffer to the land use alongside to the stream.It acts as a transitional area between aquatic and terrestrial environments, and is directly affected is affected by that body of water.[6]
River basin: The area drained by a river and its tributaries.[4]
Runoff: Water that reaches surface watercourses via overland flow.[4]
Sand: Sedimentary particles ranging from 0.074 mm to 4 mm in diameter.[4]
Saturated zone: A subsurface zone in which openings in a soil or rock formation are filled with water.[4]

Settlement Areas: Urban areas and rural settlement areas within municipalities (such as cities, towns villages and hamlets) where development is concentrated and a mix of land uses are present and have been designated in an official plan for development. Where there are no lands that have been designated, the settlement areas may be no larger than the area where the development is concentrated.[10]
Silt: Sedimentary particles ranging from 0.054 mm to 0.002 mm in diameter.[4]
Specific capacity: The amount of water pumped from a well divided by the drawdown in the well. It is a measure of productivity of the well.[4]
Streamflow: The surface water discharge that occurs in a natural channel.[4]
Subwatershed: A geographical area defining a single drainage zone within the watershed.[5]
Surface runoff: Water flowing over the land surface in streams, ponds or marshes.[4]
Surface Water: Includes water bodies (lakes, wetlands, ponds, etc.), watercourses (rivers and streams), infiltration trenches and temporary ponds.[2]
Till: unsorted or very poorly sorted sediment deposited directly from glacier ice. Tills usually have a fine fraction - known as the matrix - with particles ranging from sand to clay size, and a coarse or clast fraction with pebble- to boulder-sized material.[4]
Time of Travel: The length of time it takes groundwater to travel a specified horizontal distance.[2]
Topography: The physical features, especially the relief and contours of the land surface.[4, 2]
Transpiration: The process by which water vapour escapes from living plants, principally the leaves, and enters the atmosphere.[4]
Turbidity: The amount of solid particles that are suspended in water and produce a cloudy appearance.[4]
Unconfined aquifer: An aquifer whose upper boundary is the watertable.[4]
Unsaturated zone: A soil or rock zone above the watertable, extending to the ground surface, in which the pore spaces are only partially filled with water.[4]
Warm Water Species/Habitat: Warm water habitat is classified as waters with temperatures above 25^{o}C.Warm water species are tolerant to these water conditions.[9]
Water balance: The accounting of water input and output and changes in storage of the various components of the hydrologic cycle.[4]
Water budget: A summation of input, output, and net changes to a particular water resources system over a fixed period of time.[4]
Watertable: The top of the saturated zone in an unconfined aquifer.[4]
Watershed: The land within the confines of drainage divides.[4]
Wellfield: An area containing more than one pumping well that provides water to a public water supply system or single owner (i.e.,, Municipality).[2]
Wellhead Protection Area: The area surrounding a well through which contaminants are reasonably likely to move toward and eventually reach the water well.[2]

Zone of saturation: The space below the watertable in which the pore spaces are filled with water.[4]

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