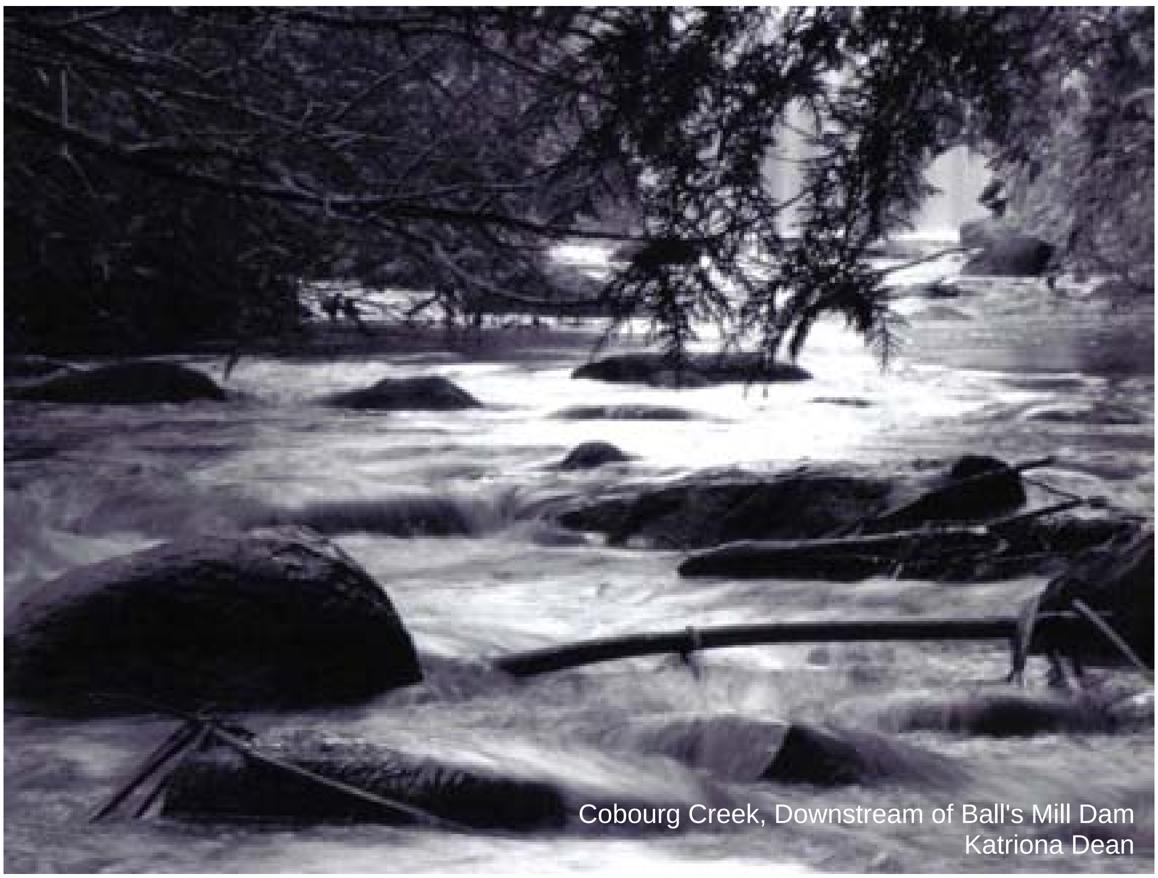
Cobourg Creek Background Report: Abiotic, Biotic and Cultural Features

for preparation of the
Cobourg Creek Watershed Plan

November 2008



Cobourg Creek, Downstream of Ball's Mill Dam
Katriona Dean

Prepared by Ganaraska Region Conservation Authority

The Cobourg Creek Background Report: Abiotic, Biotic and Cultural Features was written to document the historical and current conditions of the Cobourg Creek watershed. This document creates the foundation of the Cobourg Creek Watershed Plan.

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 resident communities, municipalities and stakeholders of the Cobourg Creek watershed. Maps were created by the GRCA GIS Department, Steve Nowak, B.A. and Jeff Moxley. This document represents the first of its kind for the Cobourg Creek watershed. Certain sections of this report have been summarized from peer-reviewed or consultant documents. Peer review of this document was conducted through the Technical Review Committee. Additional review and input was also contributed by the Community Advisory Committee, stakeholders and residents during the summer and fall of 2008. Technical Review Committee members include:

- Fisheries and Oceans Canada (informally)
- Ganaraska Region Conservation Authority
- Haliburton, Kawartha, Pine Ridge District Health Unit
- Lakefront Utilities Services Incorporated
- Lake Ontario Management Unit
- Lower Trent Conservation
- Northumberland County
- Ontario Federation of Anglers and Hunters
- Ontario Ministry of Agriculture, Food and Rural Affairs
- Ontario Ministry of Natural Resources, Peterborough District
- Ontario Ministry of the Environment
- Township of Alnwick/Haldimand (informally)
- Township of Hamilton
- Town of Cobourg

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

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Ganaraska Region Conservation Authority. 2008. Cobourg Creek Background Report: Abiotic, Biotic and Cultural Features. Ganaraska Region Conservation Authority. Port Hope, Ontario.

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

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

The Cobourg Creek watershed is located within the Township of Alnwick/Haldimand, the Township of Hamilton and the Town of Cobourg (Figure 1), all contained in the County of Northumberland. Historic events have shaped the watershed into its present day condition. Most notable are the effects on the watershed by dam construction and the settlement patterns caused by location of road and rail corridors. Today, the Cobourg Creek watershed supports a population of 9,427 people, a diverse industrial and commercial sector, a productive agriculture community, and a mix of natural resources and recreational uses. In addition, residents depend on water from the Cobourg Creek watershed for domestic and economic use, although the Town of Cobourg itself relies on Lake Ontario for its source of water.

Shaped thousands of years ago by glacial activity, the Cobourg Creek watershed lies on Palaeozoic bedrock and its topographic and hydrogeological features include the Oak Ridges Moraine, South Slope and Lake Iroquois shoreline physiographic regions (Figure 2). Corresponding surficial geology and soils help dictate where groundwater flows, where aquifers lie, and where groundwater is recharged and discharged. Groundwater models provide a better understanding of how groundwater flows and is stored beneath the Cobourg Creek watershed.

Surface water flows and the drainage characteristics of Cobourg Creek have been well studied throughout the years. Four main tributaries exist within the watershed: the Main Branch, the West Branch, the Central Branch and the Baltimore Creek Branch (Figure 3). Along with these names, Cobourg Creek is also referred to as Cobourg Brook, and historically Factory Creek represented the urbanized section of Cobourg Creek. Flows are generally resilient to stresses such as drought and water use, and adequately provide for aquatic habitat and human use.

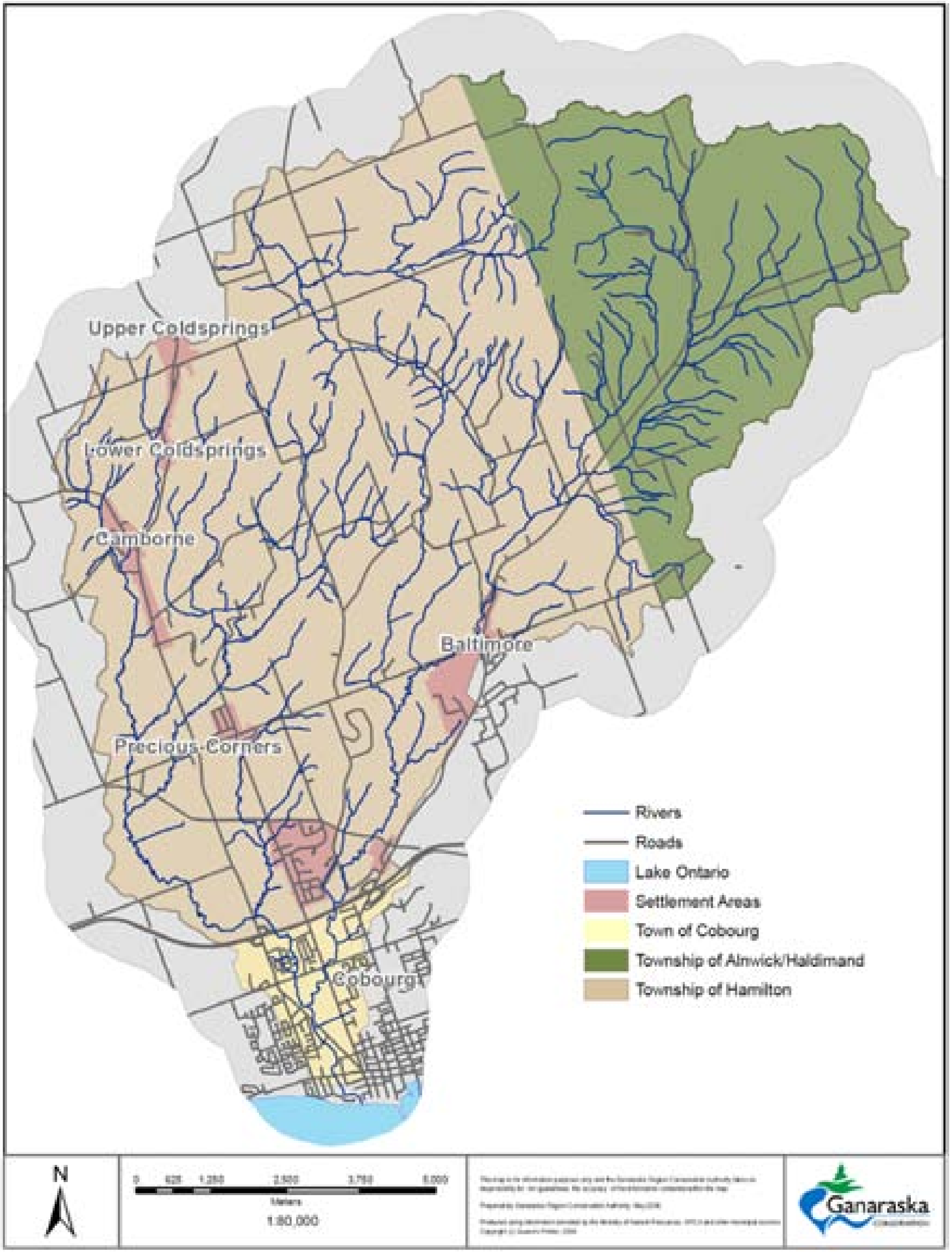

Figure 1: Cobourg Creek watershed

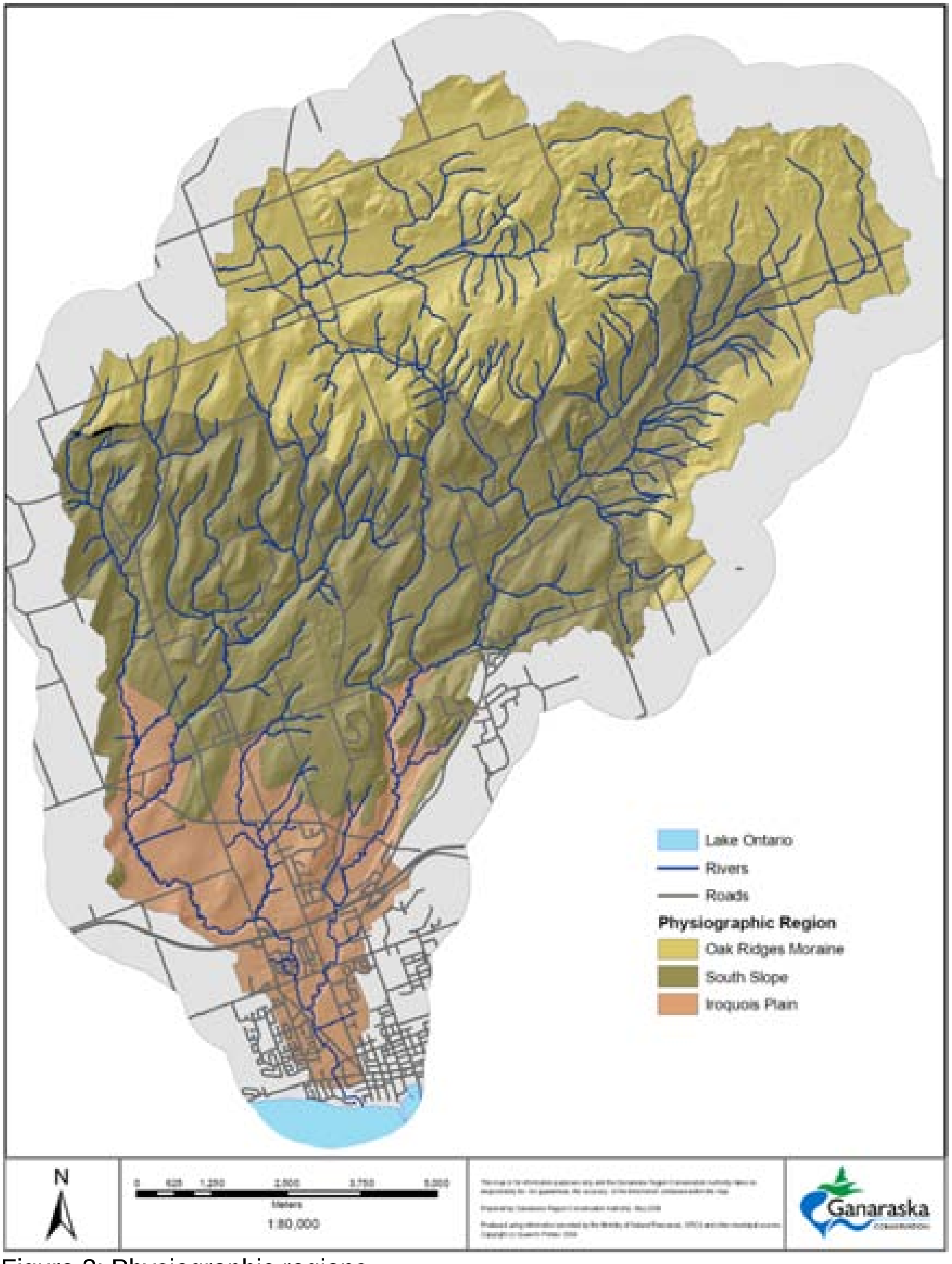

Figure 2: Physiographic regions

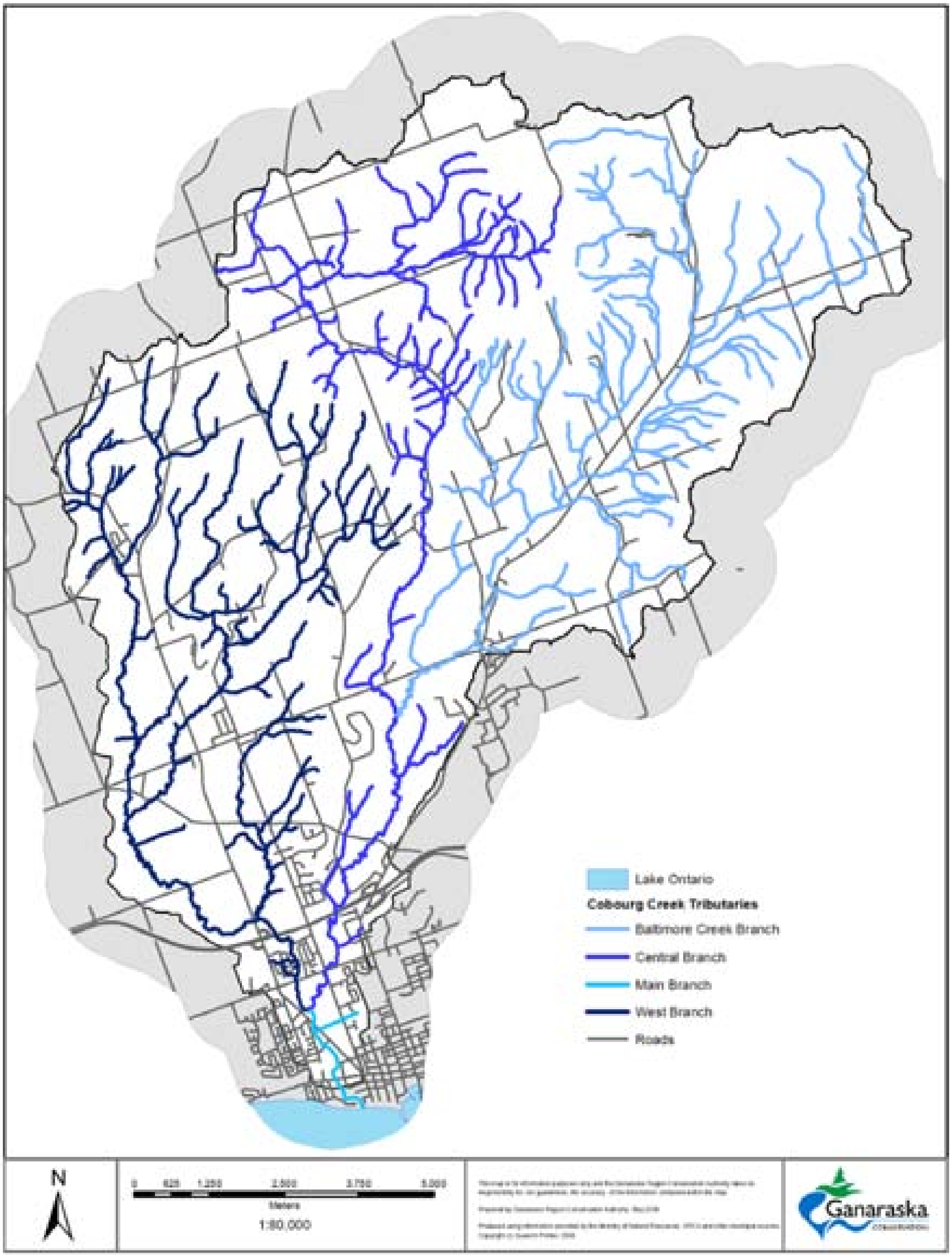

Figure 3: Cobourg Creek tributaries

Protection of Cobourg Creek has been influenced by surface water studies such as flood plain 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.

Surface water quality as a whole in Cobourg Creek is generally good, with only localized problems. The physical parameters of Cobourg Creek (dissolved oxygen, pH, conductivity and alkalinity) indicate that surface water quality can be resilient to acidification, eutrophication and chemical additions. Nutrients can be considered the surface 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. Chloride has been declining in the surface water since the 1960s.

Total phosphorus exceeds the *Provincial Water Quality Objectives* (PWQO) more often than any other nutrient, but never more than 32% of the time. Since 1964 total phosphorus has declined at the long-term Fourth Street/King Street station. Unionized ammonia has been greater than the PWQO of 0.02 mg/L 31% of the time as sampled through the Ganaraska Region Water Quality Monitoring Network (GRWQMN), but unionized ammonia never exceeded the PWQO during baseflow water quality monitoring sampling.

Nitrate-N exceeded the *Canadian Water Quality Guidelines* (CWQG) only during baseflow water quality monitoring sampling (6% of the time). Nitrite-N rarely exceeds the CWQG during baseflow water quality monitoring sampling (4% of the sites), and GRWQMN sampling (3% of the sites). At the Telephone Road PWQMN station, nitrite-N concentrations have been declining since 2002. 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, municipal water systems and the Provincial Groundwater Monitoring Network indicate 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 the groundwater quality within the Cobourg Creek watershed is generally good.

Cobourg Creek supports a diverse biological community. The fisheries community is supported by a sustainable habitat of cold to cool water within the upper two-thirds of the watershed, with warm water communities in the lower Main Branch of the watershed (Figure 4). Riparian habitats provide buffering capacity to human influences in many of the stream reaches. Cobourg Creek supports a fish community dominated by brook trout *(Salvelinus fontinalis)*, brown trout (*Salmo trutta*), rainbow trout *(Oncorhynchus mykiss)*, scuplins (*Cottidae sp.*), darters (*Etheostoma sp.)*, and cyprinids. Migratory Chinook salmon (*Oncorhynchus tshawytscha*) spawn in the lower reaches and Atlantic salmon (*Salmo salar*) are being stocked in Cobourg Creek as part of a provincial initiative to return these native top-predatory fish to Lake Ontario.

The terrestrial natural habitat of Cobourg Creek includes forest, meadows and wetlands (Figure 5). At 34%, forest cover exceeds the commonly used guideline of 30%. However, higher quality interior forest habitat is found in only about 4% of the watershed, primarily in the rural landscape. The Northumberland County Forest is a particularly valuable natural heritage feature within the headwaters of the Central Branch and the Baltimore Creek Branch. Indicator species such as birds and frogs can help us to understand the health of forest and wetland habitats. Numerous species at risk may inhabit the Cobourg 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.

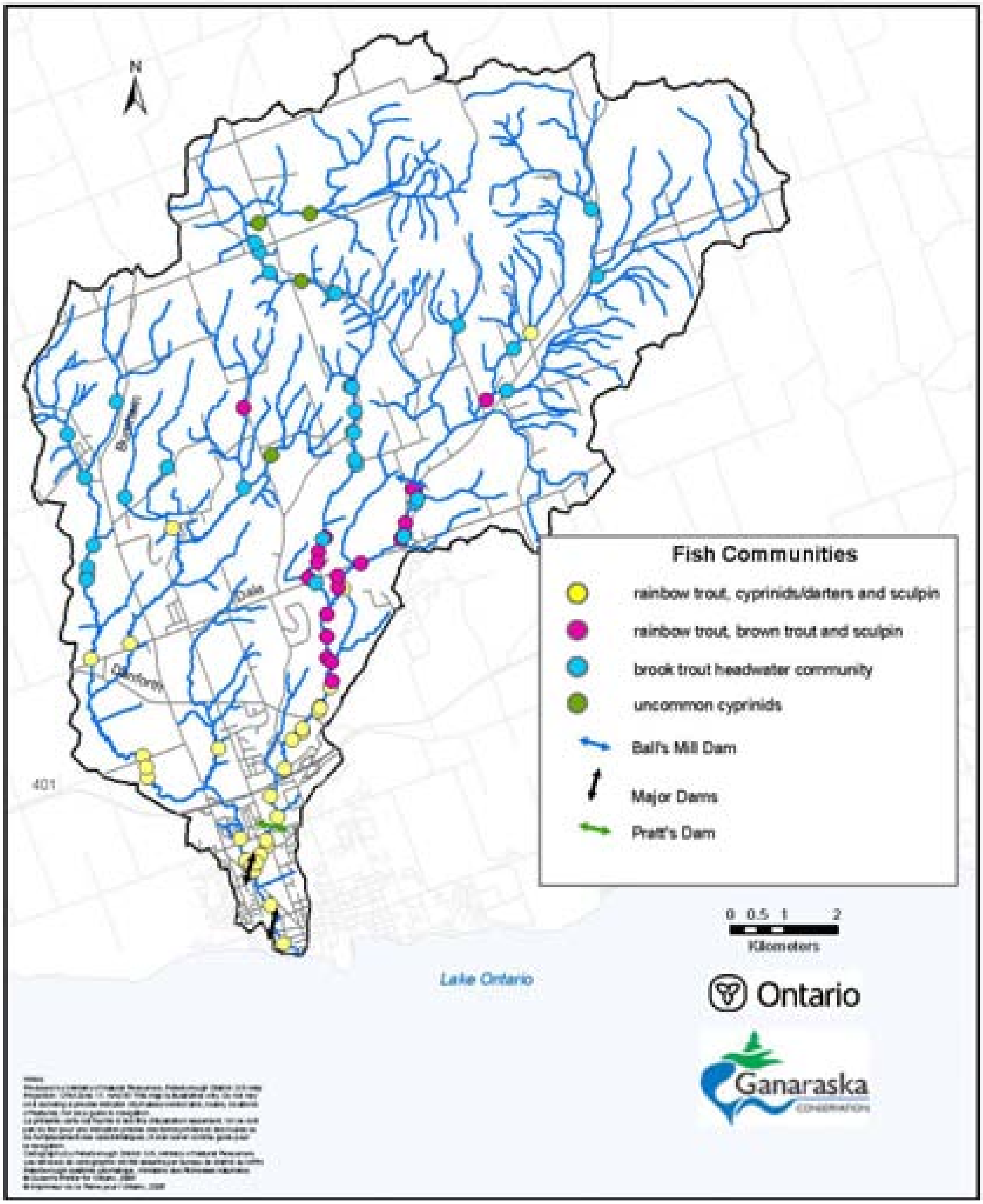

Figure 4: Fish communities within Cobourg Creek

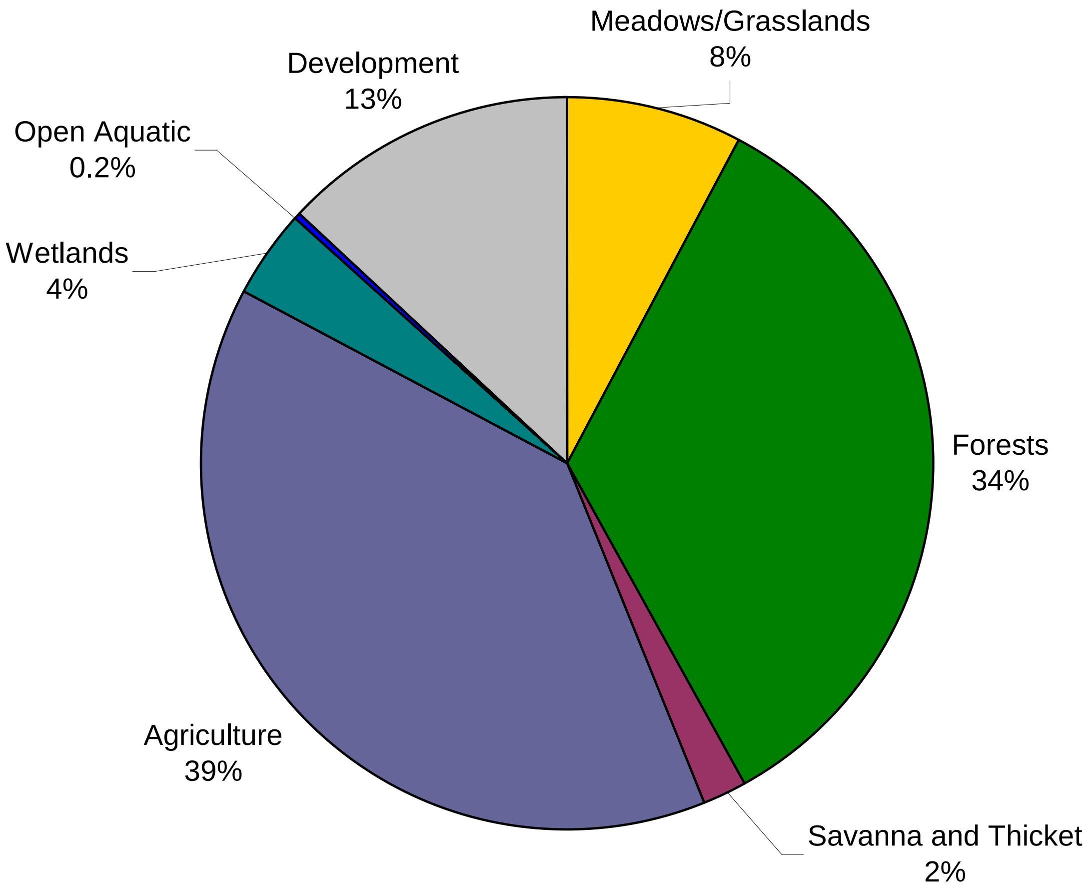

Figure 5: Land cover based on ecological land classification

The Cobourg Creek watershed is not only an important environmental feature to the communities of the Township of Alnwick/Haldimand, Township of Hamilton and Town of Cobourg; it plays an important role in a larger context. For example, Cobourg 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, Cobourg Creek has the potential to be influenced by future stresses such as climate change.

The Cobourg Creek Watershed is recognized for its fisheries resource, aquatic habitat, terrestrial natural heritage, and recreational opportunities. Cobourg Creek historically supported healthy brook trout and Atlantic salmon populations. Currently, a major effort is being undertaken to reintroduce a self-sustaining Atlantic salmon population in Cobourg Creek. This reintroduction project speaks volumes about the current sustainable condition of the Cobourg Creek watershed. The development of a watershed plan, which is required under the *Oak Ridges Moraine Act, 2001*, will aim to protect and sustainably manage the Cobourg Creek Watershed for current and future generations.

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Chapter 1 - Introduction

1.0 COBOURG 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, Ganaraska River, Gages Creek, Cobourg Creek, and smaller streams draining to Lake Ontario and Rice Lake (Figure 1.0).

The Cobourg Creek watershed within the Ganaraska Region Conservation Authority drains to Lake Ontario (Figure 1.0) as it passes through the Township of Alnwick/Haldimand, the Township of Hamilton and the Town of Cobourg. A watershed is a logical environmental planning area given that many natural functions within a watershed are interconnected. Natural cycles within a watershed need to be protected for the benefit of our local environment, watershed and community.

The Cobourg Creek watershed has been delineated from topography and urban stormwater drainage. Heights of land form the drainage basin in the rural areas of the watershed (i.e., the Township of Hamilton and the Township of Alnwick/Haldimand). Within the Town of Cobourg, urban drainage that discharges through storm sewers and along roads into Cobourg Creek is considered part of the watershed. Also within the Town of Cobourg, the main channel (instream and riparian area) that flows into Lake Ontario is considered in this study (Figure 1.1).

The Lake Ontario shoreline at the outlet of Cobourg Creek drains directly to Lake Ontario and is not considered part of the Cobourg Creek watershed for the purpose of this study. Current and future studies on the Lake Ontario shoreline address the science and management recommendations of this shoreline (Sandwell Swan Wooster Inc. 1990). It is acknowledged that the mouth of Cobourg Creek is a barrier beach, which is a feature isolating Cobourg Creek from Lake Ontario by a gravel/sand bar. This characteristic reduces mixing of lake and creek water, acts as a breakwater, and has the potential to prevent fish migration to and from the lake at low flows.

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 Township of Alnwick/Haldimand, the Township of Hamilton and the Town of Cobourg require a watershed plan to be created for the Cobourg Creek watershed, which originates on the Oak Ridges Moraine.

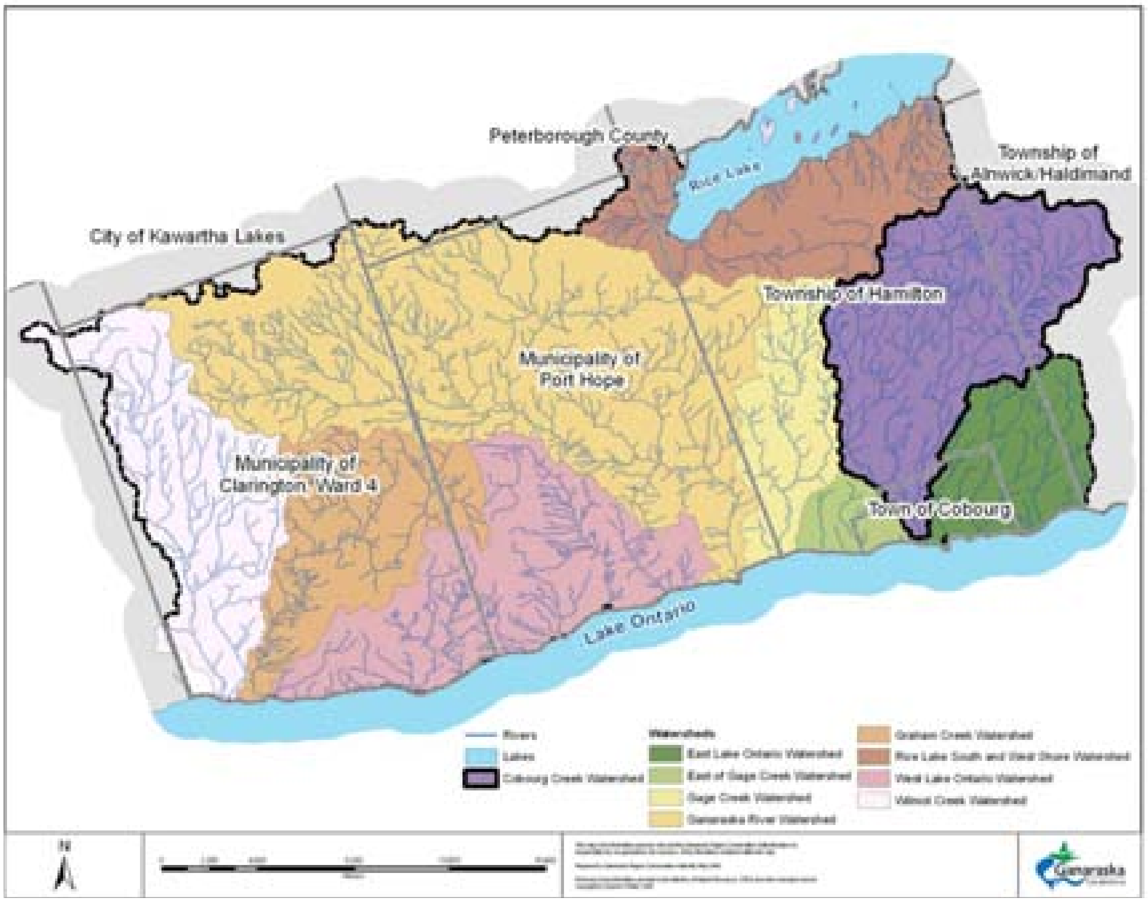


Figure 1.0: Cobourg Creek watershed within the Ganaraska Region Conservation Authority

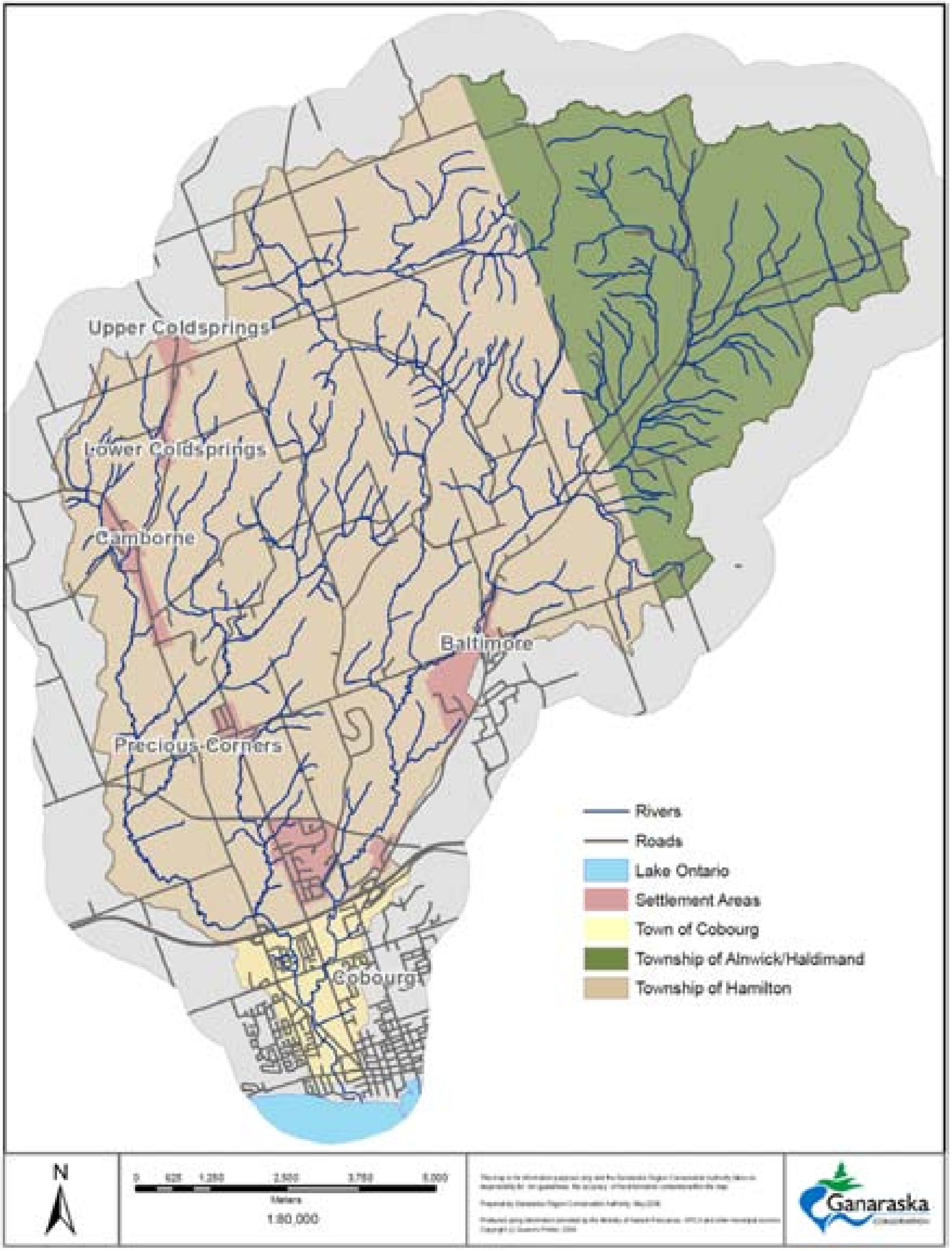


Figure 1.1: Cobourg Creek watershed

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 1993 (Ontario Ministry of 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*.

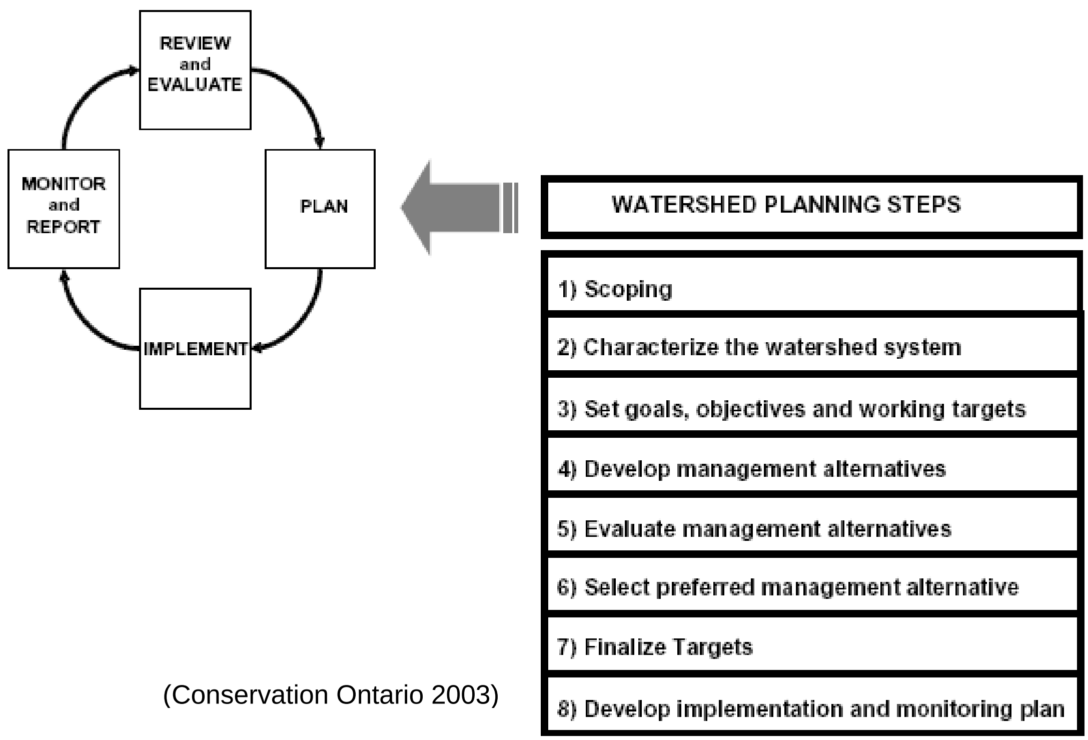


Figure 1.2: Watershed management phases and watershed planning steps

The "plan" phases 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 (i.e., 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 Cobourg Creek watershed (Ganaraska Region Conservation Authority 2004, updated in 2008).

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

The Cobourg 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 Cobourg Creek Watershed Plan can be created. Current information and model results will be used to develop the plan containing 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 2008/2009.

1.0.2 Cobourg Creek Fisheries Management Plan

While the Cobourg Creek watershed plan is being created, a Cobourg Creek Fisheries Management Plan is being developed. In the past, fisheries management in the Cobourg Creek watershed was guided by the Lindsay District Fisheries Management Plan. In 2000, the Lindsay District Fisheries Management Plan expired and the agencies responsible for fish and fish habitat management teamed up to direct the development of a new plan. These agencies include the Ontario Ministry of Natural Resources, Fisheries and Oceans Canada, and the Ganaraska Region Conservation Authority.

The *Cobourg Creek Fisheries Management Plan* draft vision for the aquatic ecosystem within the Cobourg Creek watershed is

> "*A community working together to promote a healthy aquatic ecosystem that provides sustainable benefits, contributing to society's present and future requirements for a high-quality environment, wholesome food, employment and income, recreational activity, and cultural heritage.*"

The *Cobourg Creek Fisheries Management Plan* and the Cobourg Creek Watershed Plan, and respective background documents will be created simultaneously. This will make certain that results and information presented in the documents complement each other and avoid unnecessary duplication. In addition to ensuring that public and stakeholder consultation and involvement is effective, public meetings and consultation of both background documents and plans will occur at the same time. The end result of both plans will be the protection, enhancement and proper management of the Cobourg Creek watershed and its resources, with emphasis and focus on the fisheries occurring in the Fisheries Management Plan.

Camborne School House
Pam Lancaster

Chapter 2 – History of Cobourg Creek Watershed

2.0 CULTURAL HISTORY OF THE COBOURG 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 within the Cobourg 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 Rice Lake area by the Mississaugas, a stem of the Ojibwa-Algonkins from the Lake Superior region (Martin et al. 1986). It was the Mississaugas who established the tradition of burning off the prairie vegetation on the Rice Lake Plains (Martin et al. 1986), found in the area of the Cobourg Creek watershed.

Settlement occurred later in the Township of Hamilton and the Town of Cobourg compared to neighbouring Haldimand Township and Hope Township, due to the uninviting cedar swamps that occurred in the area (Guillet 1948). Haldimand Township was settled 10 to 12 years before Cobourg saw its first settlers (Centennial Book Committee 1967). The first Haldimand Township Council met as far back as 1835.

On February 14, 1791, the Township of Hamilton was officially named after Henry Hamilton, Lieutenant Governor of Quebec. The first settlers arrived in 1797 in the Township of Hamilton (Martin et al. 1986) and in 1798 in the Town of Cobourg (Guillet 1948). By 1817 a greater influx of settlers began to arrive in the area (Guillet 1948), changing the landscape of the Cobourg Creek watershed and surrounding lands through development. In 1837 the Town of Cobourg was incorporated, making it the largest settlement area in the Cobourg Creek watershed. Historical populations ebbed and flowed in response to regional settlement patterns. In the 1830s the population in the watershed grew in response to the migration from the United Kingdom to Canada, such that in 1848 the population in the Town of Cobourg was 3,512 people (Climo 1985). Populations around the region declined in the 1860s due to economic downturn and migration to western Canada. However, over time populations have increased to current levels.

2.0.2 Historical Natural Resources

During the 1800s natural resources across Southern Ontario were exploited. Similarly, areas within and surrounding Cobourg Creek were utilized by settlers of the region. Over 15 mills were established on Cobourg Creek during the 1800s. Although not well documented, Guillet (1948) refers to many mills on Cobourg Creek.

> *"Upon entering the township from Haldimand it [Cobourg Creek] formally drove Williams' saw mill, shingle and carding mill. It also furnishes waterpower for all the mils etc., about Baltimore. Near the rear of the second concession this branch is joined by Solomon's Creek, which rises near the rear of the sixth concession and used to drive Roberts' grist mill, Fisher's, Burnett's, and Cochrane's saw mills, Dawson's oatmeal mill, and Solomon's saw mill. Another branch of this creek formerly drove Lent's grist and saw mills and McKeyes' grist mill. Still another branch of the main steam flows past Camborne and formerly was the power for a grist mill, a saw mill, and a pail factory there. These two branches unite a little southwest from the site of McKeyes' old grist mill; here they turn eastwards, and used to furnish the water power for a saw mill, pail factory, and distillery formally situated near the old Court House. They then join the main steam which after being re-enforced by Solomon's Creek, used to drive the Leaderbough planning, carding, and shoddy machine, White's grist mil, Perry's Mill, Ham's mill, a carding and fulling mill, axe factory, distillery, and a large woolen factory before entering the lake."*

In the Town of Cobourg, the first industry to form was a saw mill located downstream of the West Branch and Central Branch confluence within the town. Constructed in 1803, the saw mill allowed local settlers to use boards to construct their homes (Climo 1985). It was recorded that the large creek flowing through the area of the saw mill had a good flow of water, a large estuary, and the higher ground above the creek valley contained a rich, black loam soil (Climo 1985). Not only did the creek have a high abundance of fish, it had a large water power potential. Climo (1985) goes on to report that the levels of Lake Ontario fluctuated above five feet over the years and the high water level reached via the estuary to present-day King Street.

Not only did these mills provide local employment and goods, they caused changes in natural flows of Cobourg Creek. Major flooding occurred in 1838, 1864 and 1889, in which dams and bridges were destroyed along with other damage within the Town of Cobourg (Guillet 1948). The 1864 flood occurred when the waste gates failed at Perry's Mill (today known as Pratt's Pond), causing significant flooding downstream of Perry's Mill, property damage and loss of life (Guillet 1948). In 1913 a less severe flood was reported to have swept away more than two dozen bridges between Harwood and Cobourg and destroyed or damaged many mills (West et al. 1999). In addition, many trout were released from W.J. Crossen's trout pond into Cobourg Creek (West et al. 1999). Most recently the Town of Cobourg was flooded as a result of the 1980 flood. Although Pratt's Dam was saved, many houses were damaged south of William Street (The Cobourg Book Committee 1981).

The natural history of the Cobourg Creek watershed has been documented in many local history books; however Walker's 1994 description of the area prior to settlement paints a vivid picture.

> *"Cobourg's first settlers found here an unbroken land. The place where the town would be was marked by a strip of beach and a wide bay. Crowding in all around were dark woods full of great trees that had been growing for centuries. Where the oldest trees of the forest had fallen, there were meadows of long grass. Deer, bears and wolves roamed where the houses and streets of the town now stand. Above were clouds of birds; among them were the last generations of passenger pigeon. Along the banks of Cobourg's early creeks were swamps. These were wet cedar forests in which the roots and branches of the trees were so tangle that little sunlight reached the ground. Beaver's muskrats and mosquitoes inhabited this murky land. The thickest swamps were near the south end of Cobourg Creek. They stretched east along the lakeshore to where Division Street is today."*

The famous Catharine Parr Traill (1929) depicts a wild landscape in the Cobourg Creek watershed.

> *"The outline of the country* [Township of Hamilton] *reminds me of the hilly part of Gloucestershire…Here the bold oak, beech, maple and basswood, with now and then a grove of dark pine, covers the hills, only enlivened by an occasional settlement…"*

Catherine Parr Traill (1929) also describes the headwater areas, which contain many springs that feed cold groundwater to Cobourg Creek.

> *"About halfway between Cobourg and the Rice Lake there is a pretty valley between two steep hills. Here there is a good deal of cleared land and a tavern: the place is called the "Cold Springs." Who knows but some century or two hence this spot may become a fashionable place of resort to drink the waters. A Canadian Bath or Cheltenham may spring up where now Nature revels in her wilderness of forest trees."*

As depicted in historical accounts, the Cobourg Creek watershed was very early thought to be somewhat uninhabitable; however, the promises of hydro power and natural resources eventually changed the landscape to what is seen today. With the construction of the first sawmill in 1803, in what is now the Town of Cobourg, land was also cleared around the Main Branch of Cobourg Creek (Climo 1985). The continual settlement and transfer of land from rugged wilderness to agriculture has shaped the landscape and natural resources of the Cobourg Creek watershed.

2.0.3 Changing Landscape

Rail travel aided in shaping the current day natural landscape. In 1856 the Grand Trunk Railway connected Toronto to Cobourg (Richardson 1946), thus changing the travel corridor to the south end of Cobourg Creek. Today the Canadian National Railway operates in the same track corridor, moving freight and passengers on two sets of tracks through the Town of Cobourg and the south end of Cobourg Creek.

Although the Grand Trunk Railway was successful at bringing people and goods to the Town of Cobourg, the Cobourg and Peterborough Railway Company was not as successful. Following the incorporation of the Cobourg Harbour in 1830, which became the fourth largest port in south central Ontario by the mid-century (Petryshyn et al. 1976), it was felt that there was a need for a railway line running to Peterborough. After many delays and a failed attempt in 1837, the sod was turned in 1853 and construction began. The rail corridor followed the plank road that ran along Baltimore Creek, the eastern tributary of Cobourg Creek, leaving the centre of town (Spring Street and University Avenue) and continuing to the community of Harwood, along the south shore of Rice Lake (Figure 2.0). Freight and passengers were carried up the Cobourg Creek watershed, across Rice Lake and into the City of Peterborough starting in 1854 (Guillet 1948). However, Rice Lake was unrelenting, and severe winter ice reeked havoc on the rail bridge from 1855 to 1860, when the Rice Lake railway crossing was abandoned (Guillet 1948). Today, only remnants of the once hopeful railway line exist.

As with any settlement, the natural environment is changed through the use and exploitation of natural resources, and the transformation of land from forest to agriculture, or wetlands to towns and villages. Figure 2.1 depicts a timeline of the events that transformed the wetlands and forests of the Cobourg Creek watershed to the towns and villages we see today. Today the Cobourg Creek watershed is radically different from the pre-settlement days, both in appearance and in the natural resources that exist. The following chapters describe the current conditions of the Cobourg Creek watershed.

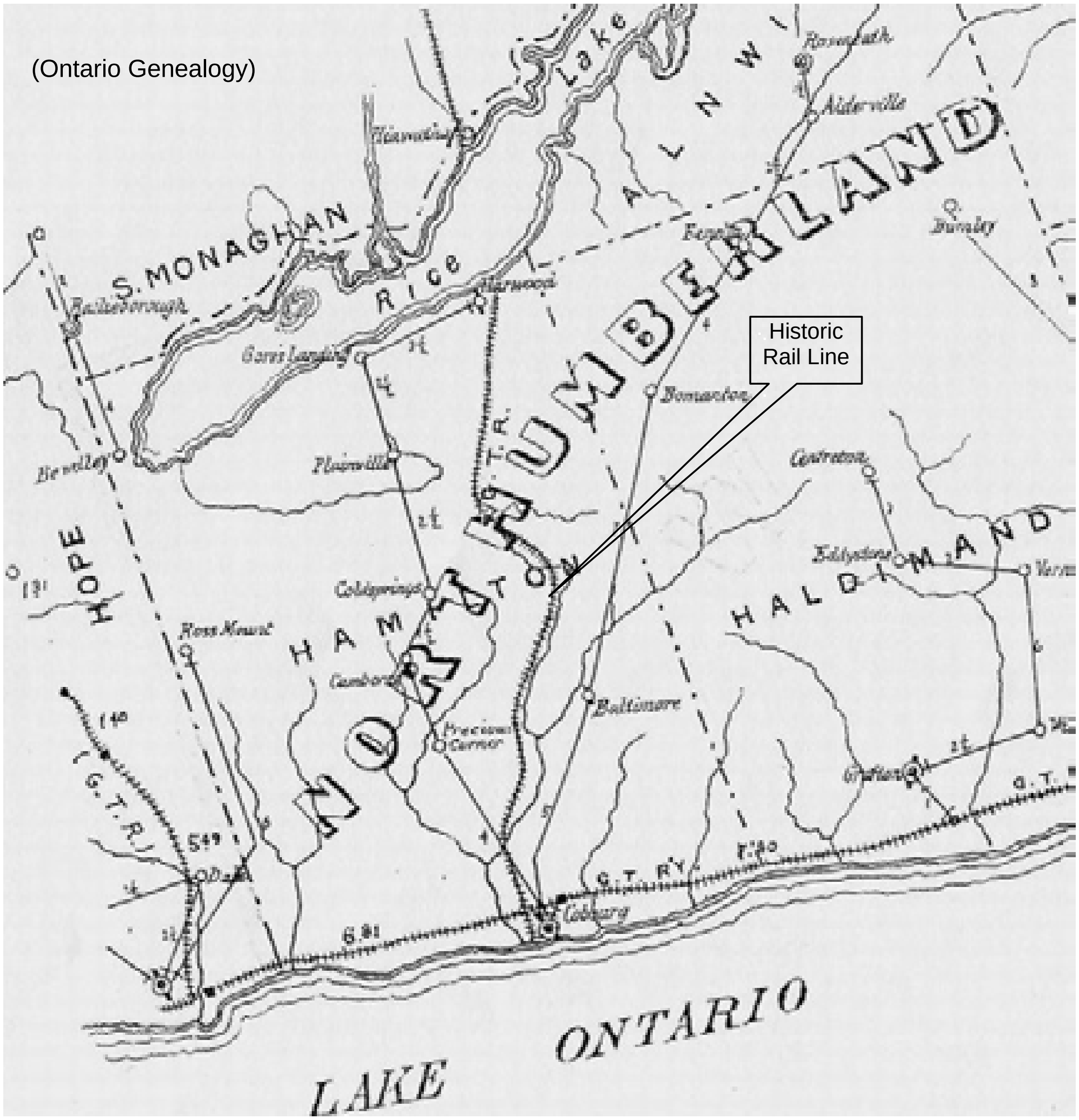


Figure 2.0: Cobourg and Peterborough Railway Company railroad

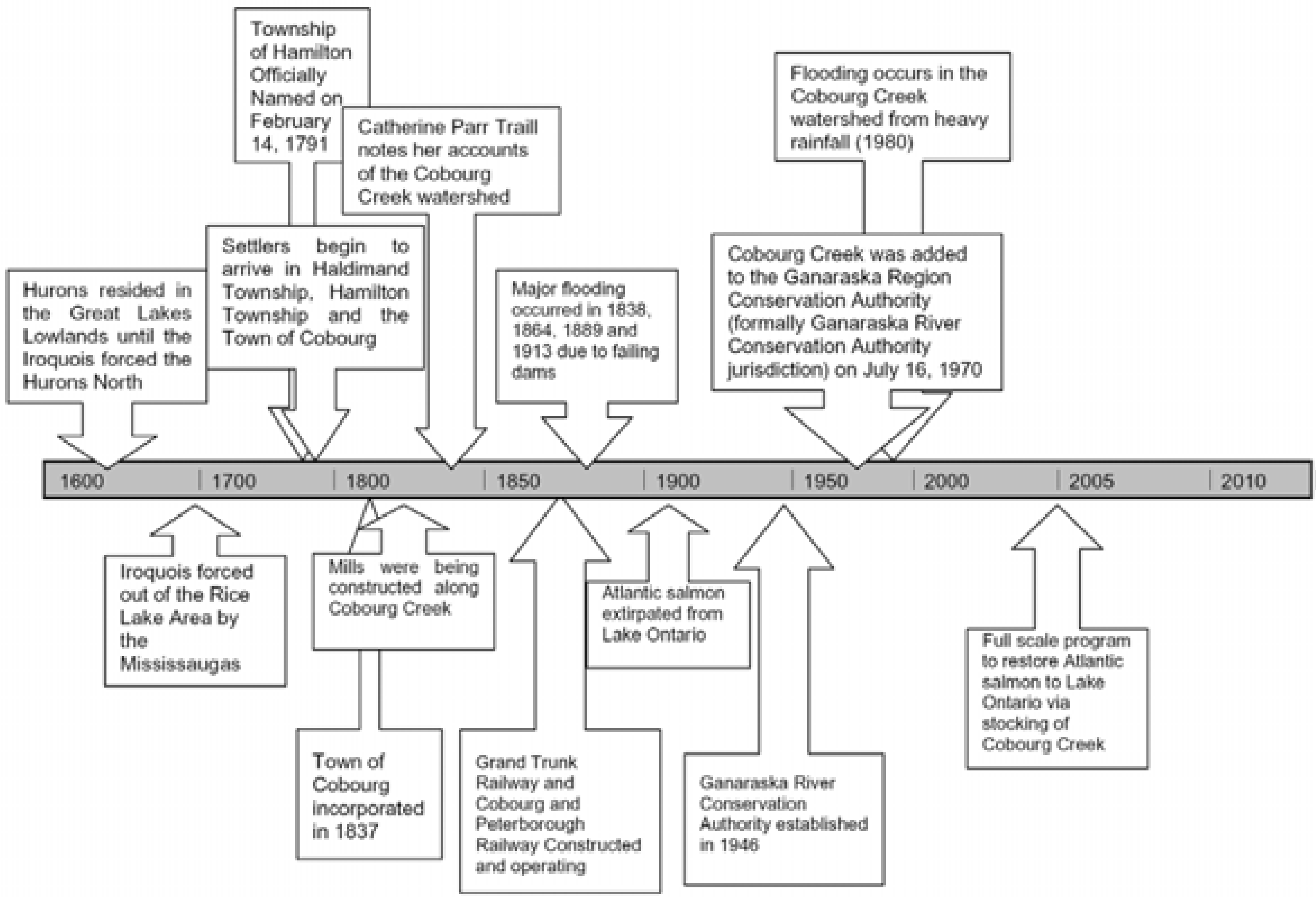


Figure 2.1: Post settlement events within Cobourg Creek watershed

Chapter 3 - Abiotic Features

3.0 REGIONAL CLIMATE

Climatic elements such as precipitation (rain and snow), evaporation and temperature have dominant effects on various components of the hydrologic cycle (Figure 3.0). Understanding these elements and patterns plays a key role in developing water budgets and understanding how natural systems will respond to changes in climate. 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 topographical relief. As such, the climate of the Cobourg Creek watershed will be discussed in a regional (Ganaraska Region Conservation Authority) and local scale.

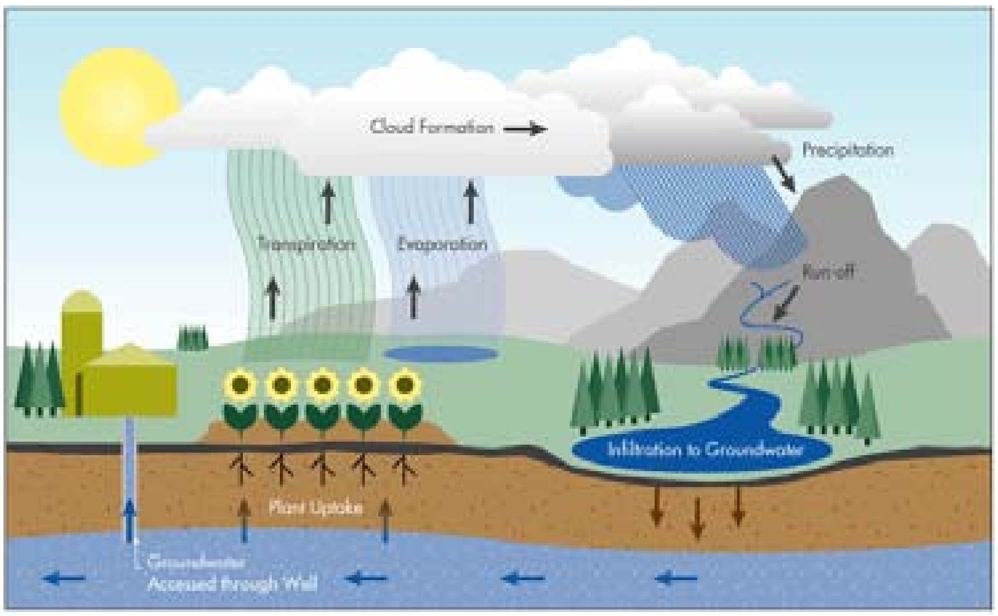


Figure 3.0: Hydrologic cycle (Pollution Probe 2004)

Topography influences local temperature and precipitation in the Cobourg Creek watershed. Average annual temperature and precipitation varies across the Ganaraska Region Conservation Authority and within the Cobourg Creek watershed due to the relatively small drainage area. The most significant factor affecting local climate is the proximity of Lake Ontario. A definite moderating effect due to lake influence is seen in the immediate vicinity of the Lake Ontario shore, 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.

According to climate data from several local Environment Canada climate stations (Figure 3.1), precipitation in the Ganaraska Region Conservation Authority shows noticeable local variation. In the lakeshore region the mean annual precipitation varies from 755 to 830 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 (Figure 3.2).

The climate in the Ganaraska Region Conservation Authority is continental, with cold winters and warm summers. Climate data from Environment Canada is available from 20 stations within and near the Ganaraska Region Conservation Authority and can be used to determine precipitation, air temperature, estimated infiltration and evapotranspiration. In addition to data from Environment Canada, the Ganaraska Region Conservation Authority operates six meteorological stations (Figure 3.1, Table 3.0) that provide hourly, 15 minute, or 10 minute interval climatic data, which can be used in a continuous hydrology model.

Table 3.0: Ganaraska Region Conservation Authority operated climate stations

Station Name	Location	Year Established	Data Interval	Type of Measurements
GRCA Main Office	2216 County Road 28, Port Hope	2002	10 min	Rainfall, Snowfall, Air Temperature, Wind Speed, Wind Direction, Humidity
Cobourg Creek at 609 William Street	609 William Street, Cobourg	2003	15 min	Rainfall, Snowfall, Air Temperature, Water Temperature, Discharge
Cobourg Pump Station	King Street pump station, Cobourg	2000	1 hr / 15 min	Rainfall, Air Temperature, Water Temperature, Discharge
Wilmot Creek	Concession Road 3, Newcastle	1999	1 hr / 15 min	Rainfall, Snowfall, Wind Speed, Water Temperature, Discharge
Forest Centre	10585 Cold Springs Camp Road, Campbellcroft	2001	1 hr / 15 min	Rainfall, Air Temperature, Wind Direction
Baltimore Creek	4494 County Road 45, Baltimore	1999	1 hr / 15 min	Rainfall, Snowfall, Air Temperature, Water Temperature, Discharge, Wind Speed, Wind Direction

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°C. The mean annual precipitation ranges from about 830 mm/yr at Port Hope in the south to about 880 mm/yr in Orono in the west. About 70 to 85% of precipitation falls as rain. January is the coldest month with mean daily temperatures in the -8°C range.

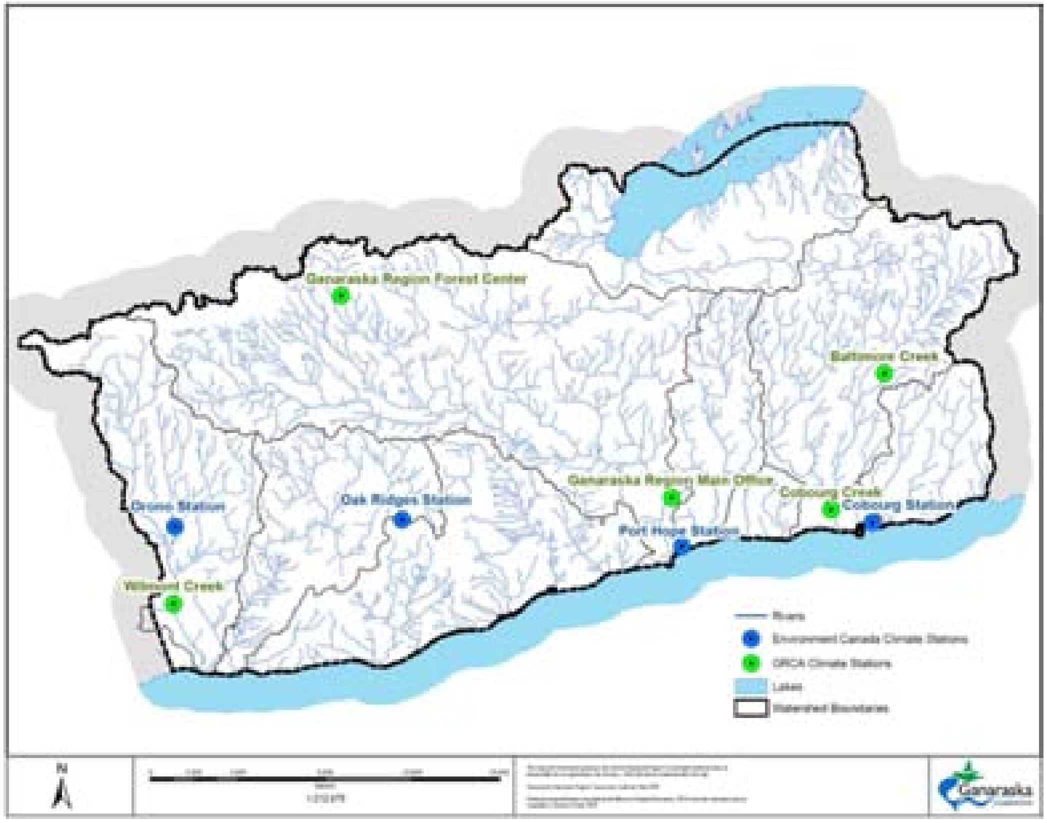


Figure 3.1: Climate stations

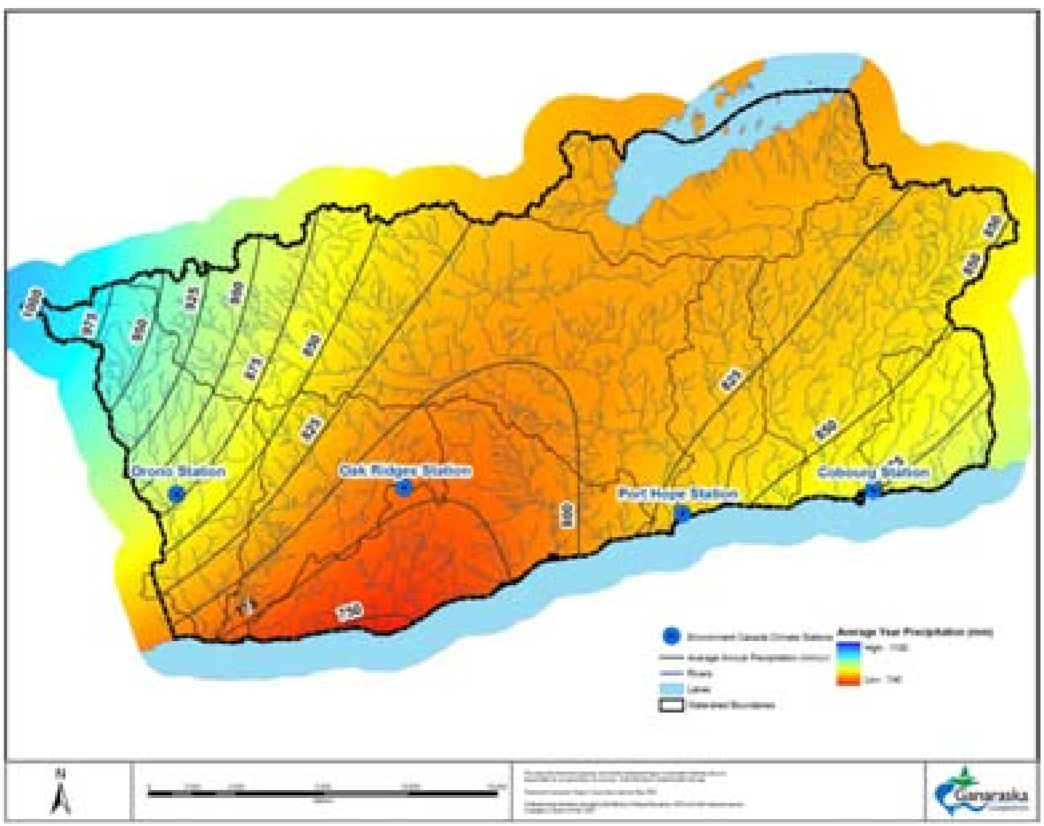


Figure 3.2: Precipitation distribution

July is the warmest month with a mean daily temperature of approximately 20°C. Precipitation patterns vary across the Ganaraska Region Conservation Authority 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. Figure 3.3 and Figure 3.4 show the annual meteorological trends based on the records of two meteorological stations within and near the Cobourg Creek watershed.

Table 3.1: Precipitation and temperature data summary (1971 to 2000) from selected weather stations

	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	--	7.1	7.3	6.8	5.9
Temperature (°C)					
Warmest Month (°C)	--	July, 19.6	July, 20.0	July, 20.1	July, 19.4
Coldest Month (°C)	--	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

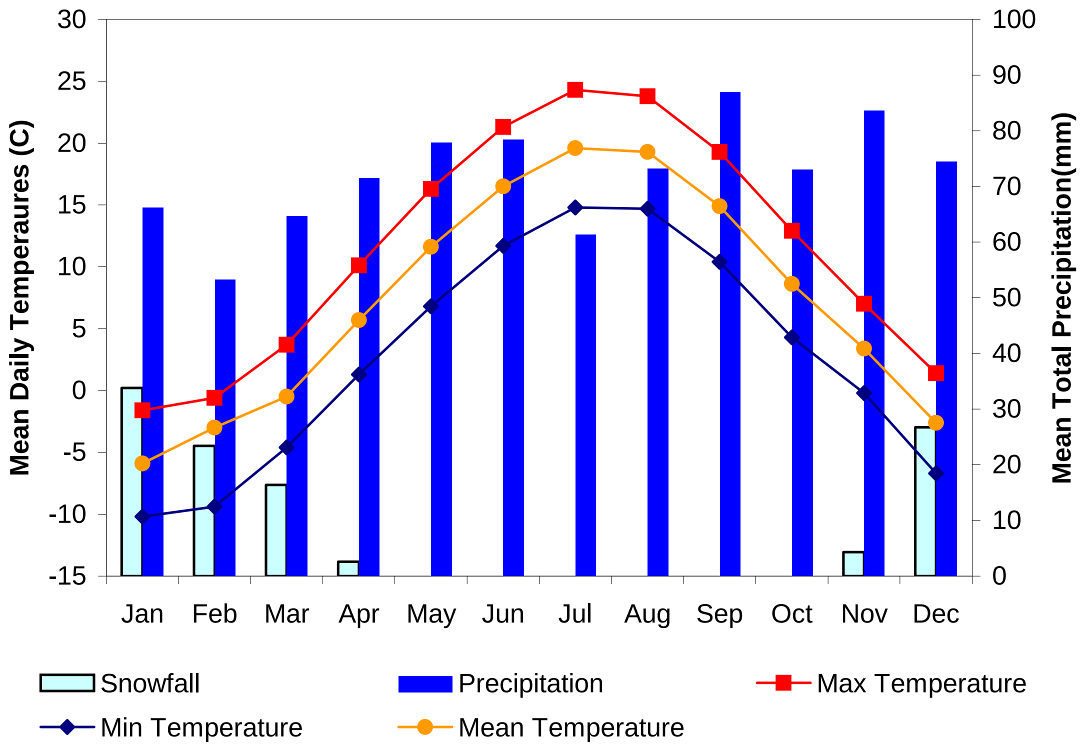


Figure 3.3: Cobourg STP meteorological station (6151689) 1970-2003

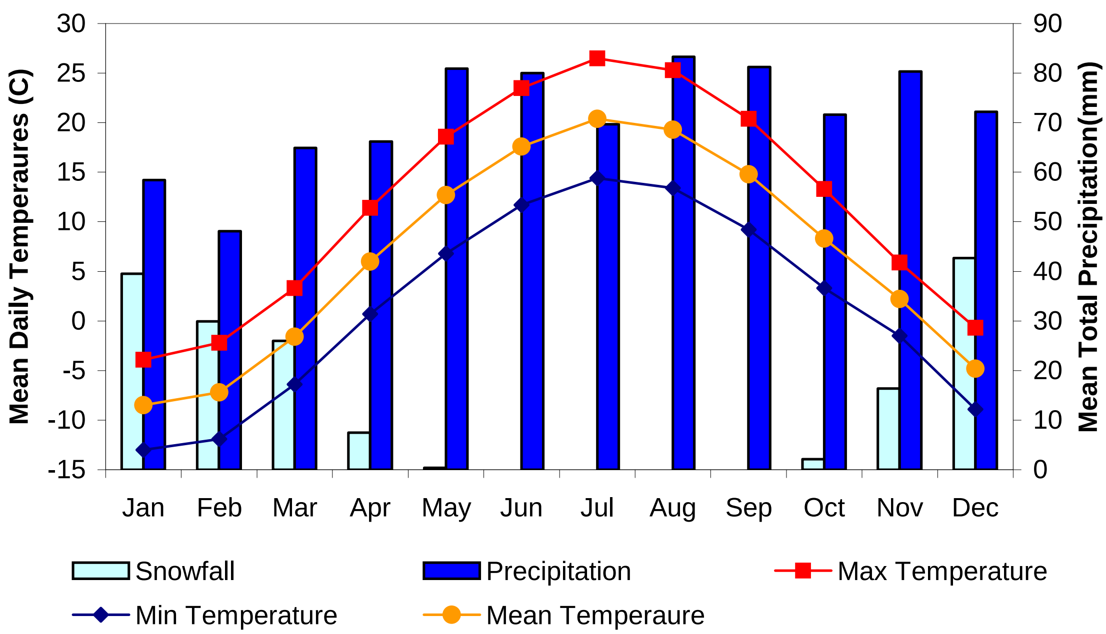


Figure 3.4: Peterborough, Trent University meteorological station (6151689) 1968-2000

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 Cobourg Creek watershed.

3.1.1 Bedrock

The bedrock beneath the Cobourg Creek watershed is Palaeozoic bedrock, which 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 within the Cobourg Creek watershed is the Lindsay Formation from the Simcoe Group, composed of coarse-grained limestone. 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 within the Cobourg 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 and Rice Lake (Figure 3.5).

3.1.2 Glacial Depositions

Geological activity during the Wisconsin Glaciation period formed the major deposits that sit on top of the limestone bedrock within the Cobourg Creek watershed. 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, referred to 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 lays on top of 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).

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 Cobourg Creek watershed. The sediments of the Oak Ridges Moraine, deposited as glacial meltwaters, traveled through a glacial lake between the Simcoe and Ontario ice lobes that covered southern Ontario (Earthfx Incorporated 2006).

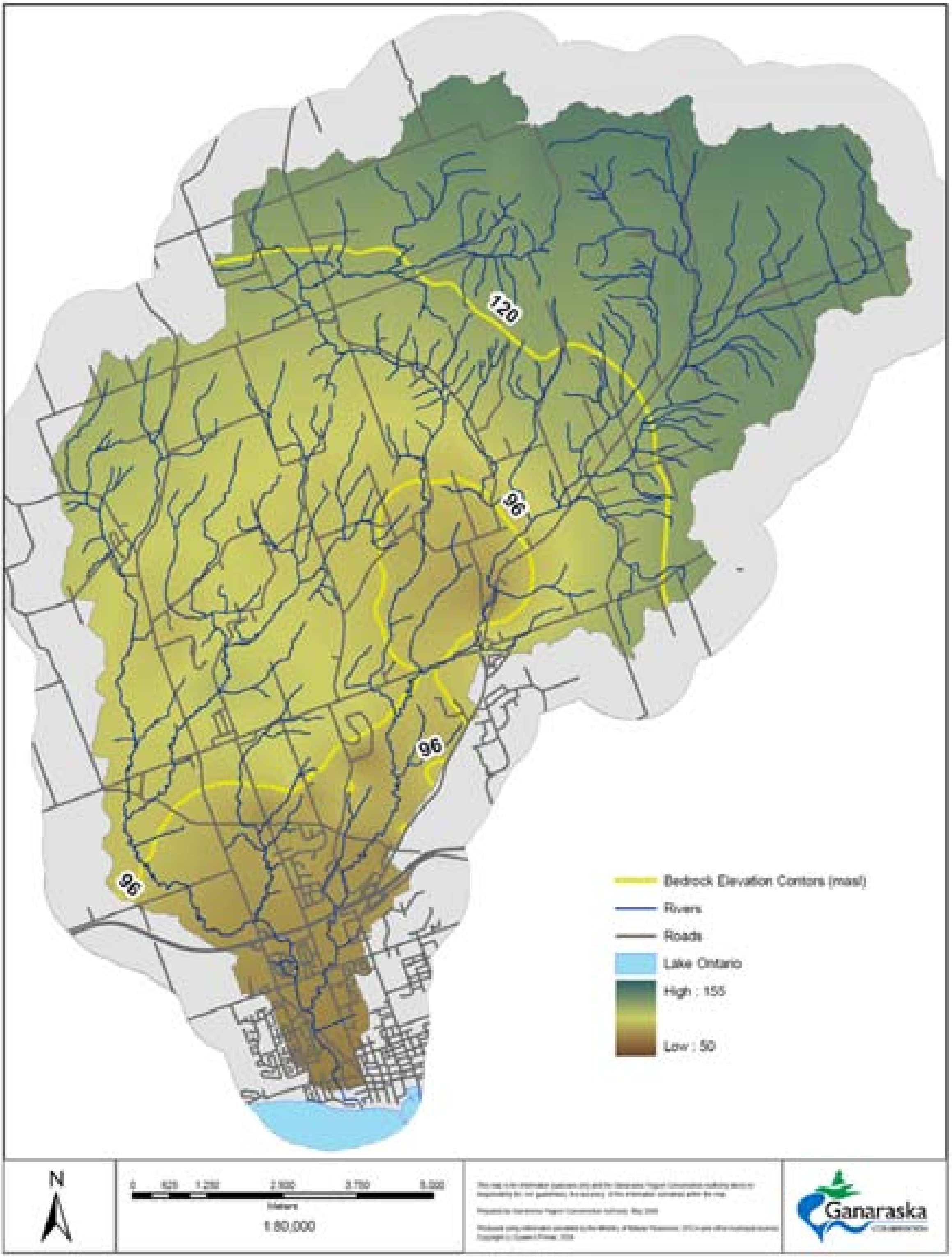


Figure 3.5: Bedrock elevation (masl)

The youngest glacial deposits within the Cobourg 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 names of the geological characteristics exist. Table 3.2 lists the names of the geological layers within the Cobourg Creek watershed.

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) Figure 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 Unweathered Bedrock	Aquifer Aquitard

A vertical cross-section of the geological characteristics of the Cobourg Creek watershed can be viewed using data from MOE water well records. Using Viewlog software, two cross-sections were generated from northwest to southeast and from east to west above Dale Road (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. This variability is acknowledged through the renaming of geological units to localized names. In this document the localized names referenced from many studies completed in the area will be used as shown in Figure 3.7 and Figure 3.8.

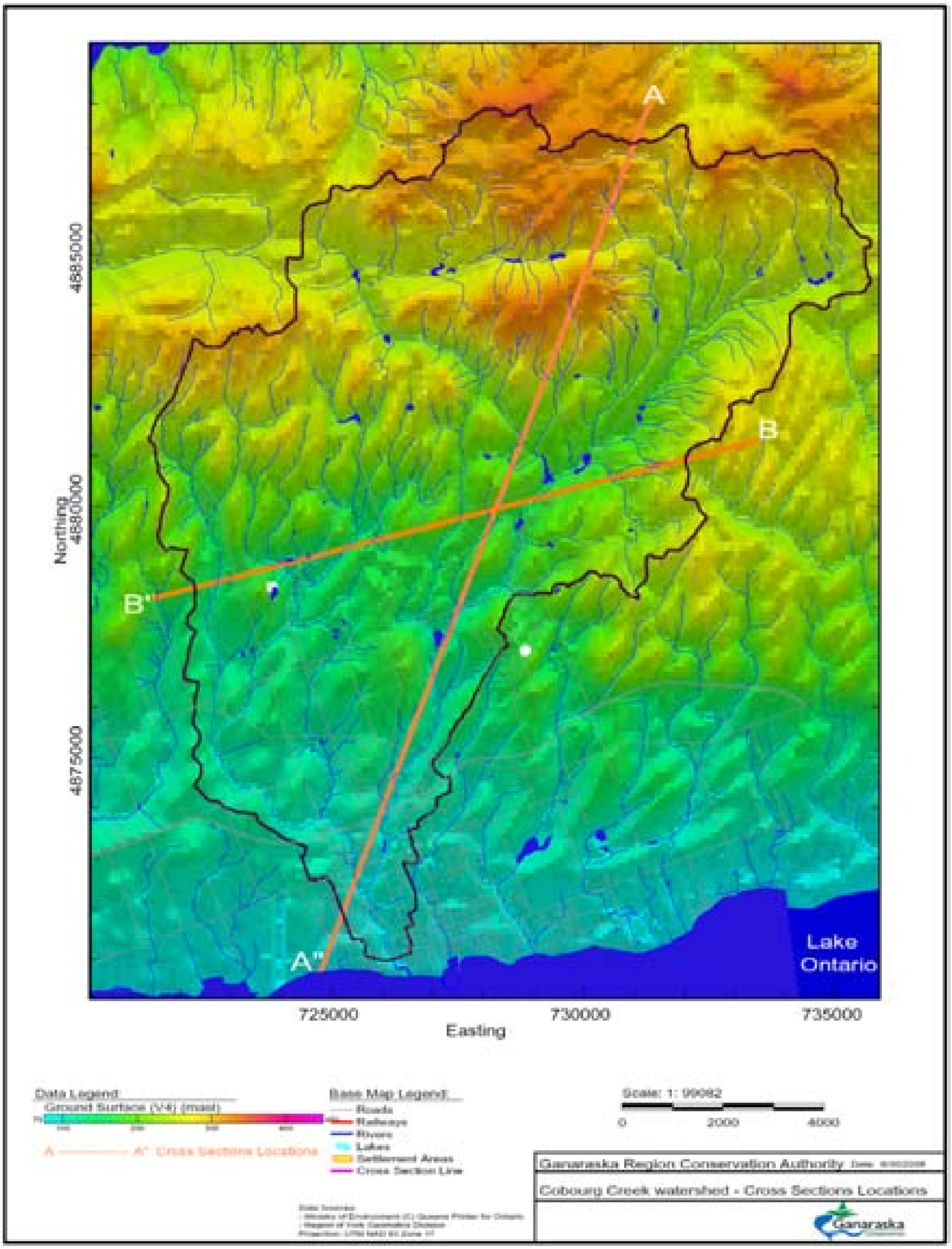


Figure 3.6: Cobourg Creek watershed cross-section locations

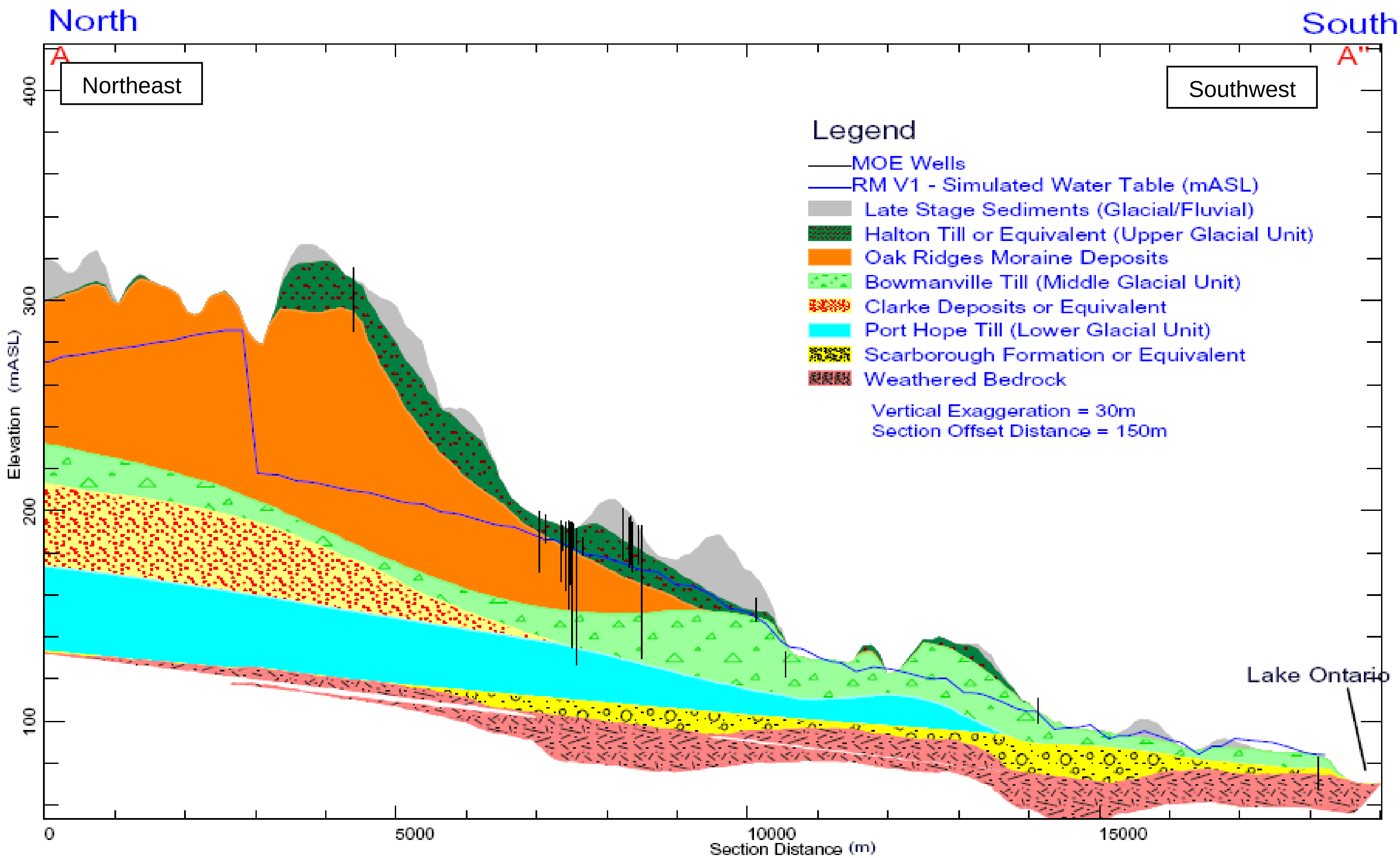


Figure 3.7: Cobourg Creek watershed cross-section A – A'

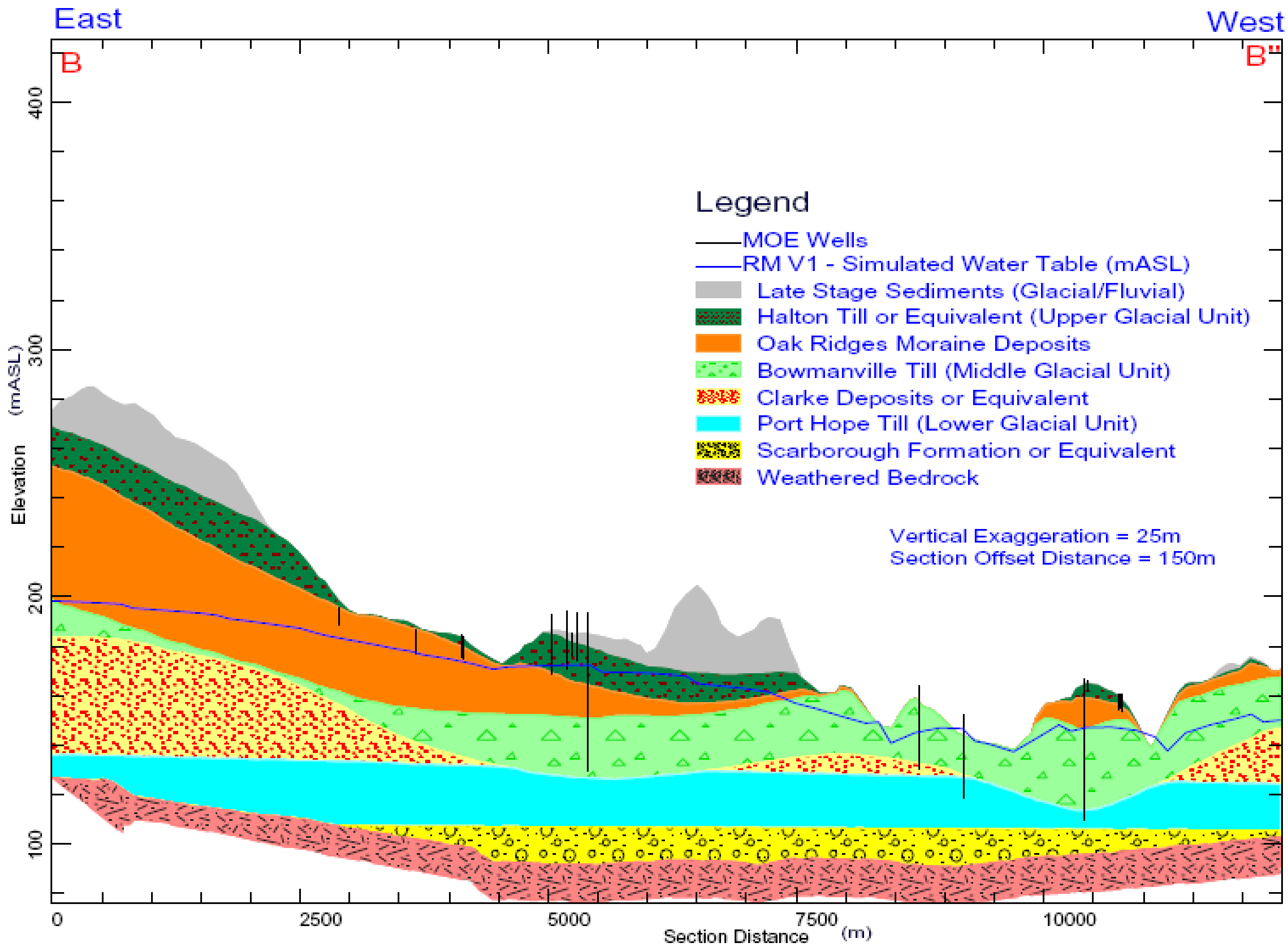


Figure 3.8: Cobourg Creek watershed cross-section B – B'

Scarborough Formation or Equivalent

The Scarborough Formation or its localized equivalent sits on top of the bedrock. The Scarborough Formation was formed by a deltaic deposit at the mouth of a very large historic river (Eyles 2002), and 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 within this formation, deep overburden aquifers are found in some localized areas.

Geologists feel that the regionally-known Scarborough Formation does not extend into the Cobourg Creek watershed; however an equivalent formation resembling the Scarborough Formation does sit 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 eastern area of the watershed. This geological unit, equivalent to the Scarborough Formation, and where it exists, forms a lower 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, which contains less clay and more silt than the Sunnybrook Drift. Figure 3.7 shows that the Port Hope Till decreases in thickness toward the south end of the Cobourg 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 sit, and clay (Earthfx Incorporated 2006). This geological unit was deposited by glacial meltwaters entering a deep, ice-dammed ancestral Lake Ontario (Earthfx Incorporated 2006). 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 and in some areas in the west end of the Cobourg Creek watershed.

Bowmanville Till (Middle Glacial Unit)
The Bowmanville Till is a distinct, dense glacial deposit of fine sediments (Jagger Hims Limited 2007) left behind at the farther reach of the Laurentide Ice Sheet. 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 within the Bowmanville Till, this geological unit acts as an aquitard. Brookfield et al. (1982) correlated the Newmarket Till to a 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. These different sediments function either as regional aquifers or aquitards. The Oak Ridges Moraine contains coarse surficial sediments and unique topography, allowing water to infiltrate through the coarse sediments.

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.

Geologists feel that the regionally-known Halton Till does not extend into the Cobourg Creek watershed, however an equivalent formation that resembles the Halton Till does exist. Brookfield et al. (1982) named this localized unit Bouchette Till, which contains less clay than the Halton Till. As shown in Figure 3.7 and Figure 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 Bouchette 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 within lower elevations and floodplains. Within Cobourg Creek the late stage deposits include gravelly beach deposits formed along the former shores of Lake Iroquois (Jagger Hims Limited 2007).

3.1.3 Topography

Topography refers to the shape, form and physical features of the Earth's surface (Eyles 2002). Within the Cobourg Creek watershed the land generally slopes from a northeast to a southwest direction. The maximum topographic elevation is approximately 330 metres above sea level (masl) and where Cobourg Creek empties into Lake Ontario the elevation is approximately 75 masl. Topography is best understood when observed in the field. Figure 3.9 displays the topographic features of the Cobourg Creek watershed along with differing elevations. The 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 in the northern part of the Cobourg Creek watershed. Topographic features are important in promoting groundwater recharge and minimizing surface water runoff.

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 Cobourg Creek watershed from north to south are the Oak Ridges Moraine, the South Slope and the Lake Iroquois Plain (Figure 3.10).

Oak Ridges Moraine

The Oak Ridges Moraine is located in the north end of the watershed, and it occupies 51 km^2 or 41% of the Cobourg Creek watershed. The Oak Ridges Moraine extends regionally over 160 kilometres (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 acts as a recharge area for Cobourg 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 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.

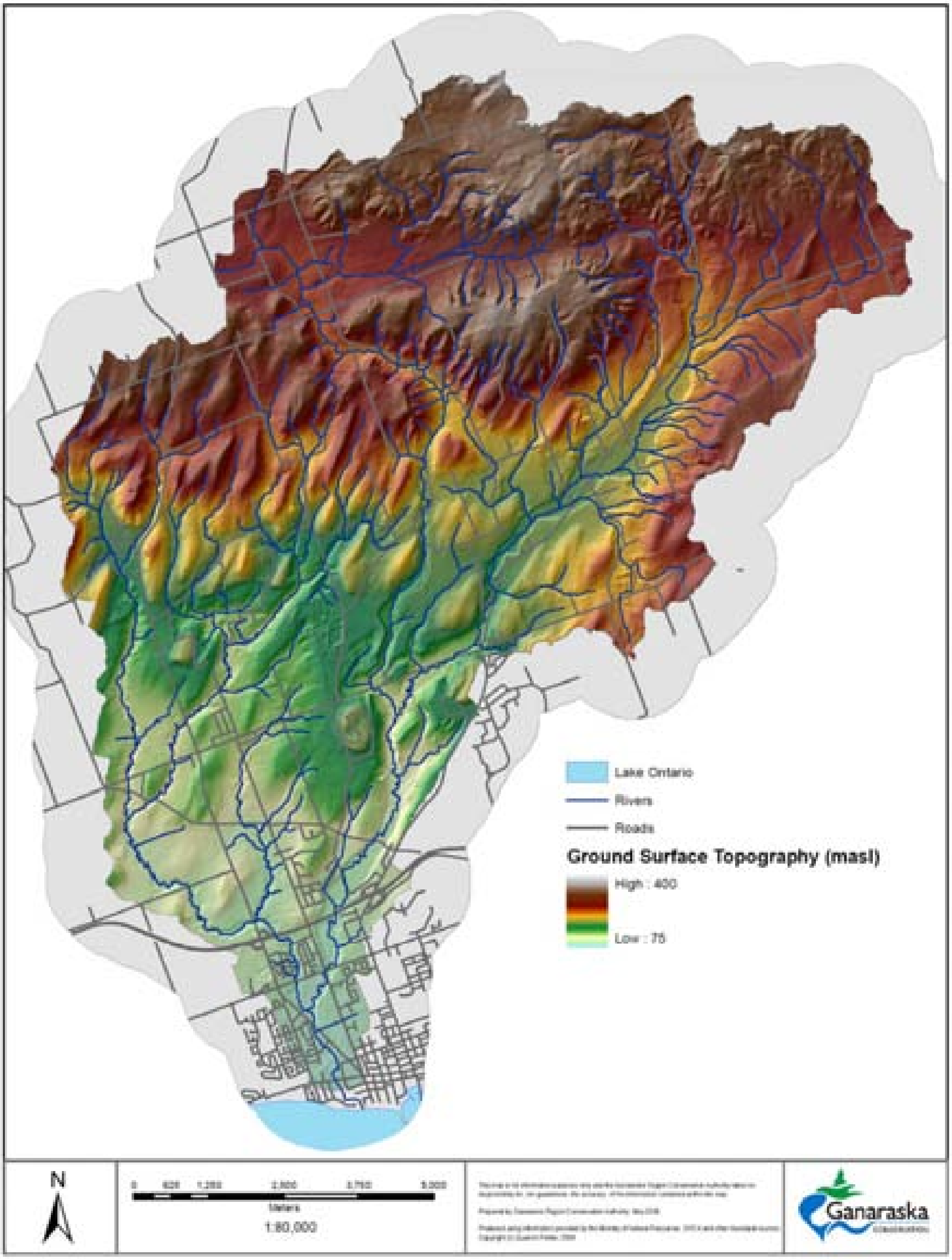


Figure 3.9: Ground surface topography

South Slope

The South Slope lies between the Oak Ridges Moraine and the Iroquois Plain and it occupies 55 km^2 or 45% of the watershed area. The South Slope is covered by drumlins that point to the southwest (Chapmen and Putnam 1966), causing tributaries of Cobourg Creek to flow diagonally down the slope of the drumlins. Within Northumberland County the soils of the South Slope are calcareous and are comprised of fine sand and silt among other soils, which have proven to contribute to the productiveness of agricultural production (Chapmen and Putnam 1966). 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.

Lake Iroquois Plain

The Lake Iroquois Plain is located south of the South Slope and occupies 17 km^2 or 14% 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 (Chapmen and Putnam 1966). The Lake Iroquois Plain contains many large drumlins, which would have been islands within Lake Iroquois. Today these former islands look like terraces, formed by historic wave action (Chapmen and Putnam 1966).

The Lake Iroquois Plain can be divided into two distinctive elevation areas resulting from the retreat of the glacial lake from north to south. At lower elevations, the Iroquois Plain has an irregular, low surface relief and includes the Lake Iroquois shore and near-shore deposits. In the shoreline area of the former Lake Iroquois, sand and gravel were deposited in beaches, bars and spits. The deposits grade into massive and laminated silts and clays to the south that defines the lower lake plain area (Ganaraska Region Conservation Authority 2007). The Lake Iroquois shoreline is well defined by cliffs and beach material, but in certain areas its position would be inferred from the presence of lacustrine materials and elevation (Ganaraska Region Conservation Authority 2007). This area defines the elevated Lake Iroquois Plain.

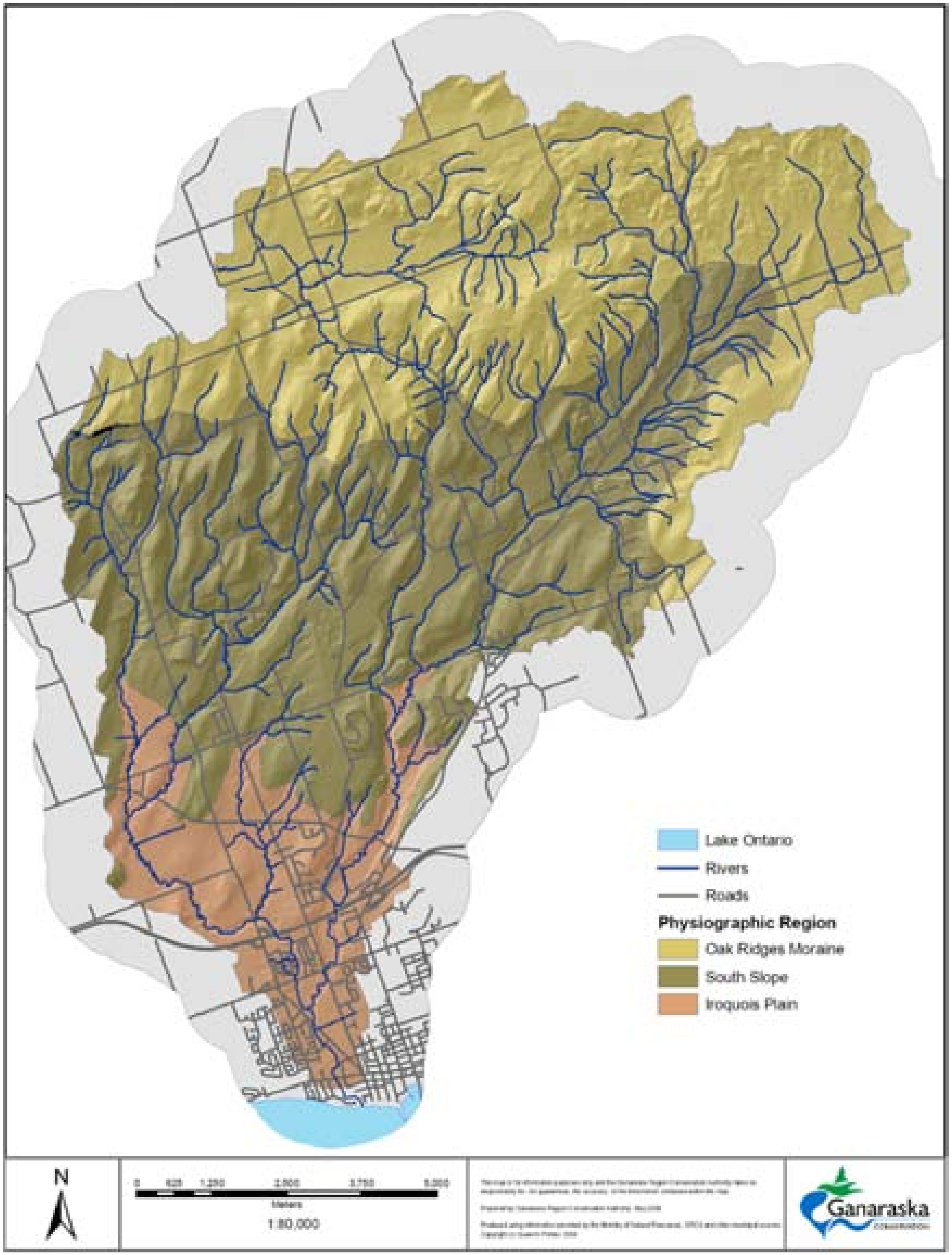


Figure 3.10: Physiographic regions

3.1.5 Surficial Geology

Surficial geology refers to the upper layer or exposed layer of geological deposits. Within the Cobourg Creek watershed there are eight surficial geological units identified by the Ontario Geological Survey and the Geological Survey of Canada (Table 3.3). The majority of these deposits on the surface of the land were created during the Pleistocene Epoch when massive ice formations and the resulting meltwaters shaped the surface that is seen today in the Cobourg Creek watershed.

Table 3.3: Surficial Geology of the Cobourg Creek watershed

Surficial Geology Unit	km^2	hectare	Percent of watershed
Glacial Lake Deposits: sand and gravel	2.2	224.1	1.3
Glacial Lake Deposits: silt and clay	16.8	1684.0	11.7
Glacial Lake Deposits: silt and sand	27.5	2749.2	19.1
Glacial River Deposits: sand and gravel	5.4	536.9	3.7
Moraine Deposits	18.1	1808.9	12.6
Bowmanville (Newmarket) Till	55.7	5568.1	38.7
River Deposits: Early postglacial deposits	1.6	156.2	1.1
River Deposits: Late Stage (Modern) Deposits	17.1	1709.1	11.8

Figure 3.11 depicts the surficial geology of the Cobourg 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 Cobourg Creek start at the margins of the Bowmanville Till through surficial runoff. Glacial lake deposits are found throughout the Cobourg 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 within the current and postglacial river valleys and beds.

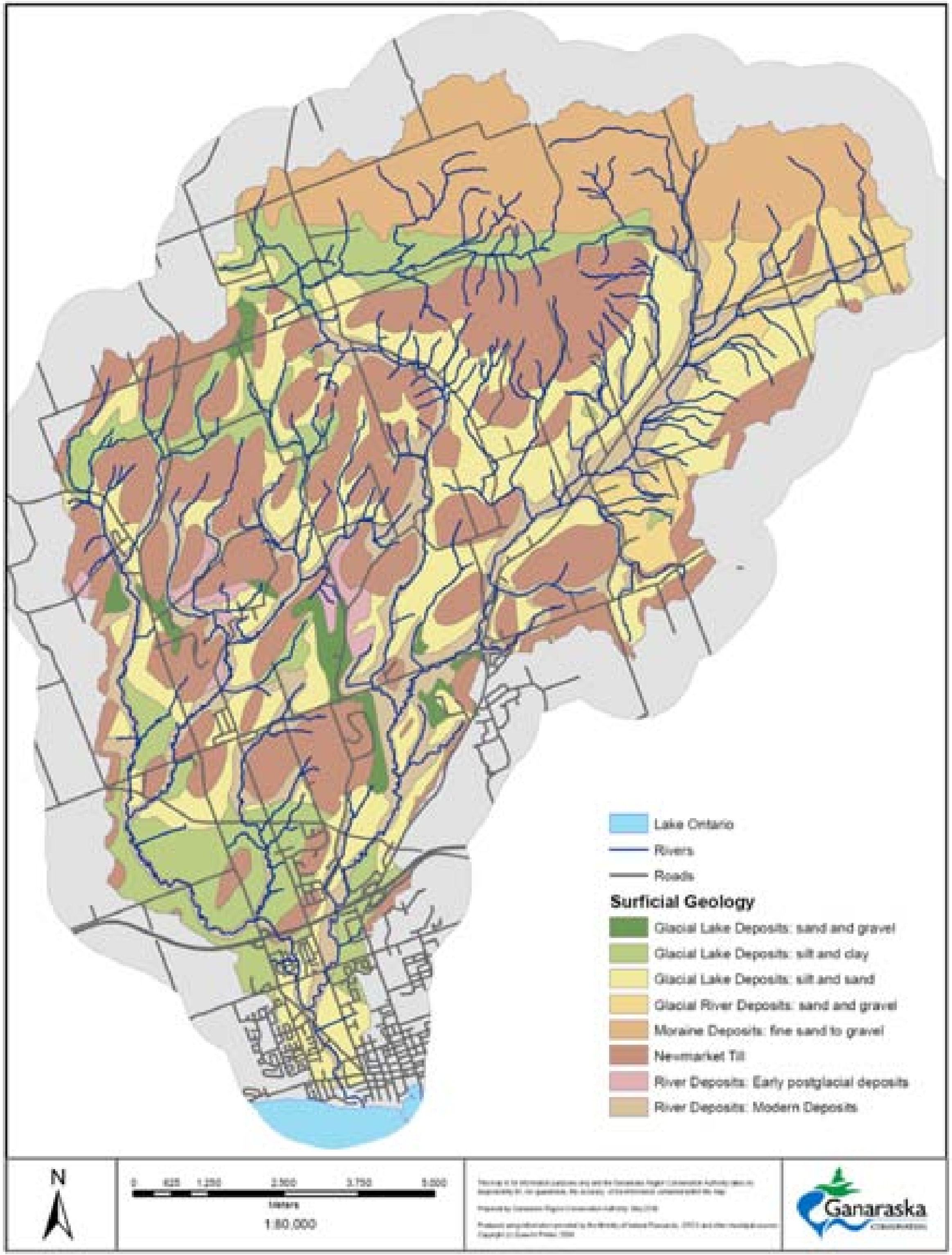


Figure 3.11: Surficial geology

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 within the Cobourg 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 Moraine area 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).

On the South Slope the soils were formed in about half a metre of sand deposits overlaying the till plain, and because of this shallower depth are not as thoroughly drained as the soils of Oak Ridges Moraine. Consequently fewer nutrients were drained away during the formative periods 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.

Little of the original till material of the Lake Iroquois plain was left unchanged by the glacial melt water. Soils are therefore different from those in the two northern physiographic regions. 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 calculation, soils may be classified into four main groups (A, B, C, and D) and three interpolated groups (AB, BC, and CD). These classifications depict how soils move water. Table 3.4 describes the features of the Hydrologic Soils Group. Within the Cobourg Creek watershed, four groups are present: A, AB, B and D. Figure 3.13 shows where these different hydrologic soil types are within the Cobourg Creek watershed.

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 dictate land uses within that area. Within the Oak Ridges Moraine, the dominant soil series is the Pontypool series. This soil series is low in fertility and generally does not suit agricultural land use. Agricultural practices that do exist within these regions of low fertile soils supplement their farming income with forestry products such as timber, firewood and maple syrup. The recommended use by Richardson (1944) for areas with this soil series was reforestation, which is the predominant land conversion on the Oak Ridges Moraine within the Ganaraska Region Conservation Authority and Northumberland County.

Within the South Slope and Lake Iroquois Plain, sandy loam soils are typical. As a result, agricultural practices within these two physiographic regions prevail. 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 within the Cobourg 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. Agricultural activities within the South Slope and Lake 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 Lake Iroquois Shoreline are favourable for agricultural practices over the Oak Ridges Moraine. Superior soils within 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 Cobourg Creek watershed, defined by local soil types and compositions.

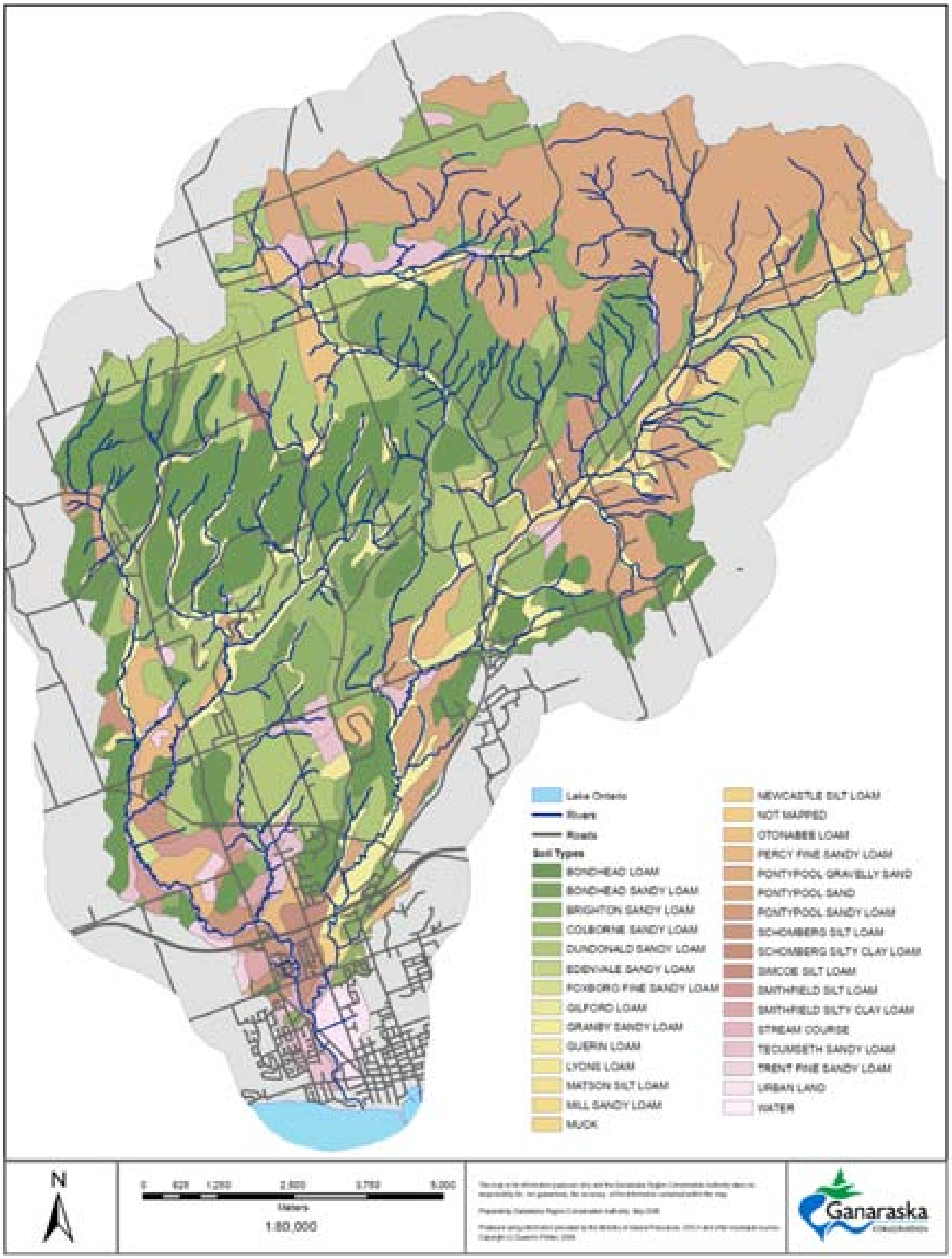


Figure 3.12: Soils

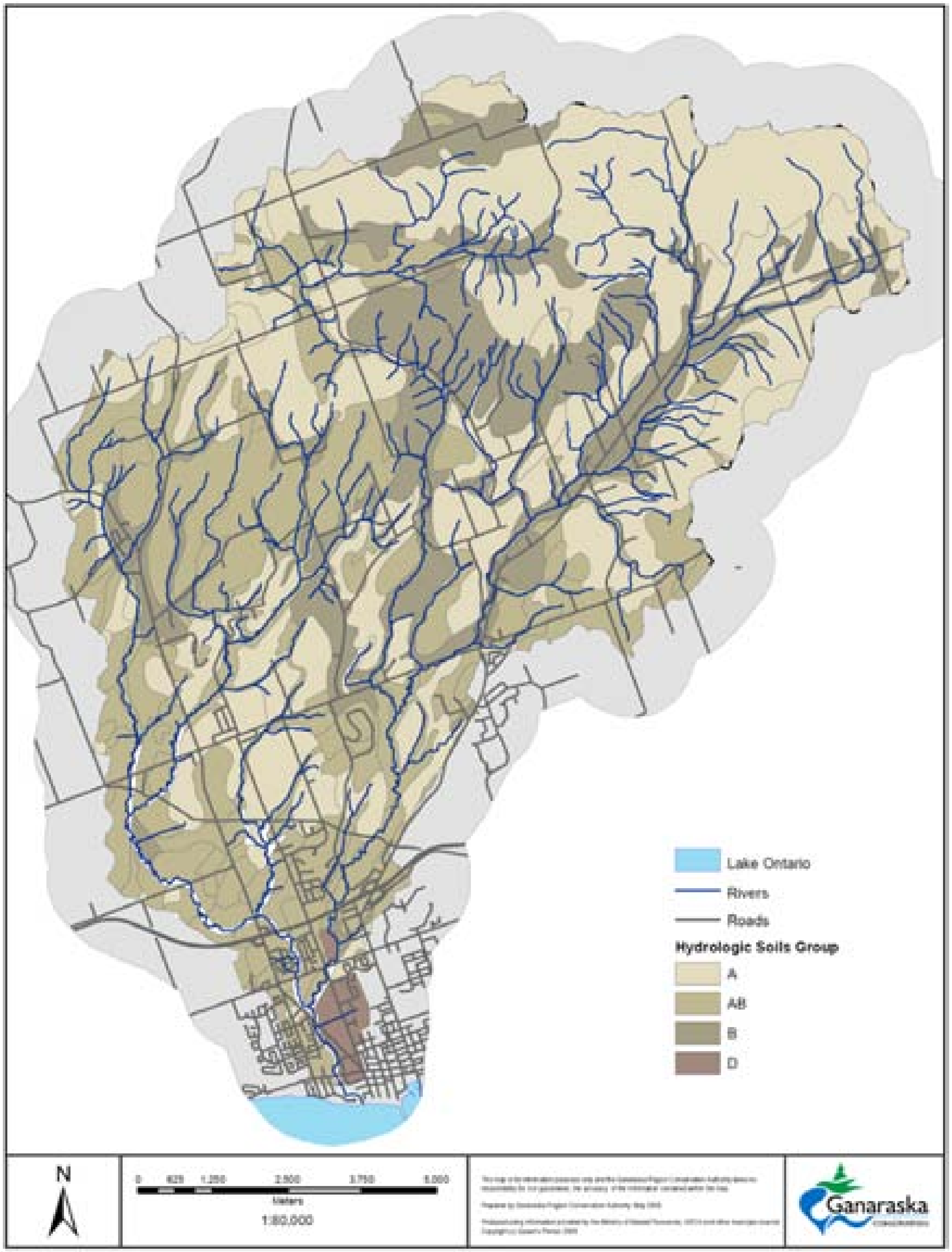


Figure 3.13: Hydrologic soils group

3.2 GROUNDWATER

The movement and location of groundwater within the subsurface is controlled by land cover, sediment types and topography. Porous surficial materials generally comprise groundwater recharge areas within the northern part of the watershed. Rainfall and snowmelt percolates 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 Cobourg 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

Distribution, thickness and hydrologic characteristics of geologic units ultimately control the presence or absence of aquifers. Grouped as hydrostratigraphic units, geologic units are categorized by their relative capacity to store and transmit different amounts of water. The physiographic landforms found within the Cobourg Creek watershed provide the framework for interpreting hydrostratigraphic conditions therein. As outlined by Widaatalla and Peacock (2007), the following geological units are defined with their respective hydrostratigraphic units.

- Glacial Lake Deposits (Lake Iroquois deposits) comprised of silt, sand and gravel, that form a discontinuous, unconfined, shallow aquifer at surface
- Glacial till aquitard comprised of Halton Till (Upper Glacial Unit)
- Oak Ridges Moraine sediments consisting of ice contact and outwash deposits that form an aquifer/aquitard complex
- Glacial till leaky aquitard comprised of Bowmanville Till (equivalent to Newmarket Till)
- A complex and relatively thick-layered unit of Lower Sediments comprised of sand and gravel aquifer (Clarke Deposits), and aquitard of silt till and clayey silt (Port Hope Till) and a deep coarse sand and gravel aquifer (equivalent to Scarborough Formation)
- Fractured limestone of the Simcoe Group that forms the bedrock aquifer

The depth to the water table in the northern area of the watershed varies and is generally deep beneath the Oak Ridges Moraine top formations. Aquifer thickness and the depth to the water table can vary depending on location, though the water table is generally found at depths of less than five metres below ground surface in the southern portion of the watershed (Morrison Environmental Limited 2004). The overburden deposits that constitute local shallow aquifers range from alluvial deposits along stream channels to glaciofluvial and glaciolacustrine deposits found throughout the watershed.

Figure 3.14 shows the regional model (Earthfx Incorporated 2006) of the simulated groundwater level elevation of the first aquifer encountered in different areas of the Cobourg Creek watershed. The figure also shows the regional groundwater-level contour elevations of shallow aquifers in the watershed, calculated from the Ministry of the Environment water well database. This figure can be used to infer the groundwater flow lines and flow directions within the watershed. Regional groundwater flow directions are generally from north and northeast to south and southwest areas of the watershed. Groundwater contour lines in Figure 3.14 support an interpretation of a groundwater divide in the northern part of the watershed.

Due to the presence of this divide, it is expected that, in the northern part of the watershed, groundwater flows north and northwest into the Rice Lake basin. Figure 3.14 also supports an interpretation that there is a potential for groundwater to flow outside of the watershed, particularly to Gage Creek watershed west of Cobourg Creek. This theory needs to be verified with focused studies and analysis in the boundary area of the two watersheds. The ongoing groundwater study and modeling project for the Township of Hamilton municipal well fields is expected to provide detailed information on the groundwater system within the Cobourg Creek watershed as well as in neighbouring watersheds.

In the central part of the Cobourg Creek watershed the rugged topography combined with relatively rapid changes in geology, particularly in deeper geologic units, resulted in fast-changing hydraulic gradients over relatively short distances. These settings provided potential conditions for flowing artesian wells in the valleys, and wells with deeper static levels on higher ground. This is particularly evident in the areas of Baltimore, Coldsprings and Camborne where many privately-owned flowing artesian wells and springs are found in these communities, as shown in Figure 3.15. In the other parts of the watershed, data suggests a mix of upward gradients (discharge gradients) occur near tributaries, and predominantly downward gradients (recharge gradients) occur away from tributaries of Cobourg Creek. This is mainly a function of the ground surface topography.

Cross-sections A – A’ and B – B’ (Figures 3.7 and Figure 3.8) show the locations of many deep overburden wells in the central watershed area. These cross-sections were generated from the updated Ganaraska Region Conservation Authority water well and surfaces data by using Viewlog software. The cross-sections show that many of the deep overburden wells were screened in the bottom unit of the lower sediments and they are most likely artesian wells. This is evident from alternating till units in the two cross-sections. Halton, Bowmanville and Port Hope till units have a relatively regional coverage in the area. Given the sharp topographic changes in the watershed, aquifers bounded by these units are most likely under artesian condition.

The majority of wells in the watershed are private wells that provide individual groundwater supplies. Although most wells in the Cobourg Creek watershed are domestic wells, the population served and the volume pumped is small in relation to the size of the watershed (Morrison Environmental Limited 2004). Two municipal well fields are located in the Cobourg Creek watershed and service Camborne and Creighton Heights communities in the Township of Hamilton. Figure 3.15 shows the locations of private (overburden and bedrock) and flowing wells within the Cobourg Creek watershed.

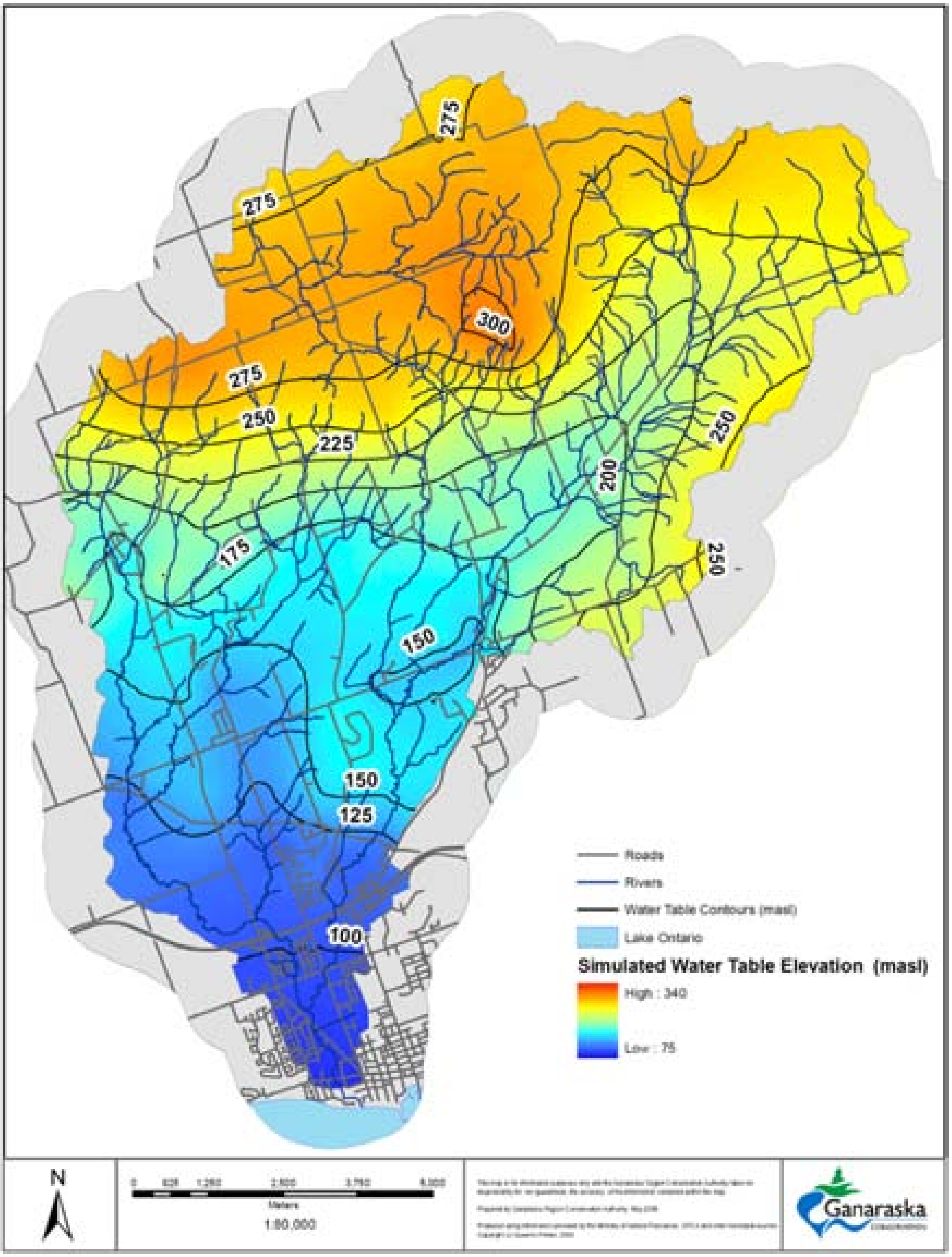


Figure 3.14: Simulated water table

3.2.2 Groundwater and Surface Water Interactions

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

Groundwater Recharge and Discharge

Recharge is the process by which groundwater is replenished, and 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 depends on surficial soil composition, land use and topography (Widaatalla and Peacock 2007). Discharge is the opposite of recharge and is a process in which groundwater is normally found in an upward gradient leaving the system through porous materials as springs, or flows into surface water features such as streams, rivers, lakes and wetlands.

The northern uplands of the Oak Ridges Moraine within the watershed represent the highest recharge areas. There are many factors affecting the distribution groundwater recharge rates in the watershed:

- The presence of the coarse sand and gravel sediments at the surface coupled with the presence of few areas with hummocky topography in the north (Figure 3.16)
- Distribution of thick overburden mainly in the northern and eastern parts of the watershed also contributes to higher recharge rates. Figure 3.17 shows the overburden thickness with thick sediment areas mainly in the northern and north-eastern parts of the watershed.
- The sharp topographic changes that created steep slopes favouring runoff in the central part of the watershed
- Upward groundwater flow directions in the central part of the watershed where little (or no) recharge is expected to occur

The spatial distribution of applied recharge to the Oak Ridges Moraine regional groundwater model within the Cobourg Creek watershed is shown in Figure 3.18. This figure has a grid of 240 m x 240 m and is based on a regional groundwater model. High recharge rates were shown to be in the Oak Ridges Moraine (360 mm/year), and moderate recharge mainly in the central watershed area. The lowest recharge rates (60 mm/year) are mainly associated with steep slope and the till-covered areas in the southern part of the watershed (Earthfx Incorporated 2006). Most of the low-recharge rate areas, shown in Figure 3.18, are within the

Lake Iroquois Plain. These areas are generally characterized by the presence of till at the surface, and glacial silt and clay in the south.

Figure 3.19 shows the potential discharge areas within the Cobourg Creek watershed. This figure was created by comparing the digital elevation model (DEM) and the groundwater level from wells tapping into the first aquifer encountered in different parts of the watershed. The size of the grid for Figure 3.19 is 240 m x 240 m, and it is based on the regional groundwater model. These potential groundwater discharge locations are mainly found in the deep valley areas of the watershed. These discharge areas provide baseflow to Cobourg Creek that is critical in maintaining stream flows during times where precipitation is minimal or does not occur. Section 3.4 “Baseflow” describes the baseflow of Cobourg Creek.

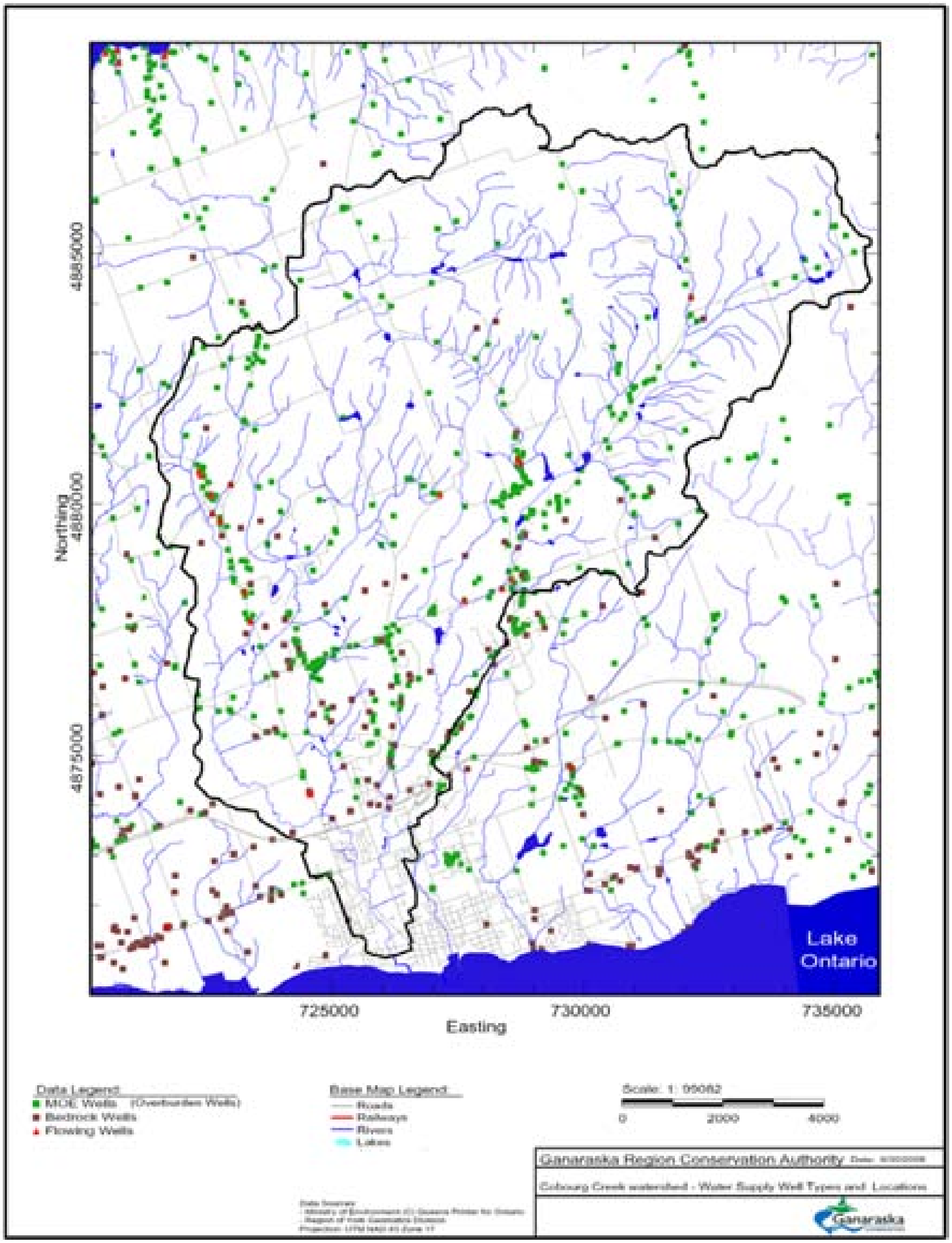


Figure 3.15: Water well types

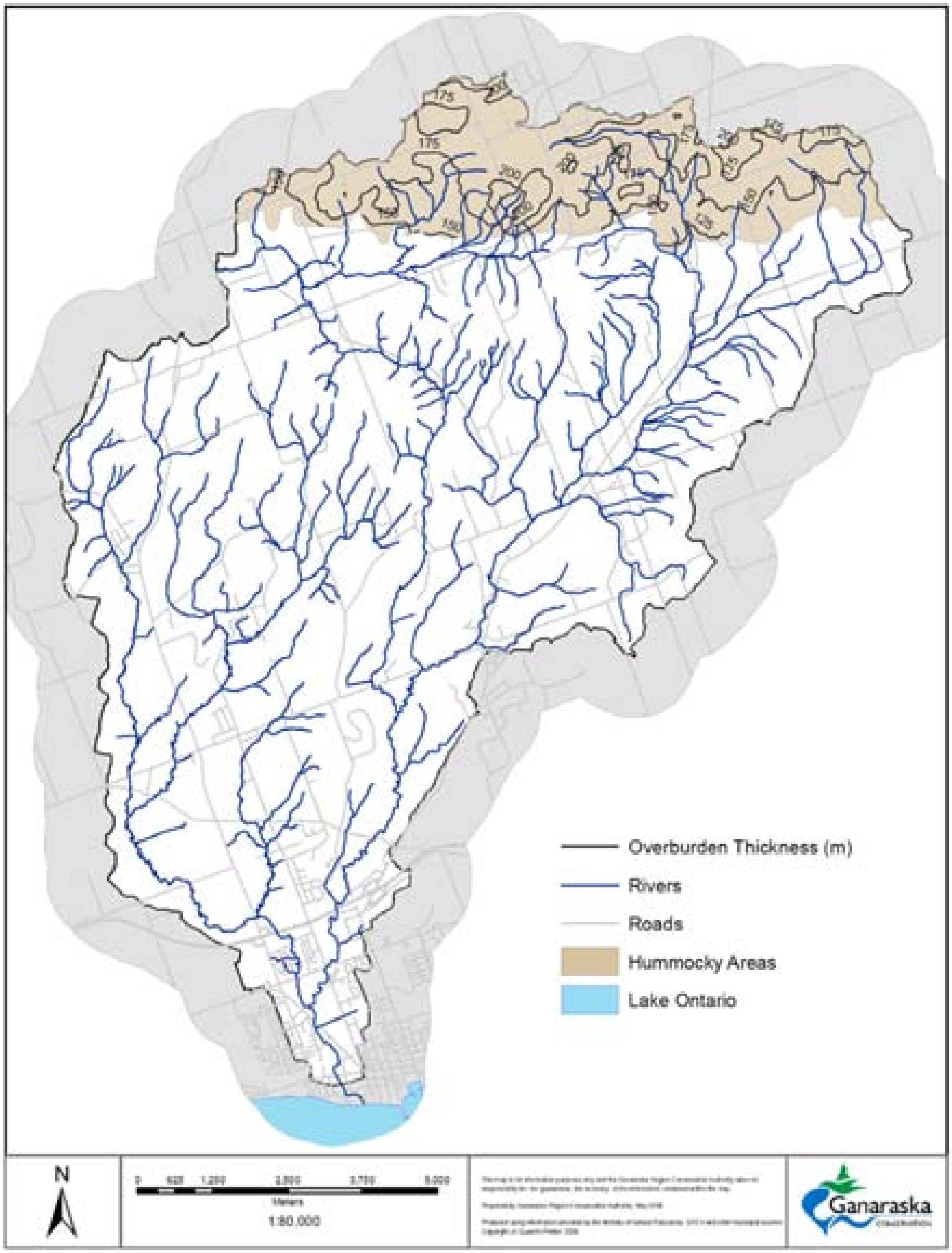


Figure 3.16: Hummocky areas

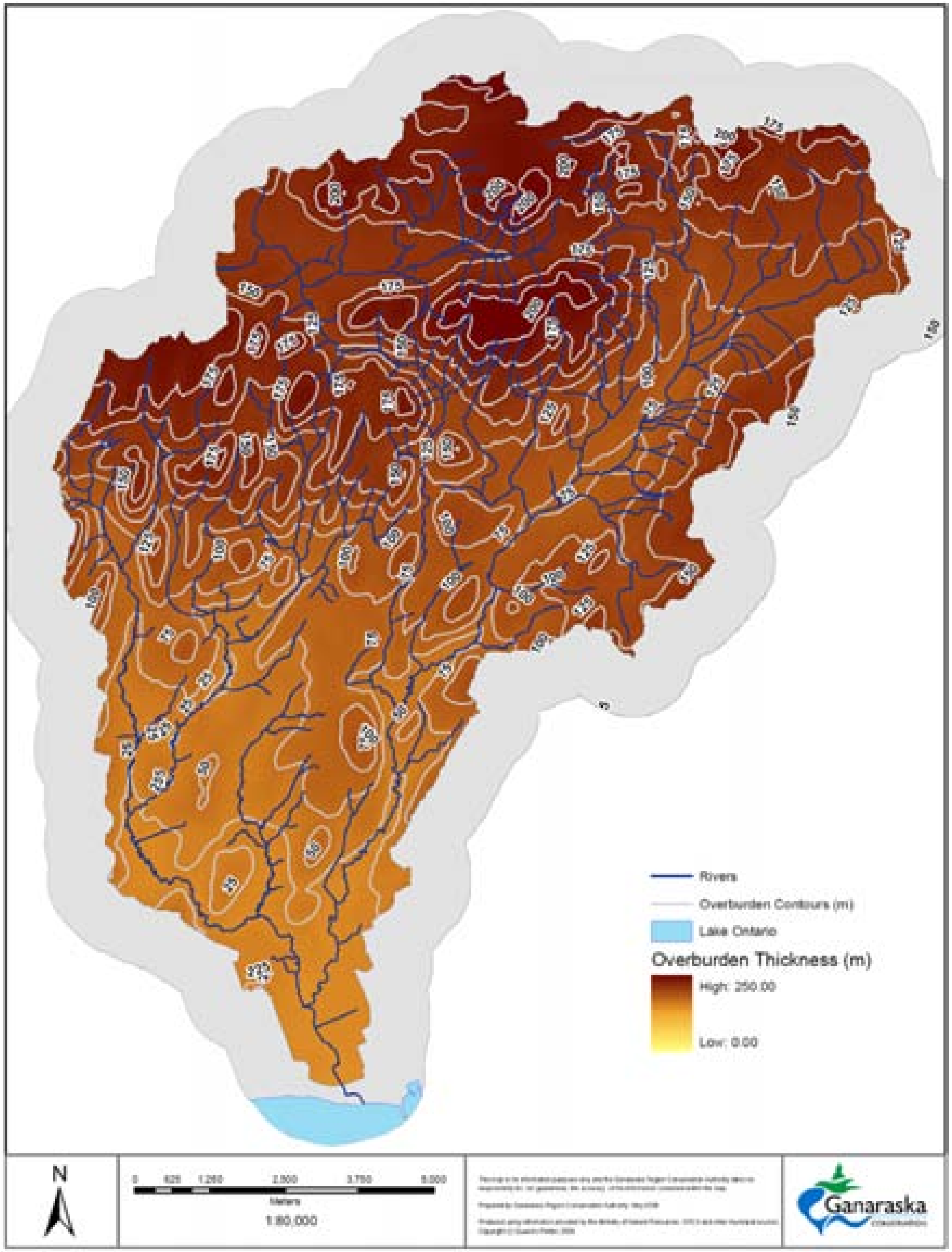


Figure 3.17: Overburden thickness

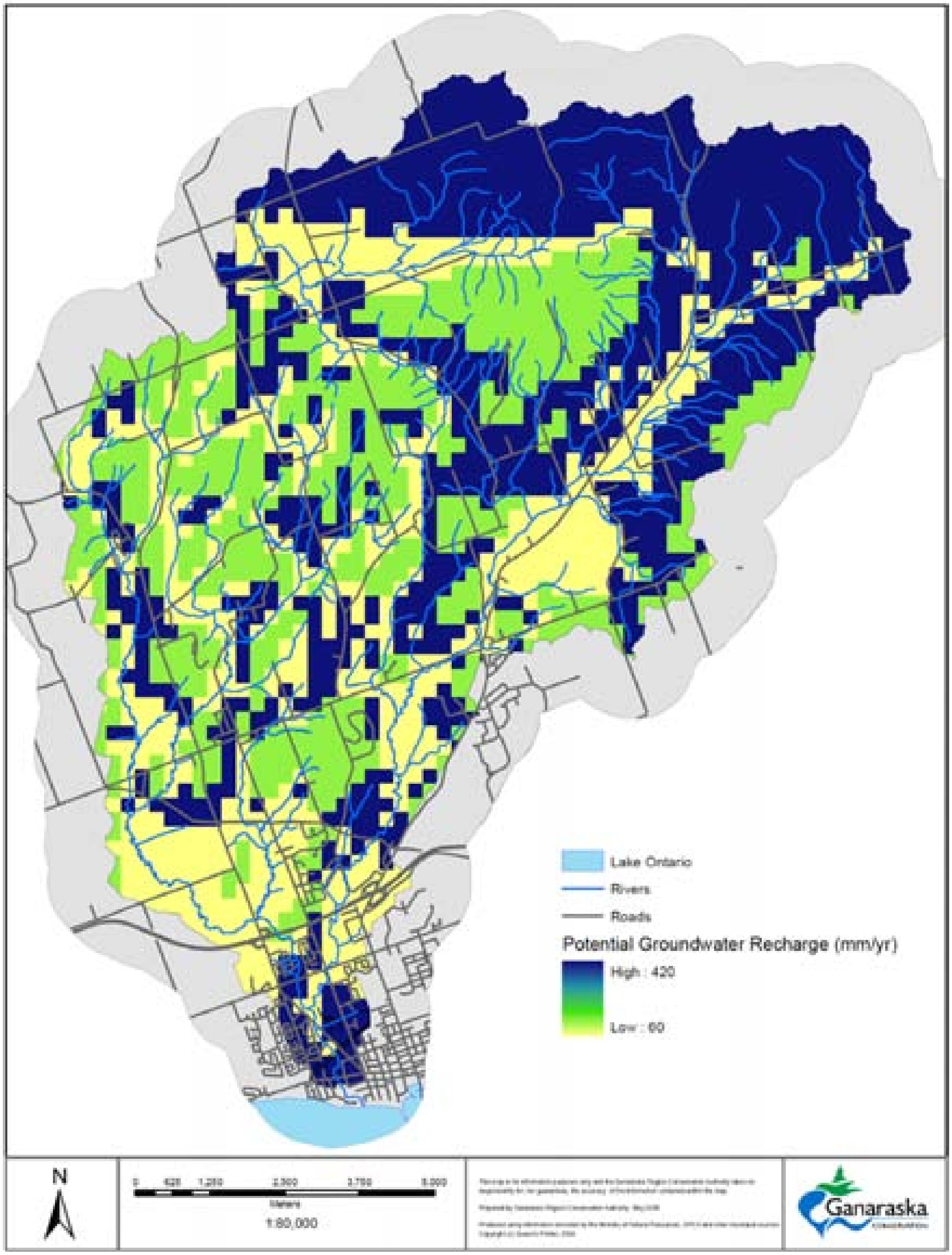


Figure 3.18: Potential groundwater recharge

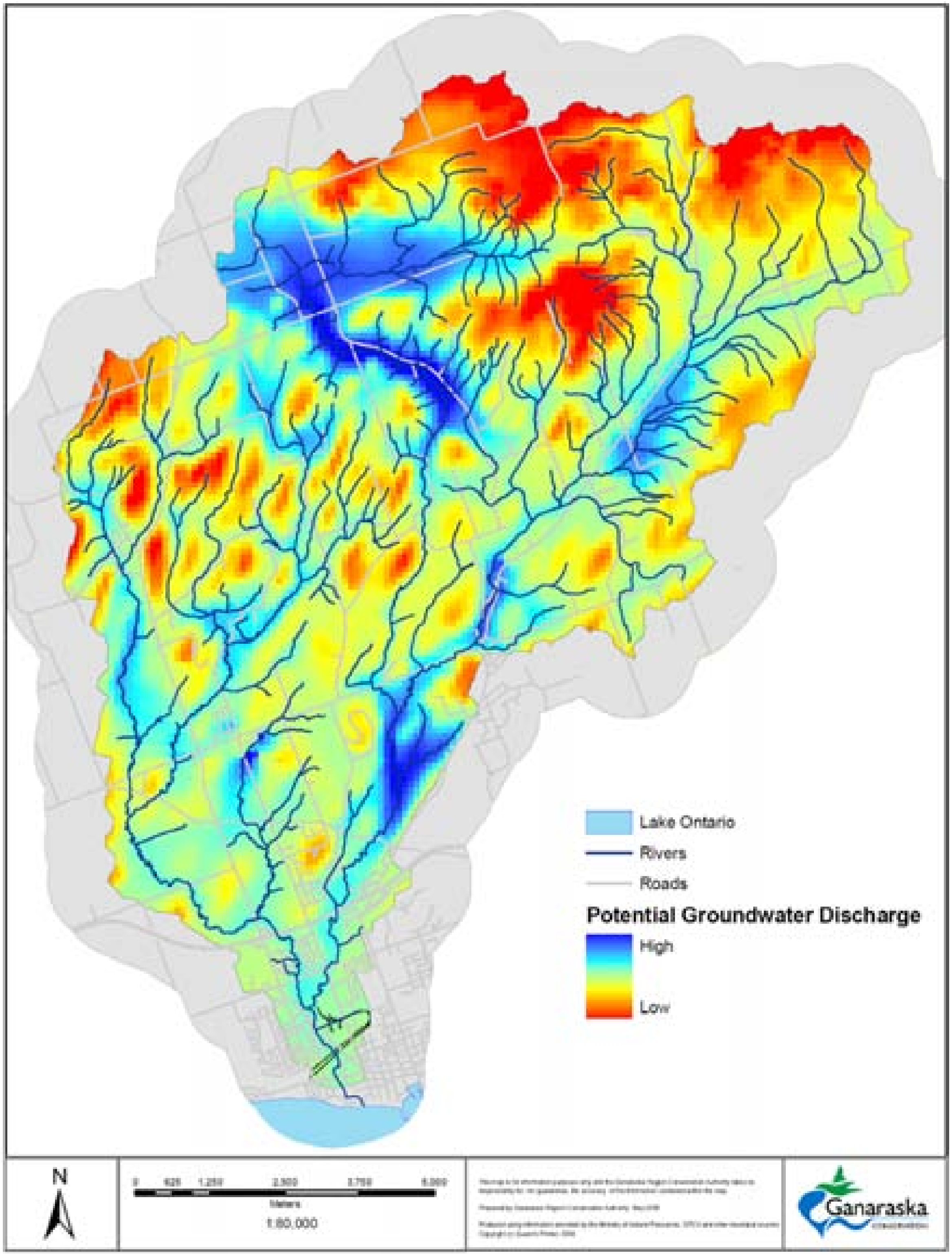


Figure 3.19: Potential groundwater discharge areas

Streambed Piezometres

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 piezometres have been recognized as an efficient tool to quantify these interactions. Widaatalla and Peacock (2007) reported on these interactions using streambed piezometres located across the Ganaraska Region Conservation Authority. Three piezometres were monitored within the Cobourg Creek watershed: Denault Road, Sheffield Property and Centreton Road (Figure 3.20). During analysis however, only the Centreton Road piezometre was analyzed as it had the longest data record, whereas Denault Road had insufficient data available.

When analyzing the vertical hydraulic gradient, it was determined that the Centreton Road piezometre was the most fluctuating eastern site during monitored seasons. This could be related to a potentially quick response of the site's catchment to precipitation or groundwater withdrawals (Widaatalla and Peacock 2007). When comparing the vertical hydraulic gradient with rainfall, it was seen that the Centreton Road piezometre relatively mirrored the rainfall data during certain months of 2005 and 2006, indicating matching responses of its catchments (Figure 3.21). The vertical hydraulic gradient reflected the increased precipitation during 2006 compared to 2005 (Widaatalla and Peacock 2007). These streambed piezometre studies bring validation to the modeled groundwater and surface water interactions within the Cobourg Creek watershed.

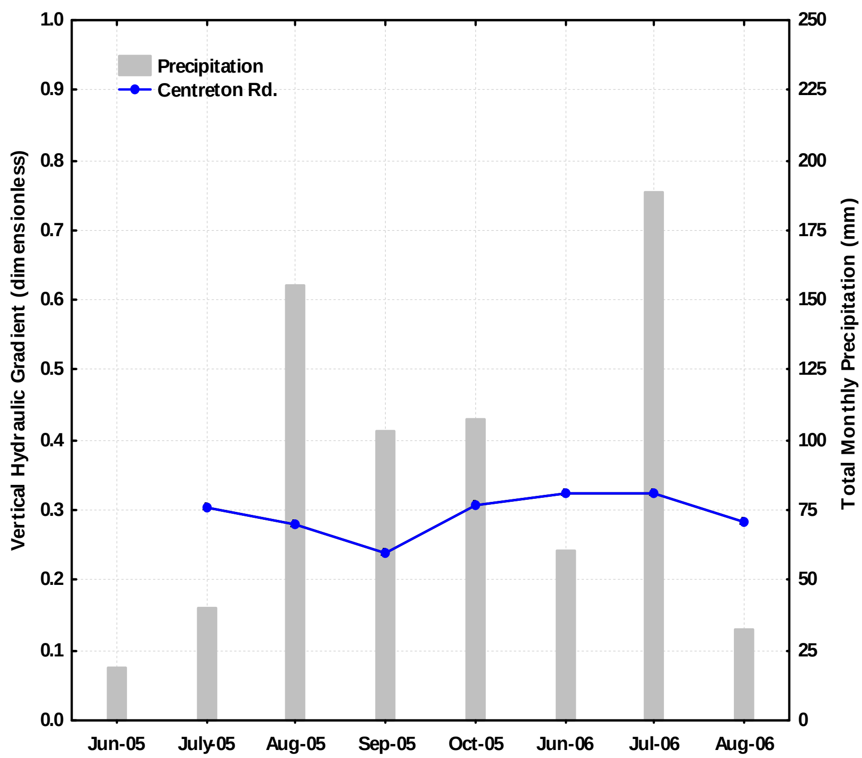


Figure 3.20: Monthly hydraulic gradients in relation to precipitation

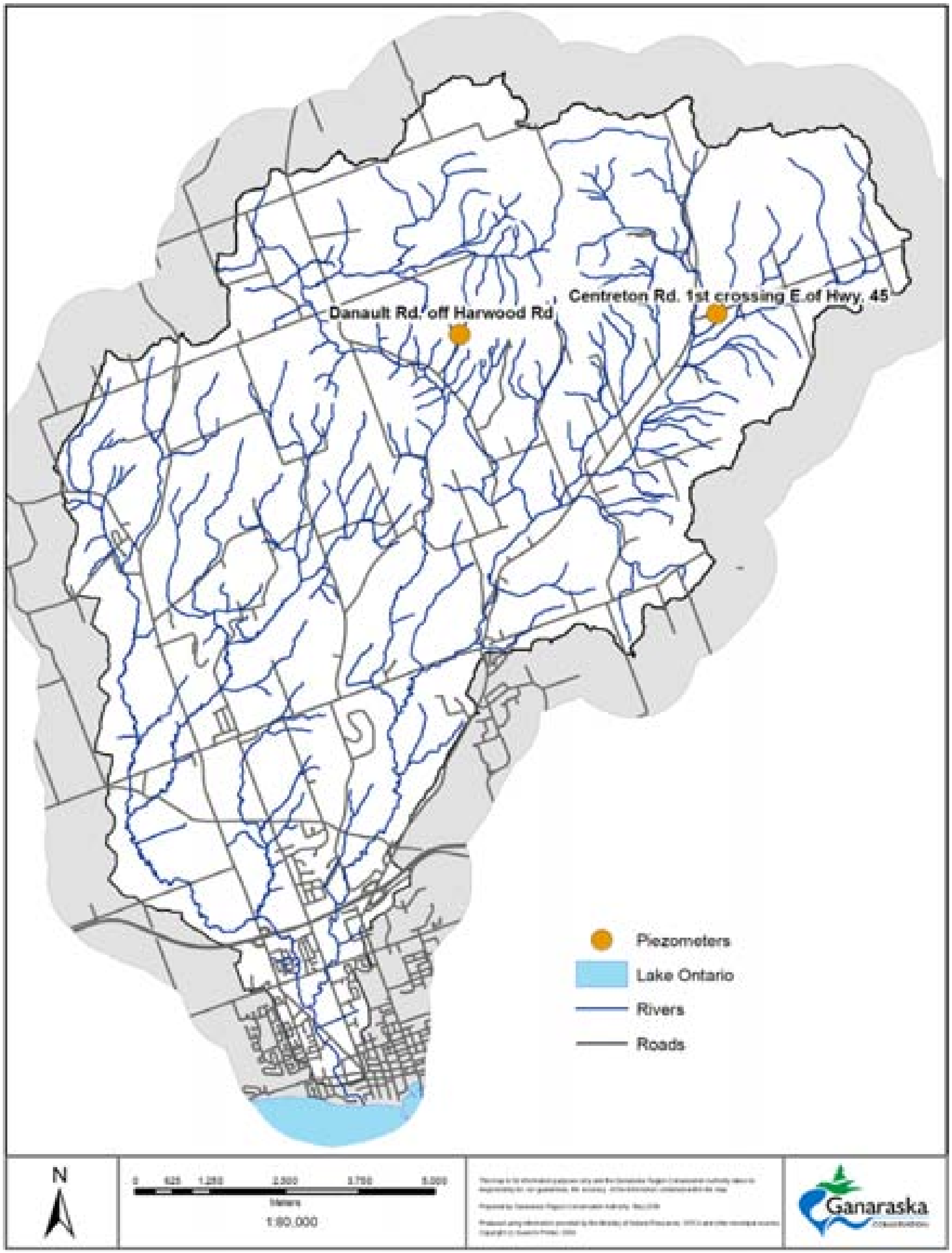


Figure 3.21: Piezometre locations

Baseflow

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 the periods when storm flow has ceased and stream flow consists entirely of delayed sources of flow (i.e., baseflow). However, depending on the purpose of the study, baseflow or low flow can also be interpreted more narrowly as the flow during a period of prolonged dry weather (Hinton 2005).

Baseflow is a result of groundwater discharge to a stream, and 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 affects the quantity and quality of surface waters. Within the Ganaraska Region watersheds, streams are under baseflow conditions approximately 70% of the time. Areas where groundwater discharges to streams (upwelling areas) provide cooler water temperatures that makes these areas attractive refuges and suitable habitats for aquatic species. For instance, groundwater discharge areas provide places of refuge from warm stream temperatures, and fish tend to take advantage of these locations (Power et al. 1999). In Cobourg Creek during baseflow conditions, surface water quantity is entirely determined by groundwater discharge. Surface water quality is also affected by the quantity and quality of groundwater entering the system as baseflow.

Methods

From August 15 to 23, 2006 baseflow was surveyed at 98 locations. Pygmy flow metres 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. Eight reference sites were selected to represent eight groups of baseflow sampling sites. Reference sites were selected based on their suitability for accurate flow measurements and their location within sub-catchments. The eight reference sites were sampled on three days; the first and last day of the study, and the day the represented group of sites were sampled. The variations in flow which possibly 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 upstream. This data was then used to show gains and losses per unit area of sub-catchments and per unit length of flowing channels within sub-catchments.

Sub-catchment 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 in the Cobourg Creek watershed were measured from each sample site to each sample site immediately upstream, using a combination of the attribute lengths of these segments. If there was no site upstream of a site, it was recorded as a headwater site and measured to the end of the source of flow. Further 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.

Results

Analysis from field sampling indicates that the majority of the baseflow in Cobourg Creek is gained or lost from specific locations attributed to their geological and hydrogeological features. The Oak Ridges Moraine and Lake Iroquois Shoreline physiographic features have a dramatic effect on baseflow occurrences and distribution due to their coarse soils 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) that acts as an aquitard that restricts groundwater flow downward, and the sandy aquifers that allow water to move upward, downward, and laterally towards surface water at lower elevations.

The topography and coarse surficial sediments associated with the moraine deposits in the northern part of the watershed generally have high infiltration capacities that allow for significant groundwater recharge during wet periods. In the summer, as evapotranspiration rates increase due to temperature and vegetative activity, the water table drops and the first order streams within the moraine sediments tend to become dry (Figure 3.22).

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 or the Bowmanville Till. This is especially evident in the upper reaches of Baltimore Creek where many small tributaries are collecting groundwater forming the main branch and a significant amount of the total baseflow observed in Cobourg Creek (Figure 3.23). Significant baseflow contributions were also observed along the lower moraine boundary on the Central and West Branches of Cobourg Creek due to similar conditions.

Along deeply-incised stream valleys in many of the middle reaches of the Cobourg Creek watershed, baseflow gains are also observed. In the South Slope physiographic region, the Bowmanville Till aquitard is the dominant hydrostratigraphic feature. Many streams have cut through overlying sediments creating deep valleys that come into contact with the underlying Bowmanville Till. Above the till layer groundwater moves laterally within local aquifers due to the low permeability of the till. When the till is exposed, groundwater comes to the surface and runs into stream channels.

It is possible that some deeply-incised stream valleys have cut through the Bowmanville Till layer into a deeper aquifer layer. This would be a confined aquifer that would cause the groundwater to be forced upward at any points where it is exposed, forming springs. These areas are especially sensitive because the deep groundwater is likely to be very clean and cold, creating a high quality cold water refuge for fish.

As water flows downstream in Cobourg Creek it encounters the Lake Iroquois Shoreline feature that consists of coarser sediments than the underlying till layers. Some losses in baseflow were observed in these areas. Coarse sediments and less topography allow the surface water to percolate into the ground more easily. As the shoreline feature becomes thin further downstream, groundwater reappears as springs or seeps at the surface as lower till sediments are exposed again.

Downstream of Highway 401, Cobourg Creek encounters a broad floodplain where the two main branches are joined. Losses were observed in this area as the creek enters the urban areas of the Town of Cobourg. There are a number of natural and anthropogenic influences that may be affecting baseflow quantities within the town. Around the confluence of the two branches, there is a broad, flat floodplain of river deposits. In this area, baseflow losses may be attributed to natural processes such as hyporheic flow, where water flows within sediments adjacent to the stream toward its outlet. These losses could also be explained by anthropogenic water takings that were not observed in the baseflow survey. Likewise the development in the town has the ability to hide further contributions to baseflow as observed further downstream. In urban areas the drainage of shallow groundwater is more efficient due to the use of foundation drains, storm water systems and other drainage infrastructure.

This baseflow analysis reveals the important and significant connection associated between topography, hydrostratigraphy and the contribution of groundwater to Cobourg Creek. 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 within the South Slope have lower hydraulic conductivity and therefore cause groundwater to discharge to streams rather than seeping downward. The coarse sediments of the Lake Iroquois Shoreline draw surface water below the surface to be reintroduced into the streams downstream. Within the Town of Cobourg the urban infrastructure makes it difficult to draw accurate conclusions about the baseflow contributions downstream of the 401. A more detailed study of the urban area would be necessary to understand the complex nature of baseflow in the Town of Cobourg.

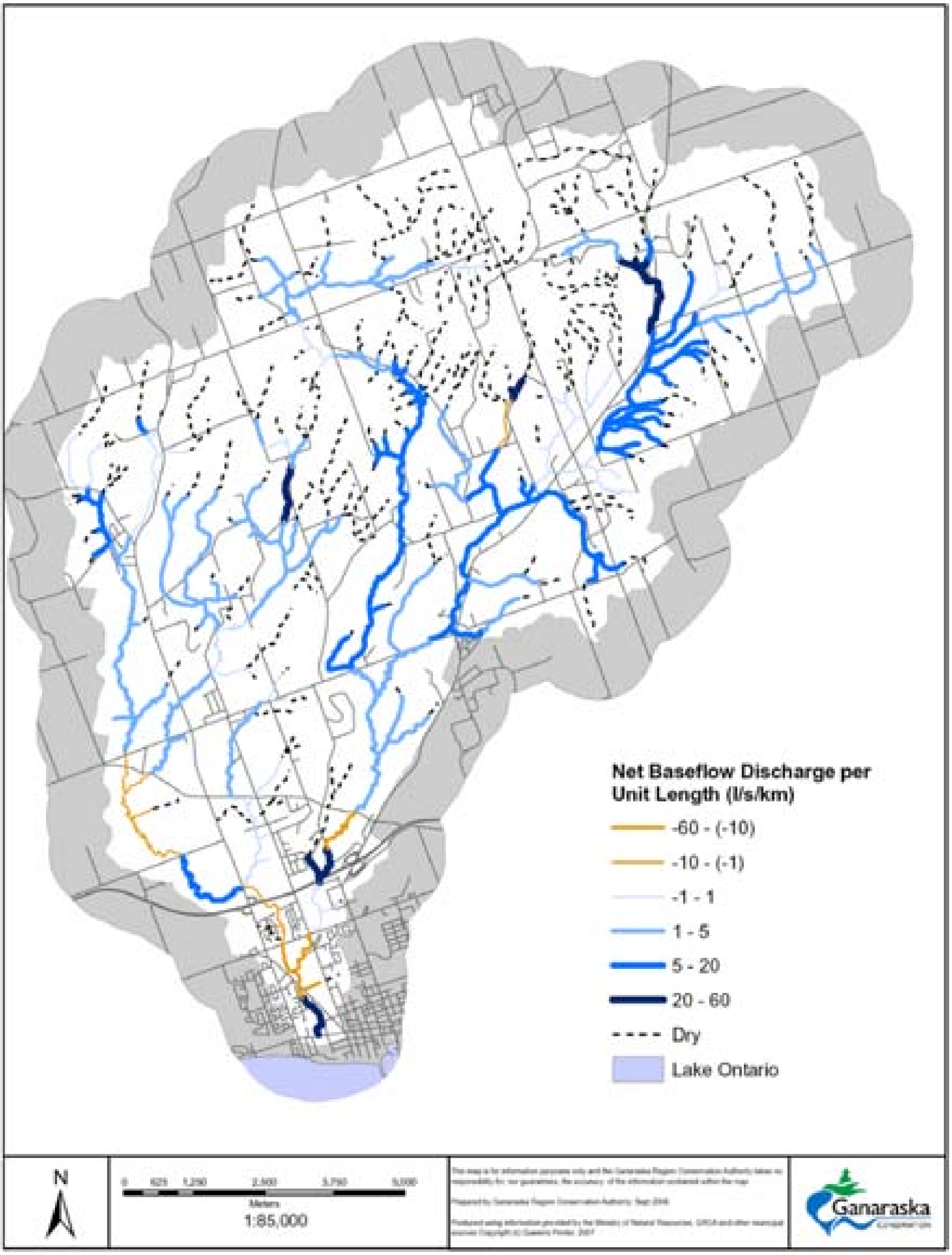


Figure 3.22: Net baseflow discharge per unit length

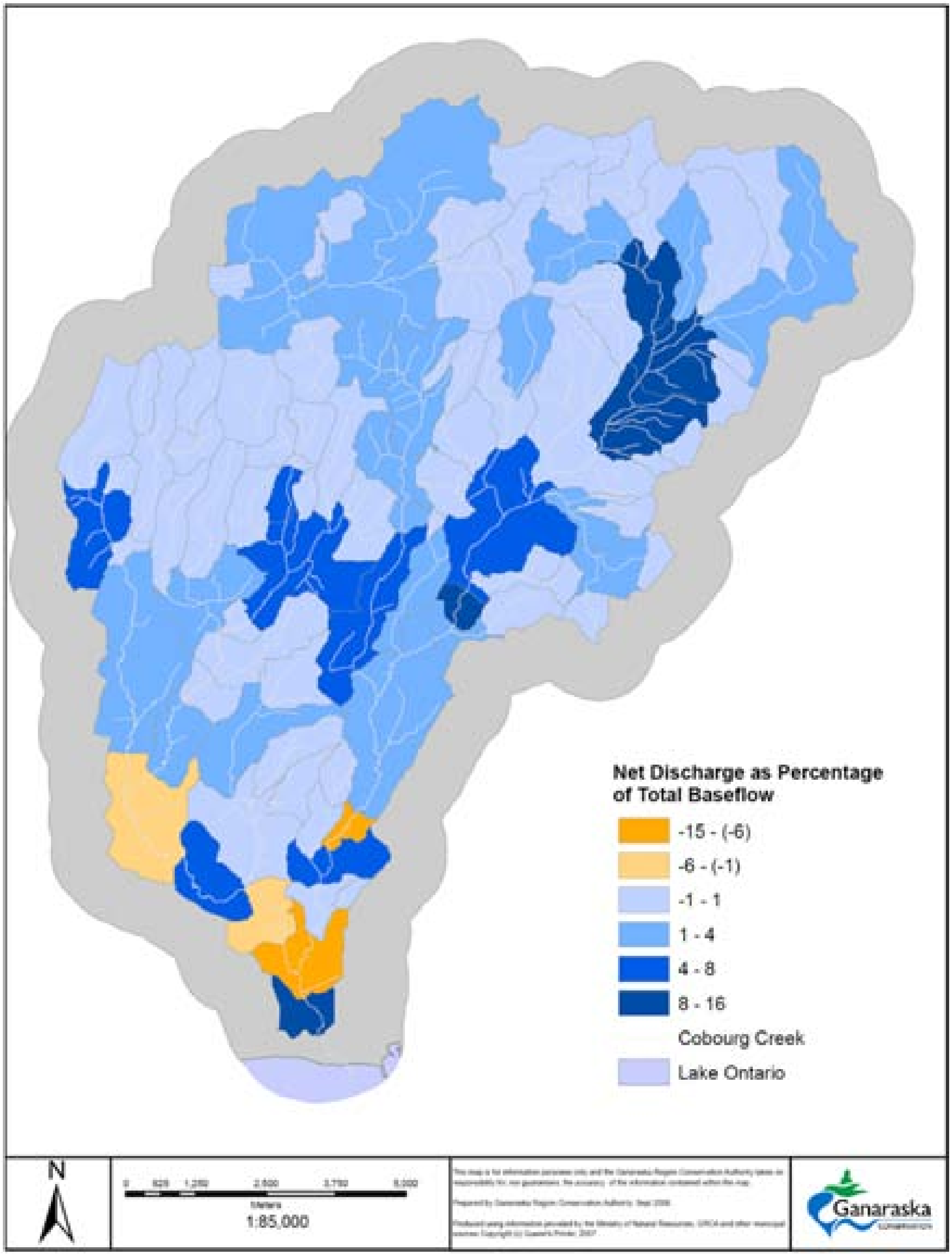


Figure 3.23: Net baseflow discharge

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

Numerical groundwater flow models are powerful tools to accomplish a number of results such as confirming a conceptual understanding of groundwater flows, distribution of aquifers within a defined area, and evaluating the effects of existing human land use on groundwater resources. Additionally, existing condition models can be altered to replicate future development scenarios and evaluate these scenarios regarding their impact on groundwater. In the Cobourg Creek watershed, the Township of Hamilton municipal wells in Camborne and Creighton Heights were the initial reason to create a detailed groundwater model of the area. Groundwater models are being used in drinking water source protection to help understand groundwater flow and protect drinking water sources. A study by Jagger Hims Limited completed in March 2007 for the Hamilton Township municipal wells describes this work (Jagger Hims Limited 2007).

Groundwater Model Data Sources

The data sources for the Jagger Hims Limited study included available technical reports and other literature made available through work by the Ganaraska Region Conservation Authority, the Township of Hamilton, Morrison Environmental Limited and the Conservation Authorities Moraine Coalition groundwater program.

The Conservation Authorities Moraine Coalition has created a regional groundwater model for the Oak Ridges Moraine and areas south of the Moraine. Jagger Hims Limited used geological layers and surfaces from this regional model as a starting point for their work. The improvements made to this model by Jagger Hims Limited included the use of local field data to improve the accuracy and local knowledge contained within the model. Field data was collected from the study area to more accurately locate well positions and determine water levels for use as calibration targets for the new revised numerical model. Approximately 184 properties were visited during the field survey to collect necessary data. Additionally, data on stream baseflow was collected by the Ganaraska Region Conservation Authority in 2006 in the Cobourg Creek watershed and in other watersheds within the Township of Hamilton from 2002 to 2005. All relevant baseflow data was used in calibrating the numerical groundwater flow model.

Three-Dimensional Numerical Groundwater Flow Model

The following section summarizes the Groundwater Study, Creighton Heights and Camborne Wellfields, Hamilton Township Jagger Hims Limited March 23, 2007.

A three-dimensional numerical groundwater flow model was constructed and calibrated to simulate the groundwater flow system beneath Cobourg Creek. The model was constructed on a sub-regional scale using a similar MODFLOW (modular finite difference groundwater flow model) modeling approach to the one documented by the Conservation Authorities Moraine Coalition (Earthfx Incorporated 2006). A boundary area outside of Cobourg Creek was modeled to ensure that the model appropriately addressed groundwater flows across watershed boundaries.

Model Assumptions

Some of the simplifying assumptions made by Jagger Hims Limited (2007) in the construction and calibration of the numerical groundwater flow model are:

- The geology is represented by a "layer cake" approach, and all layers are continuous with a minimum layer thickness of 0.1 m.
- Hydraulic properties are constant in each layer. An exception to this was in Model Layer 3, where some hydraulic conductivity was supplied in the database. Local adjustments were made to hydraulic conductivity in Layer 7 locally around the municipal wells.
- Recharge was assigned in discrete fields based on the Quaternary geology map and Conservation Authorities Moraine Coalition estimations.
- Surface water features, other than Lake Ontario and Rice Lake, were constructed in the model assuming a linear gradient between points, where surface water elevations were available in the database.
- Boundary conditions at the eastern and western edge of the model corresponded to observe surface water divides between watersheds. A divide between sub-ground-watersheds was assumed to correspond to the surface water divide in these areas.
- The water taking from private wells is typically returned locally to the groundwater flow system through local septic disposal. Water removal from private wells has not been included in the numerical groundwater flow model.
- Much of the numerical model domain contains artesian conditions for the deeper aquifer layers. These are observed in the form of flowing artesian wells. Flow from some artesian wells is known to contribute to the baseflow to local streams. Some identified artesian wells have been considered in the numerical flow model. Many more artesian wells exist and have not been confirmed or included.

Numerical Model Selection

The numerical groundwater flow model was constructed using Visual MODFLOW Version 4.2 as an interface to the modular finite difference groundwater flow model (MODFLOW) numerical code. The numerical groundwater flow model was constructed using 250 m x 250 m grid cells and up to eight vertical layers. The vertical layers were assigned based on interpreted hydrostratigraphic layers summarized in Section 3.1.2 of this report. The area modeled is shown in Figure 3.24.

Boundary Conditions

The model was constructed such that boundaries of groundwater flow could be established. Some of these boundaries were considered to have constant flow associated with them and some boundaries were considered to have no flow passing them. Rice Lake and Lake Ontario were treated as constant head boundaries. The sub-watersheds along the east and west boundaries of the model (Gages Creek and the areas north of the east-west regional surface water divide to Rice Lake) were treated as no-flow boundaries and the base of the model (unfractured bedrock) was considered as a no-flow boundary.

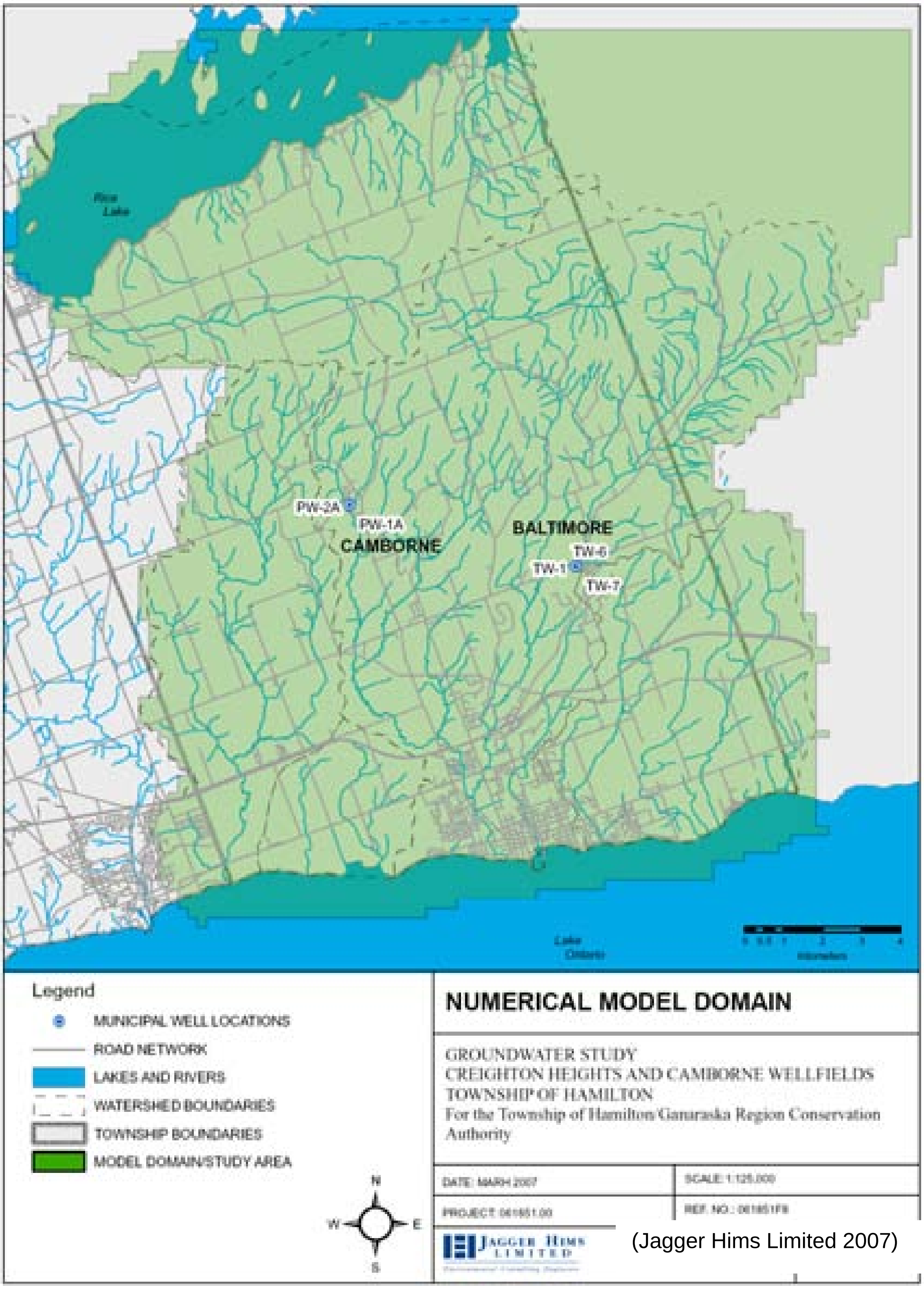
Surface Water Features

Visual MODFLOW has the capacity to represent surface water features. Rivers and creeks were modeled in Visual MODFLOW using the MODFLOW river package. This allows water both to enter the model from the river (losing stream reach) or to exit the model from the aquifer (gaining stream reach).

Model Calibration

The model was calibrated to ensure that the measured stream baseflow predicted by the model was produced. This was completed for Cobourg Creek, Gage Creek, and Plainville and Harwood Creeks. The model was also calibrated to generate groundwater elevations as defined within the Ministry of the Environment Water Well Record Database and the supplementary set of local groundwater elevations obtained through field investigations. Groundwater elevations from approximately 1080 wells in the Water Well Record Database were used in the calibration.

Calibration resulted in a groundwater flow model that met industry standards and produced a simulated groundwater flow system with groundwater elevations that provides a valuable tool for managing groundwater in the Cobourg Creek watershed.



(Jagger Hims Limited 2007)

Figure 3.24: Groundwater model area

Groundwater Model Summary
Numerical groundwater flow models are used in simulating groundwater flow conditions and evaluating the effects of various scenarios. The results of the model can provide insight into either possible or most likely behaviour of a groundwater flow system. However, this understanding is controlled by the availability of data which was used by the model (Jagger Hims Limited 2007). The current results of the groundwater model for the area within the Township of Hamilton are the delineation of Well Head Protection Areas for the Camborne and Creighton Heights municipal well fields, and an estimate of aquifer vulnerability. Future work and additional data into the model can increase the understanding of groundwater flows within the Cobourg Creek watershed and among neighbouring watersheds (i.e., Gages Creek, Burnley Creek, Shelter Valley Creek and Midtown Creek).

3.3.2 Wellhead Protection Areas

By using the numeric groundwater flow model, capture zones were created for the Creighton Heights and Camborne municipal wells. This understanding will assist in the protection of the municipal drinking water systems. The defined wellhead protection areas will be used by the Township of Hamilton and the province in drinking water source protection planning and will be acknowledged in the Cobourg Creek Watershed plan.

Creighton Heights and Camborne Wellhead Protection Area
Jagger Hims Limited (2007) summarized the conclusions of the Creighton Heights and Camborne capture zone groundwater modeling and the vulnerability analysis.

Capture Zone Delineation

- The capture zones for the Creighton Heights municipal wells extend in a north to north-easterly direction away from the wells to beneath the height of land associated with the Oak Ridges Moraine (Figure 3.25).
- The capture zones for the municipal wells in Camborne extend in a north to north-easterly direction away from the wells to beneath the height of land associated with the Oak Ridges Moraine (Figure 3.25).
- The steady-state capture zone (Zone E) represents the recharge area required to vertically transmit recharge to the water supply aquifer at the maximum permitted rate of taking. Further work is required to demonstrate whether there are any spatially significant recharge areas within Zone E.
- The particle tracking analysis typically showed that groundwater removed from the wells has been within the deep aquifer layer for more than 25 years. Artesian pressures near the wells will minimize the likelihood that water from the surface in these locations will reach the underlying aquifer.

Vulnerability Analysis

- The “time of travel” for a contaminant to move downward from ground surface to the water supply aquifer is greater than 65 years for the Creighton Heights wells and greater than 96 years for the Camborne wells. Based on this observation, both wellhead protection areas have been assigned a low vulnerability.
- There are relatively few preferential pathways within wellhead protection area A (0 to 100m) through D (< 25 year time of travel). These primarily constitute deep wells that are no longer in use (abandoned wells) and deep wells that remain in use that do not conform to the Ministry of the Environment current well construction standards. There are gravel pits within Zone E (Steady state capture zone), but these are not considered a sufficient threat to the quality of water drawn from the municipal wells.
- The vulnerability scoring primarily reflects the horizontal travel times determined within the water supply aquifer. High vulnerability scores are assigned within wellhead protection area A (0 to 100 m), since this area is nearest to the wells. All other wellhead protection areas have a low vulnerability score.
- The vulnerability scoring for DNAPL (dense nonaqueous phase liquid) contaminants indicates that the area within the five (5) year time of travel distance (Zone C) is potentially vulnerable to contamination by DNAPLs if sufficient quantities are released.

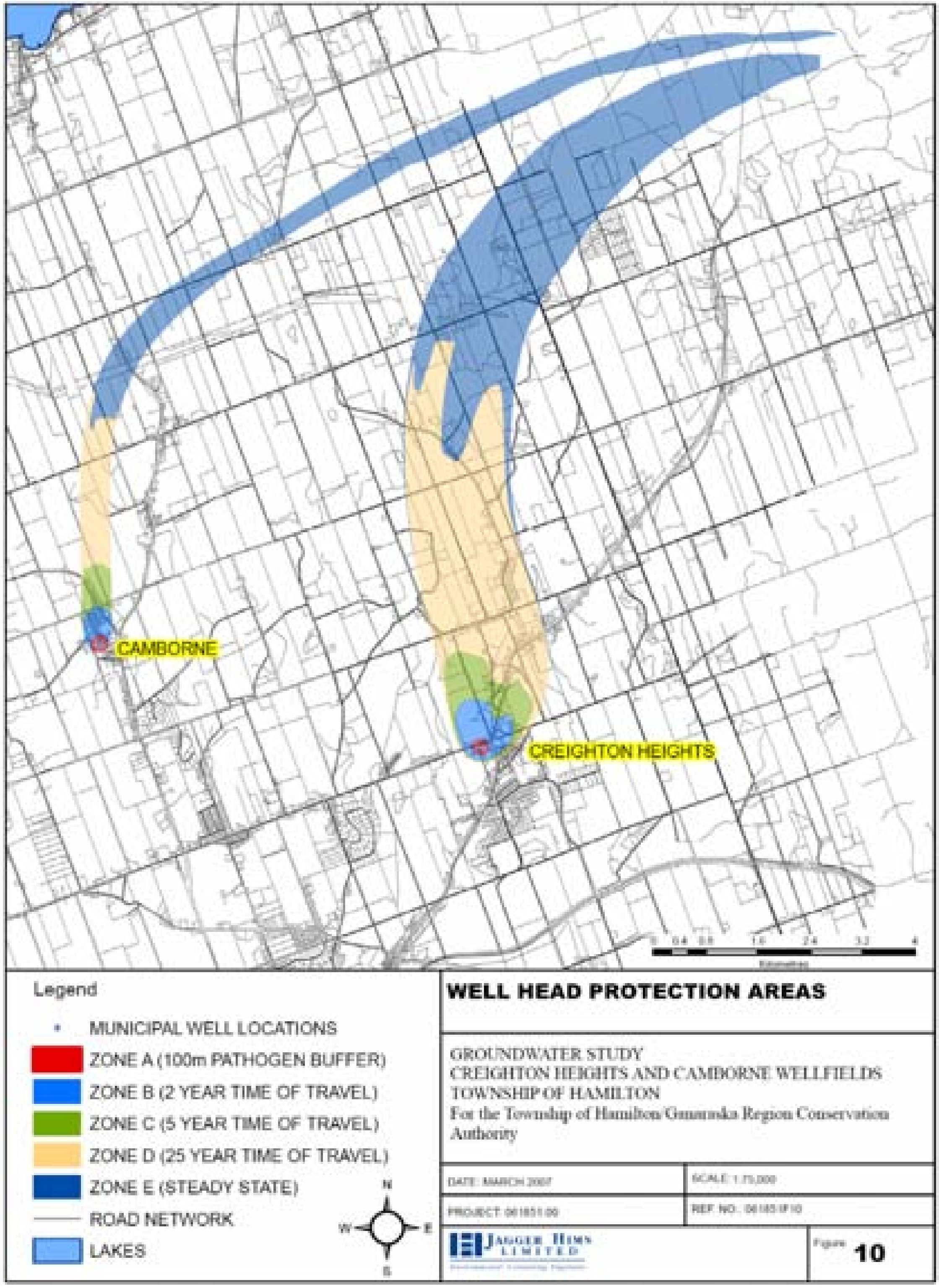


Figure 3.25: Wellhead Protection Areas within the Township of Hamilton

3.3.3 Aquifer Vulnerability

The movement of groundwater within the area is a subtle reflection of local topography and drainage as interpreted from the Ministry of the Environment (MOE) Water Well Records. The lateral movement of groundwater in the shallow aquifers within the Cobourg Creek watershed occurs from topographic highs to topographic lows. The dominant regional groundwater flow direction is southerly, off the Oak Ridges Moraine toward the Lake Ontario basin, with a westerly component in some local areas. In the northern part of the watershed, groundwater flows in a north and northwest direction into the Rice Lake basin.

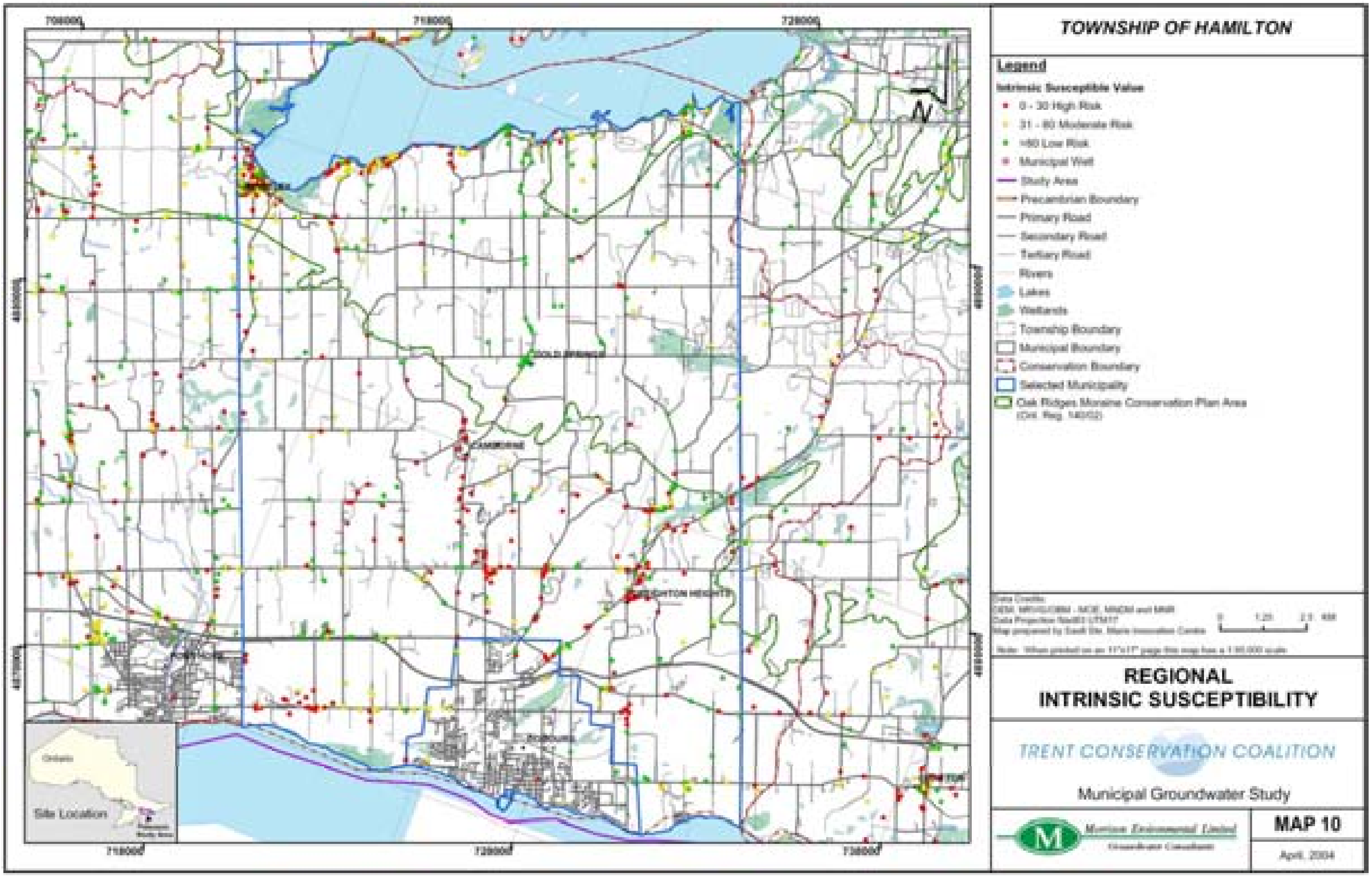
Deep aquifers are mainly recharged in the northern portion of the watershed at the Oak Ridges Moraine. The deep groundwater then flows south to be intersected by streams, rivers, Lake Ontario, or groundwater wells. The deep aquifers are generally under confined conditions, resulting in high groundwater pressure heads, in which some wells are found to be flowing artesian wells.

The objective of delineating vulnerable aquifers is to address groundwater source protection in areas that are not delineated as municipal Wellhead Protection Areas (Section 3.3.2). These 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 within the Ganaraska Region Conservation Authority have been delineated through municipal groundwater studies (Morrison Environmental Limited 2004).

The vulnerability of the aquifers to contamination has been evaluated using the Intrinsic Susceptibility Index (ISI) approach on a well-by-well basis (Figure 3.26). The ISI method is a relative evaluation of vulnerability of an aquifer with respect to contamination originating at the surface. This method is based on calculating an ISI at each well by summing the product of the thickness of each geologic unit described on the well log and a corresponding K-Factor (loosely related to the exponent of the vertical hydraulic conductivity of the unit). This calculation is normally performed from the surface to a lower limit defined by the water table configuration. Using the protocol set out in the MOE Technical Terms of Reference (Ontario Ministry of the Environment 2001), a regional Groundwater Intrinsic Susceptibility map was developed for the Ganaraska Region Conservation Authority (Morrison Environmental Limited 2004c).

The delineation of aquifer vulnerability from groundwater studies and modeling is provided in Figure 3.27. This map was generated using Aquifer Vulnerability Index (AVI) approaches. AVI is an index approach in which spatial calculations are completed with the available hydrogeological data and mapping products (e.g., overburden soil type and thickness, depth to aquifer, etc.) to produce an index or numerical score that reflects the relative amount of protection provided by the physical features that overlay the aquifer. An AVI is a numerical indicator of an aquifer's intrinsic or inherent susceptibility (as a function of the thickness and permeability of overlaying layers) to contamination that would result in an adverse effect to both human and natural sources of groundwater. In some areas, the aquifer or landscape index mapping has been applied to the water table or uppermost aquifer only.

In developing aquifer vulnerability maps, it is important to note that the ISI/AVI maps are regionally-derived products based largely on water well records. Using these maps for specific prescriptive management actions must be considered carefully. For instance, ISI/AVI mapping is suitable for prohibiting certain higher-risk land uses, such as those that involve hazardous chemicals (e.g., landfills), but the risk assessment process, carried out during the preparation of drinking water source protection plans, should consider the limited precision of regionally-derived maps, as risks are evaluated and ranked within a study area.



(Morrison Environmental Limited 2004)

Figure 3.26: Intrinsic susceptibility index

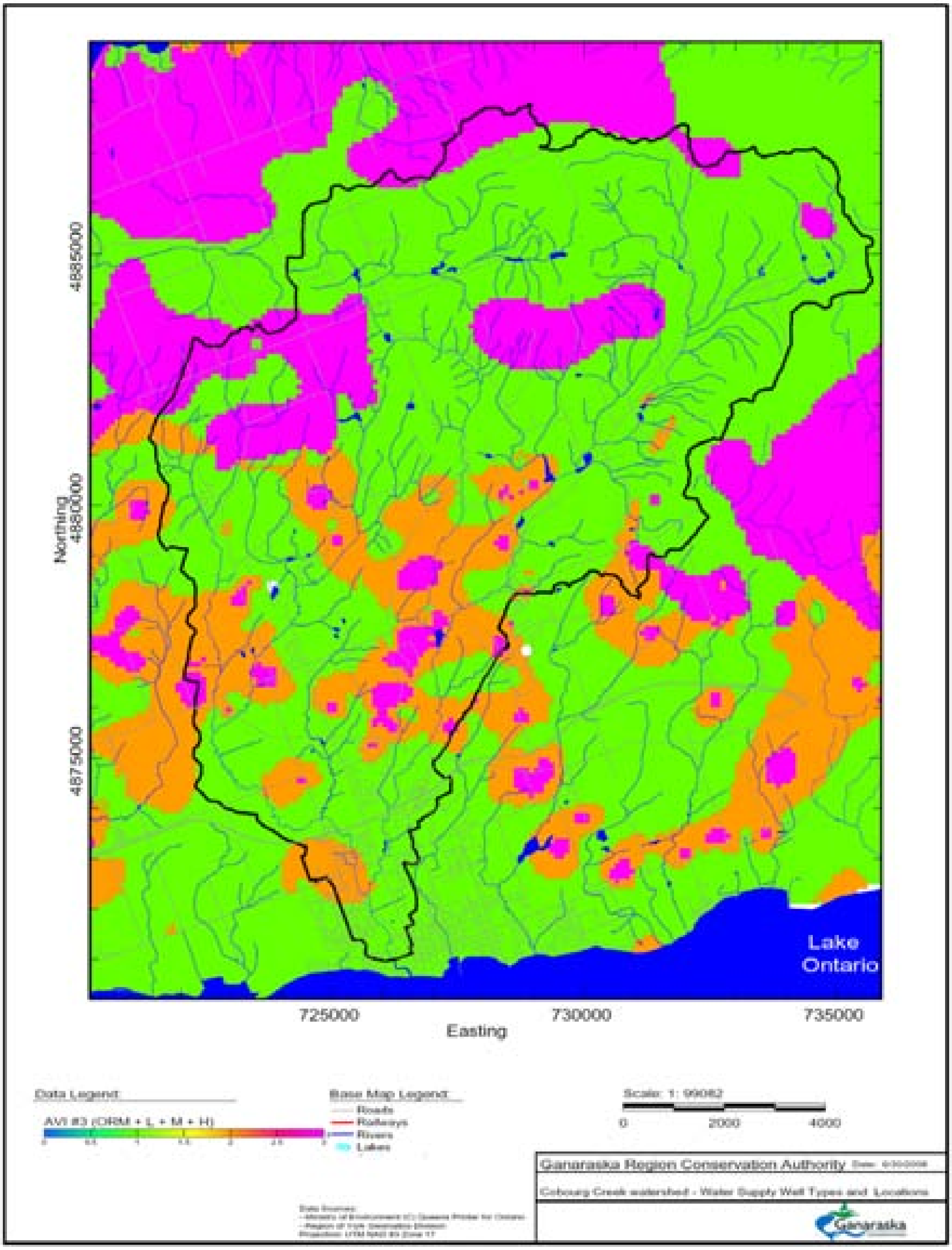


Figure 3.27: Aquifer Vulnerability

3.4 SURFACE WATER

Surface water is water that flows and occurs on the surface of the ground. Water enters the surface via precipitation and groundwater discharge, and moves via 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 Cobourg Creek watershed is the second largest drainage basin within the Ganaraska Region Conservation Authority jurisdiction. Originating in the Oak Ridges Moraine at an elevation of approximately 300 masl, Cobourg Creek drains a land base of 123.2 square km[1], and is approximately 17.7 km long and 6.7 km at its widest point, near the northern boundary of the watershed (Ontario Ministry of Natural Resources 1976). Cobourg Creek is also referred to as Cobourg Brook, and many different tributaries have localized or historical names (Table 3.5).

Table 3.5: Cobourg Creek Tributary Names

Tributary Referenced in Document	Other Localized or Historical Names
Cobourg Creek	Cobourg Brook
Baltimore Creek Branch	Solomon's Creek
West Branch	Tributary A*
Central Branch	East Branch
Main Branch	Factory Creek

* Referred to in Ontario Ministry of Natural Resources 1976 and Figure 3.28

The Baltimore Creek tributary drains the upper eastern portion of the watershed (Figure 3.28, Figure 3.29). Baltimore Creek flows 11.6 km to the confluence of the Central Branch Cobourg Creek (Ontario Ministry of Natural Resources 1976). The West Branch drains the upper western portions of the watershed and travels a distance of 10.9 km to the confluence with the Main Branch (Ontario Ministry of Natural Resources 1976). The drainage areas of the major tributaries are listed in Table 3.6. Ultimately, Cobourg Creek outlets into Lake Ontario with a total fall of about 181 m with an average slope of about 7.1 m/km.

A drainage basin such as Cobourg 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. Cobourg Creek, as defined by

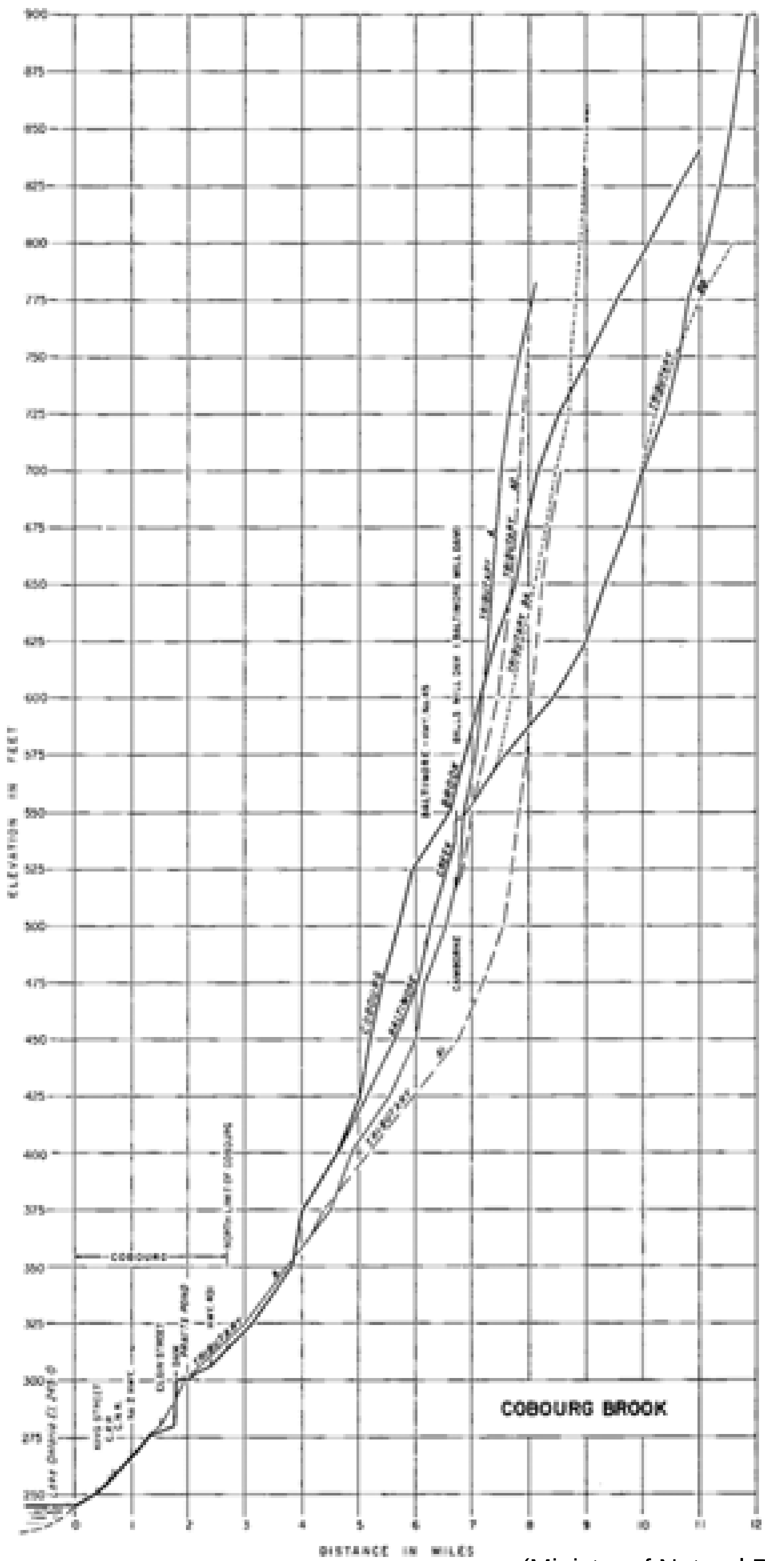
[1] Calculated from Arc Hydro in 2008. Watershed boundary delineated in Arc Hydro and adjusted to acknowledge storm drainage infrastructure.

the Horton-Strahler method, consists of six stream orders that in total travel a distance of 261.4 km. Stream order lengths are as follows: first order 137.8 km, second order 44.4 km, third order 25.4 km, fourth order 31.6 km, fifth order 19.6 km, sixth order 2.5 km (Figure 3.30). In addition to these stream orders, many intermittent and ephemeral streams contribute to the flows and habitat of Cobourg Creek during differing times of the year.

Table 3.6: Drainage areas of the major tributaries in Cobourg Creek

Stream/Tributary	Drainage Area (km^2)
Entire Cobourg Creek	123.2
West Branch	43.7
Central Branch	32.2
Baltimore Creek	45.4
Main Branch	1.9

As Cobourg 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. Imperviousness areas are areas that are hardened through paving (i.e., parking lots and roads) and development (i.e., buildings and infrastructure). These land cover types prevent water from infiltrating through the ground, increase surface runoff rates, and alter pathways of surface water (i.e., drainage through storm sewers to a stream). Areas of high imperviousness are located primarily south of Highway 401 within the Town of Cobourg, and in the areas north of Highway 401 within the Township of Hamilton (i.e., Ontario Street and County Road 45) (Ganaraska Region Conservation Authority 2007b). These impervious areas cause a response in a stream to be seen even during small rainfall events, since water must run off all hardened surfaces. In natural areas, or areas with limited imperviousness, many summer rainfall events create no runoff and little stream response, as the entire volume of rainfall is infiltrated into the soil.



(Ministry of Natural Resources 1976)

Figure 3.28: Historical cross-section of Cobourg Creek

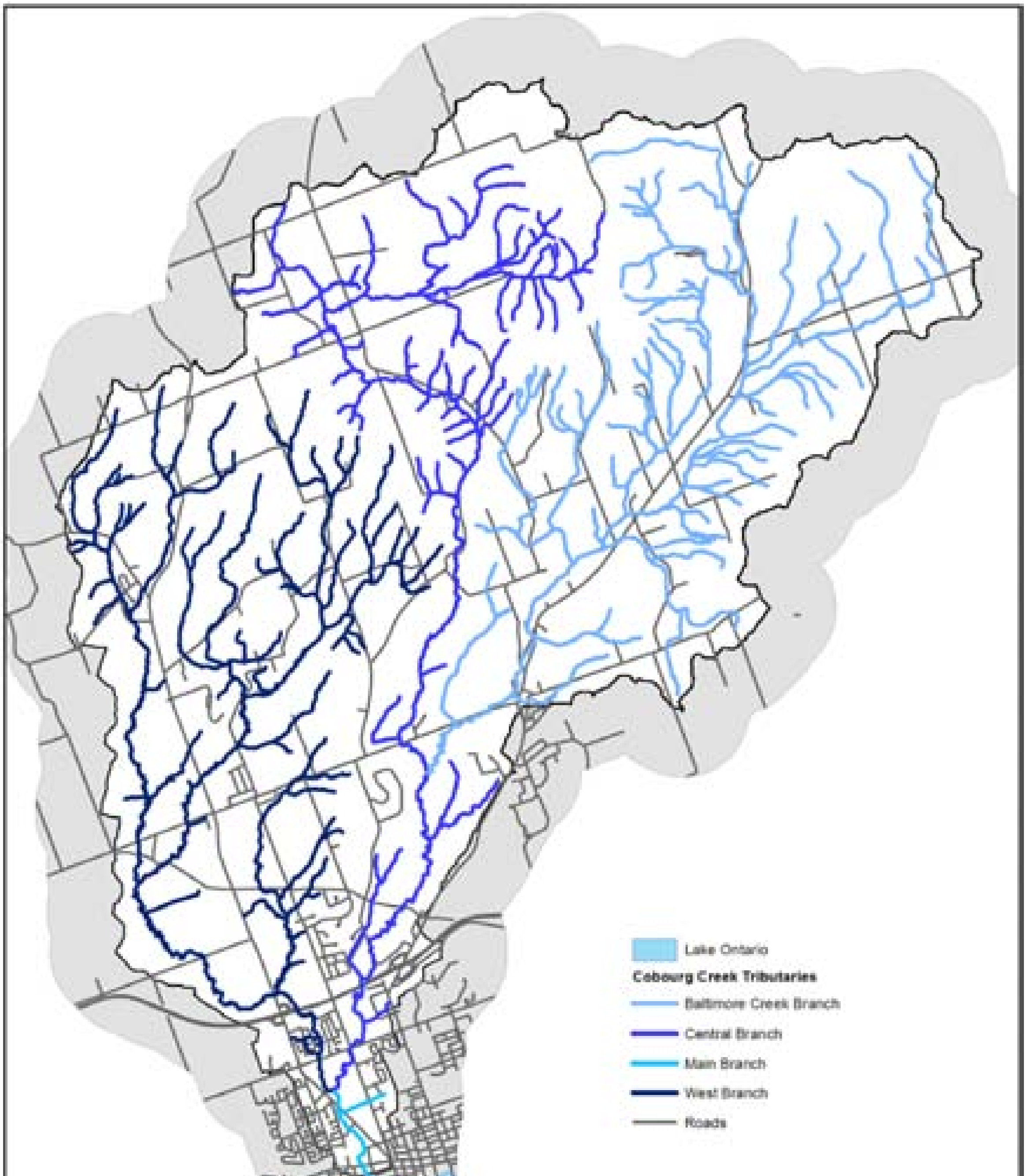


Figure 3.29: Cobourg Creek tributaries

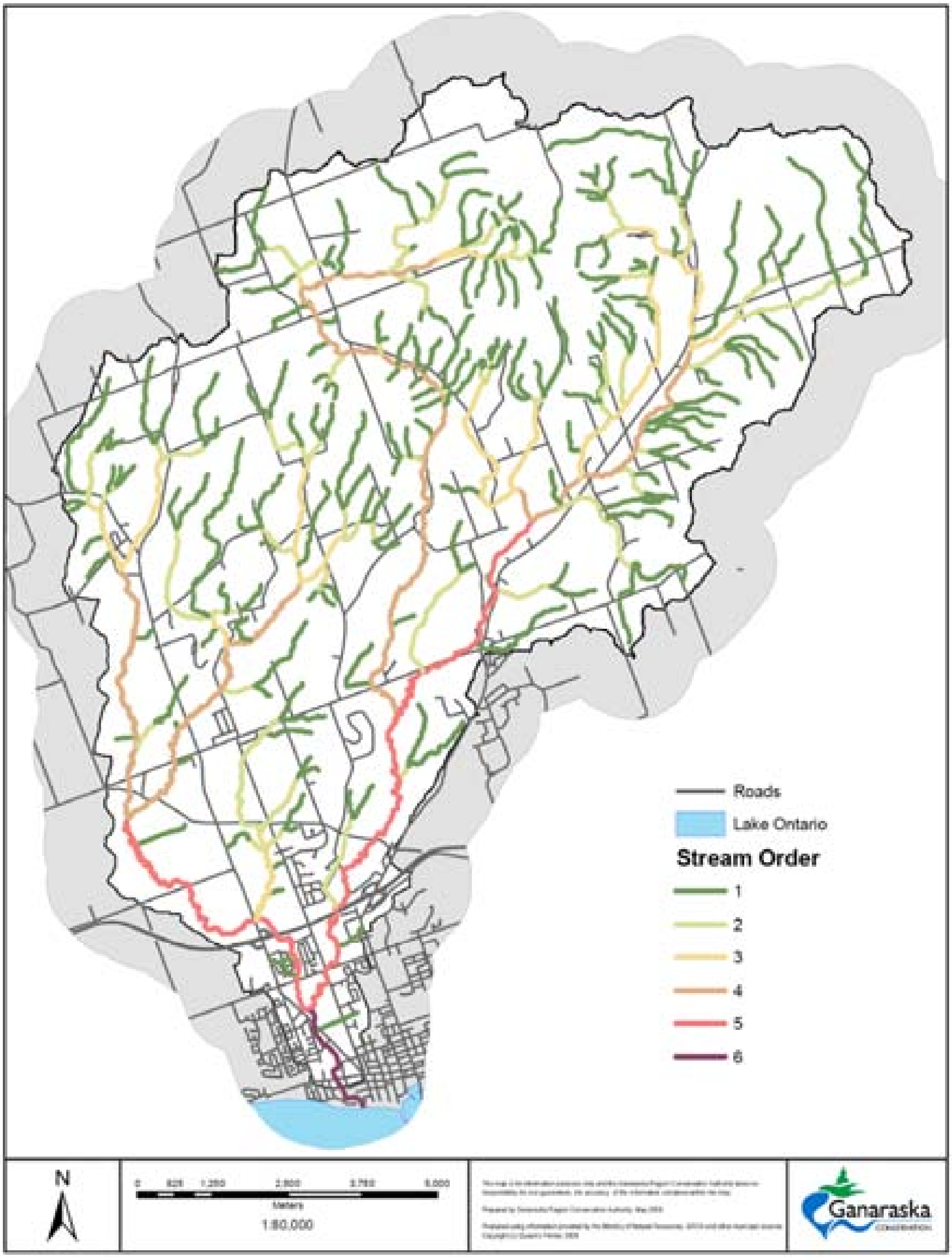


Figure 3.30: Stream order

3.4.2 Dams and Water Control Structures

There were 32 private dam and water structures identified in 1999, located along Cobourg Creek. Figure 3.31 shows the locations of dams and control structures within the Cobourg Creek watershed, along with corresponding ponds and impoundment areas. The condition and existence of these dams are unknown. The two largest dams are Pratt's Dam, which is privately owned, located on the Main Branch and the Ball's Mill Dam, owned by the Ganaraska Region Conservation Authority, located in the Baltimore Creek tributary. Dams and ponds have the potential to create negative effects on water quantity, quality and aquatic habitat, and dams inhibit natural fish migration to areas above them.

Pratt's Dam does not have any upstream impoundment area or a fish way. Adult rainbow trout have been manually lifted since 1979 in order to improve reproduction and create fishing opportunities upstream (Snider 2001). Pratt's Dam was built in the 1830s to provide a power source for a local grist mill. It is an earthen dam with a spillway consisting of two concrete weirs that are each 7.25 m wide (Snider 2001). Today there is no pond behind the dam, only a slow-moving reach of Cobourg Creek.

Ball's Mill Dam is currently owned and operated by the Ganaraska Region Conservation Authority for the purpose of providing a community pond, increasing downstream summer flows in Baltimore Creek, and impounding spring runoff in the upper reaches of the Cobourg Creek watershed to help increase groundwater supply (Macpherson 2004). The dam is earth-filled with a double concrete spillway and a concrete emergency spillway. Three stop logs regulate the water within the reservoir. The drainage area to Ball's Mill pond is 38.1 km^2 and it contains a 3.2 ha reservoir (Macpherson 2004).

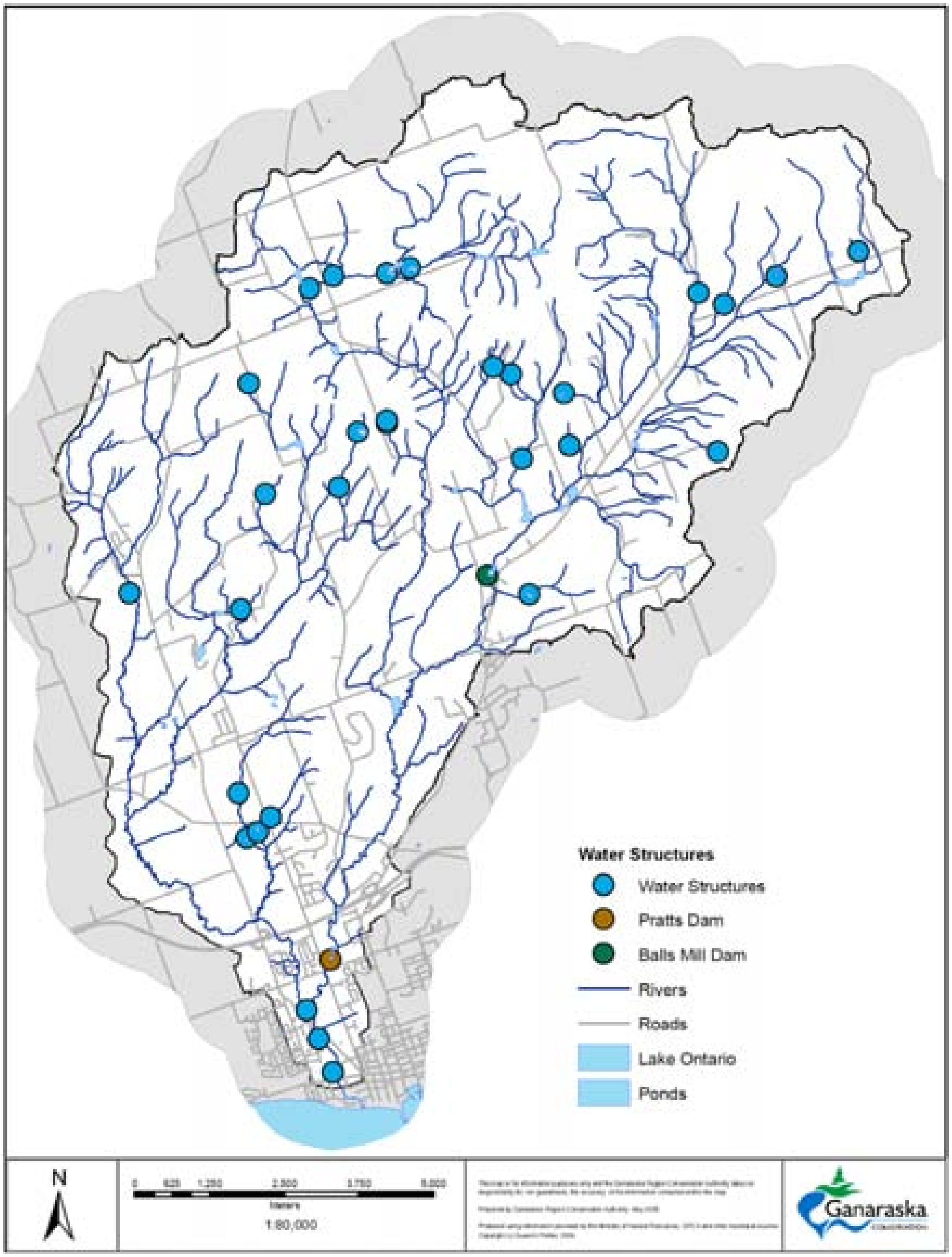


Figure 3.31: Water structures

3.4.3 Stream Gauge Stations

Starting in 1982, flow data has been collected in the Cobourg Creek watershed. Daily data is provided by the Hydroclimatological Data Retrieval Program (HYDAT) from Environment Canada. Descriptions of the gauge stations in the Cobourg Creek watershed are below, and Figure 3.32 shows their locations.

- Station 02HD822 is located downstream of King Street. The drainage area to the gauge is about 123 km^2. This gauge was installed in 1982. Water level and rainfall data are available for this gauge station. This station was discontinued after a replacement station (02HD019) was constructed in 2003, about one km upstream.

- Station 02HD019 is located at 609 William Street. This gauge was installed in 2003 and its drainage area is about 122 km^2. Water level, rainfall, and air and water temperatures are available for this gauge station. Data from 02HD822 can be used in conjunction with this station due to their close proximity to each other.

- Station 02HD022 is located at Telephone Road, about one km west of County Road 18 on the West Branch of Cobourg Creek. This gauge was installed in 2005. The drainage area to the gauge is about 34 km^2. Water level, and air and water temperatures are available for this gauge station.

- Station 02HD020 is located at County Road 45, about 0.5 km north of Old Harwood Road (County Road 15) on the Baltimore Creek Branch. This gauge was installed in 1999 and the drainage area to the gauge is about 41 km^2. Water level, rainfall, air and water temperatures, and wind speed and direction are available for this gauge station.

Station 02HD019 at 609 William Street can provide a glimpse at water flows within Cobourg 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 3.33 shows that between January and December monthly flows within Cobourg Creek are highest in March and lowest in August. These flows reflect 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 Cobourg Creek for each month, as measured at the William Street 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 Cobourg Creek.

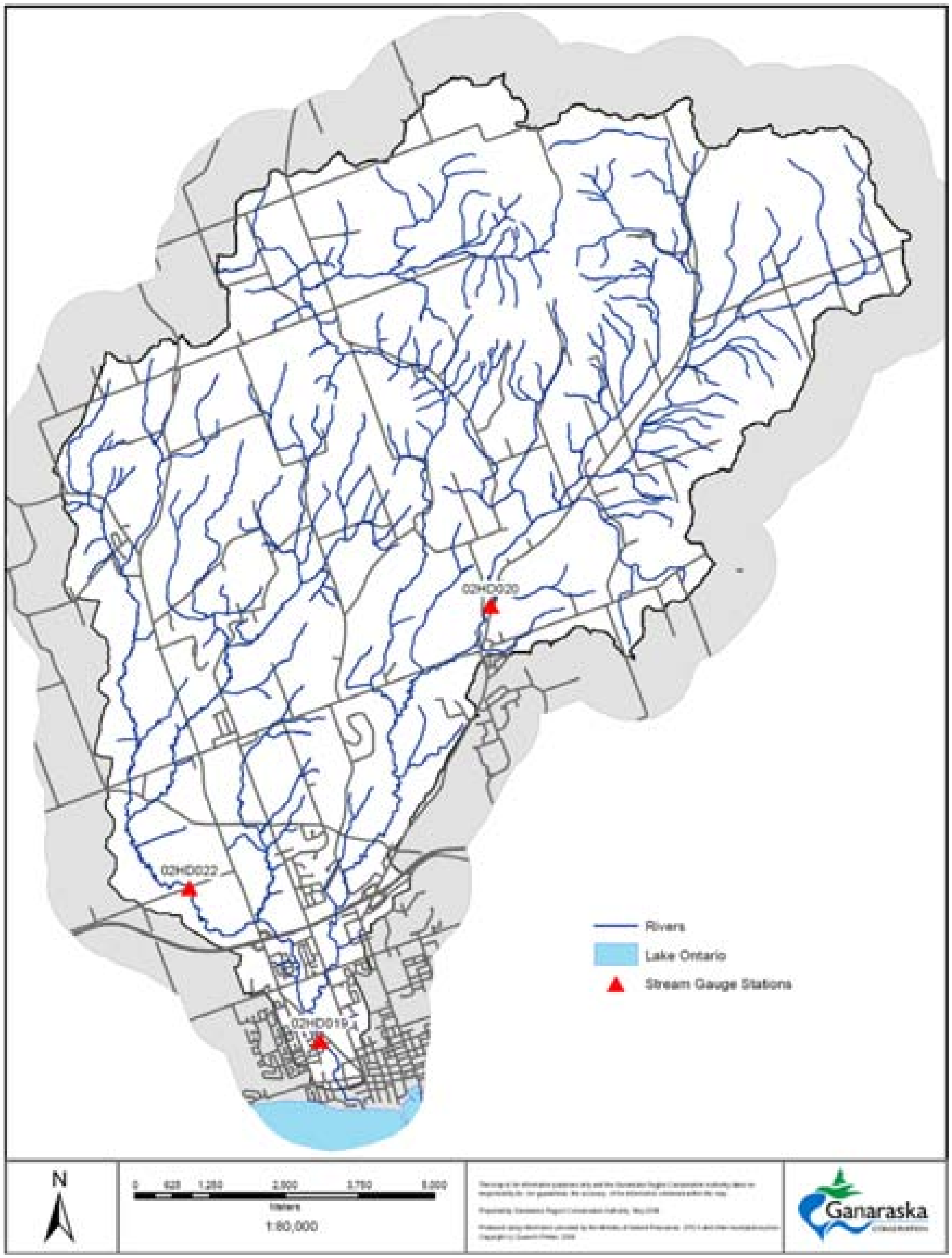


Figure 3.32: Stream gauge stations

Differences between years can also be observed at the William Street gauge station. In 2006 higher flows in Cobourg Creek were observed in the winter and fall compared to the mean monthly flows, with a summer flow near normal levels (Figure 3.33). The increase in flows can be attributed to increased surface runoff during the spring freshet and greater precipitation in the fall.

Flows in Cobourg Creek in 2007 were higher over a relatively short time period during the snowmelt runoff season (March and April) however summer baseflow conditions were below the mean monthly flow for an extended period of time (May to December) (Figure 3.33). This difference in monthly flows within Cobourg Creek can be attributed to the lack of precipitation in the summer. The difference in flow between 2006 and 2007 can also be seen through the annual mean flow. In 2006 the mean annual flow was 1.70 m^3/s compared to 1.39 m^3/s in 2007.

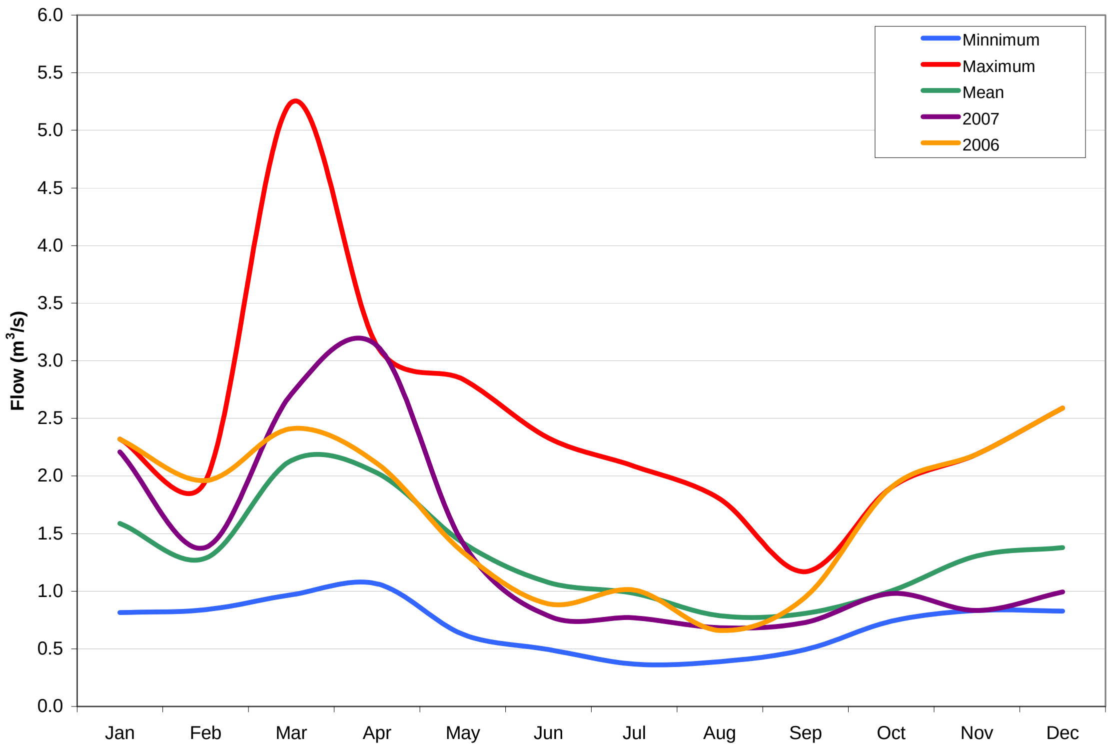


Figure 3.33: Cobourg Creek flows at the William Street gauge station

Flow data is also available from the Baltimore and Telephone Road gauge stations, which can be used in comparing flows at different locations within the watershed. Limited data exists at these sites to analyze mean monthly flows between years. Figure 3.34 indicates that mean monthly flows are lower at that receives water from a larger drainage area.

The Baltimore and Telephone Road gauge stations have comparable drainage areas, yet flows at the Baltimore gauge (annual mean flow = 0.54 m^3/s) are greater than flows at the Telephone Road gauge (annual mean flow = 0.44 m^3/s). This difference could be related to the contribution of groundwater as baseflow in Cobourg Creek within the drainage area to the Baltimore gauge. This possible contribution of baseflow is also seen in Figure 3.34 by higher flows during July and August baseflow, when Cobourg Creek is sustained primarily by groundwater contributions. The difference in baseflow contribution between the two catchments may also be due to baseflow loss within the sandy areas of the former Lake Iroquois shoreline located upstream of the Telephone Road gauge. Section "Baseflow" describes in detail the baseflow conditions within Cobourg Creek.

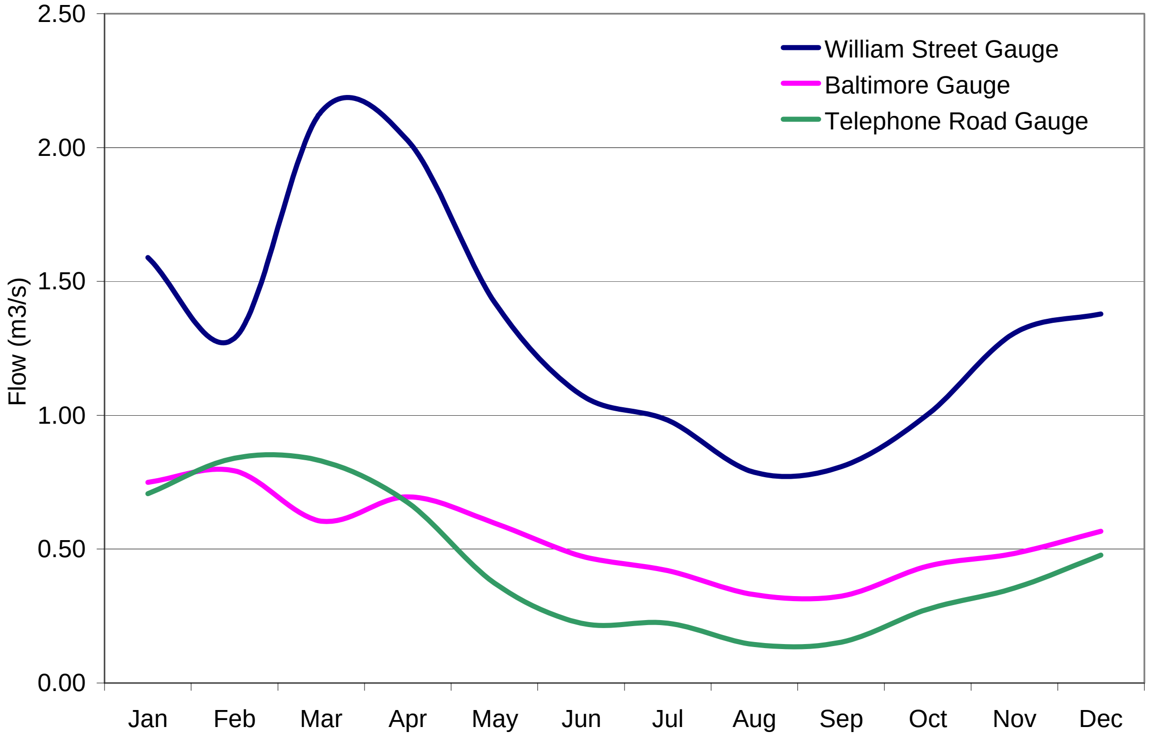


Figure 3.34: Mean monthly flows at Cobourg Creek gauge stations

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

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 for 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 2007c). At the local level, this facilitates the monitoring of water levels, information collection and program delivery.

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 3.7). Methods used to determine threshold levels are defined in Ganaraska Region Conservation Authority (2007c).

Table 3.7: 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 < 7.6mm 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 2007c)

Once a low water condition has been identified, an appropriate response is carried out. The following, as defined in Ganaraska Region Conservation Authority (2007c), 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 that 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 Cobourg Creek watershed has experienced a Level 1 low water condition in 2005 and 2007. As such, a voluntary reduction in water use by 10% was encouraged.

3.5 Surface Water Analysis

Analyzing surface water can be done from a flow perspective and a use perspective. Understanding the quantity, the characteristics, and the effects of water flow and resources allows for protection of surface water and residents near surface water. The following sections discuss hydrology, hydraulics, floodplains and water budgeting of the surface waters of the Cobourg Creek watershed.

3.5.1 Cobourg 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 use, infiltration and evaporation to determine the runoff associated with a rainfall.

Cobourg Creek was modeled in 2006 by Greenland International Consultants (Greenland Consulting Engineers 2006) and updated by the Ganaraska Region Conservation Authority (Ganaraska Region Conservation Authority 2007b). The hydrology model was calibrated using monitored flows from permanent stream gauges. The results of the updated model provide design storm flows for the two through 100-year return periods as well as the Regional Storm (Hurricane Hazel) for points throughout the watershed. The flow values were used as input into a hydraulic model that established regulatory floodlines within the Town of Cobourg boundaries.

Many hydrology studies have been completed for the Cobourg Creek watershed, all of which have been used in the current hydrology modeling project.

- MM Dillon. 1977. Floodplain Mapping Study, Township of Hamilton.
- Totten Sims Hubicki Associates. 1981. Town of Cobourg 5, 10, 25, 50 and 100-year flows.
- Totten Sims Hubicki Associates. 1984. Town of Cobourg Regional Floodline Review.
- Sandwell Swan Wooster Inc. Shoreline Management Study. December 1990.
- RV Anderson Associates. 1992. Cobourg/Midtown Creeks MDP study.
- Totten Sims Hubicki Associates. 2002. Burnham Street North Stormwater Management Pond – Retrofit 2002 Design Brief.
- Paul Theil Associates Limited. 1992. Stormwater Management Planning Study Cobourg Creek – Elgin Street/Burnham Street West.
- Totten Sims Hubicki Associates. 2003. Densmore Road Realignment Stormwater Management Pond Design Brief.
- Greenland Consulting Engineers. 2006. Cobourg Creek Watershed Hydrology Update – draft.

Methods

Return Periods

Rainfall volumes were provided by Atmospheric Environment's (AES) Mostert gauge in Bowmanville, the closest AES gauge to the Town of Cobourg. It was felt that this gauge provided the most representative and conservative data for the hydrology study.

Three different parameters were reviewed regarding rainfall to generate return period events that represent extreme conditions. These parameters were the total volume of rain, storm duration, and rainfall distribution. The worst-case storm (the duration and distribution producing the highest discharges at key nodes (locations)) was selected as the critical event for the watershed. The flows generated in this way represent a conservative approach providing a high level of protection for watershed residents.

The Regional Storm event applicable to watercourses in this region of Ontario is Hurricane Hazel, with a total rainfall of 285 mm. Only the last 12 hours of the storm was applied to the model, with soil moisture characterized by antecedent moisture content (AMC) condition III (saturated), or AMC (III).

Sub-catchments

Catchment areas for the key creek nodes were selected at individual sub-catchment outlets, keeping in mind parameters upstream of the node, including surficial geology, fisheries information, major hydraulic features and land use. For the areas outside of the Town of Cobourg boundary, Arc Hydro Version 1.1 was used in conjunction with Ministry of Natural Resources 5-metre Digital Elevation Model and enhanced flow direction grid 1.0 to automatically delineate the creek's watershed into sub-catchments. Within Town of Cobourg boundaries, plan/profile drawings were reviewed to determine sub-catchment and sewer shed boundaries. Field visits confirmed sub-catchment breakpoints where there were gaps in the data, and staff at the Town of Cobourg was consulted to confirm findings.

Sub-catchments whose total imperviousness readings were less than 20% were coded using the NASH rural unit hydrograph (NASHHYD) and sub-catchments of 20% or greater total imperviousness were coded using the urban Standard Unit Hydrograph (STANDHYD). In this way, runoff from urban and rural areas was referred to differently in the model.

Flows

The area, channel length and overland flow length of each sub-catchment were derived using Arc Hydro. In this process, the downstream node is selected by the user, and Arc Hydro calculates the longest flow path, both overland and in the channel.

The Time of Concentration represents the length of time required for all areas of a sub-catchment to contribute flow to the outlet. It includes the flow paths for overland flow, channel flow within the catchment, and main channel flow from where the catchment flow path intersects the main channel to the downstream channel node. The Time to Peak is the time required for the watershed to generate the maximum flow response from a storm event.

Runoff

The Soil Conservation Service curve number (CN) is used to determine runoff. Modellers must choose which antecedent moisture condition (AMC I, II or III) is relevant for the model: AMC I represents a dry soil condition and AMC III represents saturated soil.

For the hydrology study, the 2002 ELC (Ecological Land Classification) and other GIS (Geographic Information System) data were used to extract land use, drainage area, soils, and hydrologic soils group data, and a weighted CN (AMC

II) value was calculated. Where categories were different, the hydrologist decided which categories best fit the land use. For instance, pits and quarries were defined with a CN value equivalent to streets and roads (dirt).

Soils information, land use and analysis through aerial photography were used to determine the runoff capability of catchments in the Cobourg Creek watershed.

Hydrologic model

Each sub-catchment has one channel cross-section representing an average geometry for the routing reach; this information was inputted to the channel-routing routines in the model. Within Town of Cobourg boundaries, the cross-section information was obtained from the 2006 Light Detection and Ranging (LiDAR) data geometry. Upstream of Town of Cobourg boundaries, Ganaraska Region Conservation Authority staff cut new sections from the Digital Elevation Model data and provided a general description of base flow channel characteristics at each cross-section. A conservative approach was used by generalizing the base flow section as the smallest that would occur naturally.

The VO2 model was calibrated and it verified the existing conditions land use scenario using available observed flow and rainfall data. Flow data from 1999 to 2004 was used from the William Street gauge, and rainfall data was used from the Environment Canada STP climate station. Detailed methods pertaining to all steps in creating the hydrology model can be found in Ganaraska Region Conservation Authority (2007b).

<u>Hydrology Model Results</u>

The Ganaraska Region Conservation Authority scrutinized the rainfall events used in the Greenland model, and decided that two of the storms were too small to be used for calibration. Hence the following storms were used in the calibration process (Table 3.8).

Table 3.8: Summary of Calibration/Verification Storms

Rainfall Event	Rainfall Depth (mm)	Event Type
June 25, 2000	32.5	Calibration
May 22, 2001	19.0	Verification
October 5, 2001	22.5	Calibration
October 15, 2003	34.5	Calibration

The 24-hour AES storm provided the critical event in the model. Table 3.9 shows the flows calculated by the GRCA models for the two to 100-year events.

Table 3.9: GRCA Peak Flows (2 and 100 year events)

Node	2 yr (m^3/sec)	10 yr (m^3/sec)	50 yr (m^3/sec)	100 yr (m^3/sec)	Regional (m^3/sec)
907 (Golf Course)	10.8	14.0	23.4	28.0	253.7
3023 (East Branch)	10.9	14.6	24.3	29.0	253.7
3045 (West Branch)	11.7	15.4	25.0	29.8	227.5
3046 (Main Branch)	22.3	30.0	49.2	58.6	469.0
3047 (Lake Ontario)	22.8	30.3	49.6	59.0	465.6

Future Land Use Scenario

The Town of Cobourg and the Township of Hamilton official plans were used as a basis for creating a future land use map Figure 3.35. It was assumed all developable areas, as indicated in the Official Plans, would be fully built out. It was also assumed that the sub-catchment slopes would remain unchanged. New CN values and Times to Peak were calculated for each sub-catchment. Table 3.10 highlights the changes in the 100-year and Regional flow for key nodes in the model.

Table 3.10: Future Flows based on Official Plan Full Build-out

Node	Flow (m^3/s)			
	100-year Flows		Regional Flows	
	Existing	Future	Existing	Future
907 (Golf Course)	28.00	28.06	253.65	247.30
3023 (East Branch)	29.03	29.09	253.68	247.33
3045 (West Branch)	29.79	30.07	227.46	224.94
3046 (Main Branch)	58.57	58.98	468.96	460.95
3047 (Lake Ontario)	59.04	59.48	465.59	458.09

It is expected that when land development occurs, the rate of runoff increases. This was the case for the 100-year peak flow rates; they increased slightly (1%) in the revised model. Interestingly, the Regional flow rates decreased slightly (2%) for future conditions. Upon review of this phenomenon, it was discovered that the existing and future scenario hydrographs were identical throughout the watershed, except for the cases where individual sub-catchment land use changed significantly, necessitating a change in the model from a NASHHYD command to a STANDHYD command. Sub-catchment 20 in the Baltimore growth area is an example of this change. The following hydrographs (Figures 3.36 to 3.38) show the resulting changes at node 3010 (immediately upstream of sub-catchment 20), in sub-catchment 20 itself, and at node 3011 (immediately downstream of sub-catchment 20).

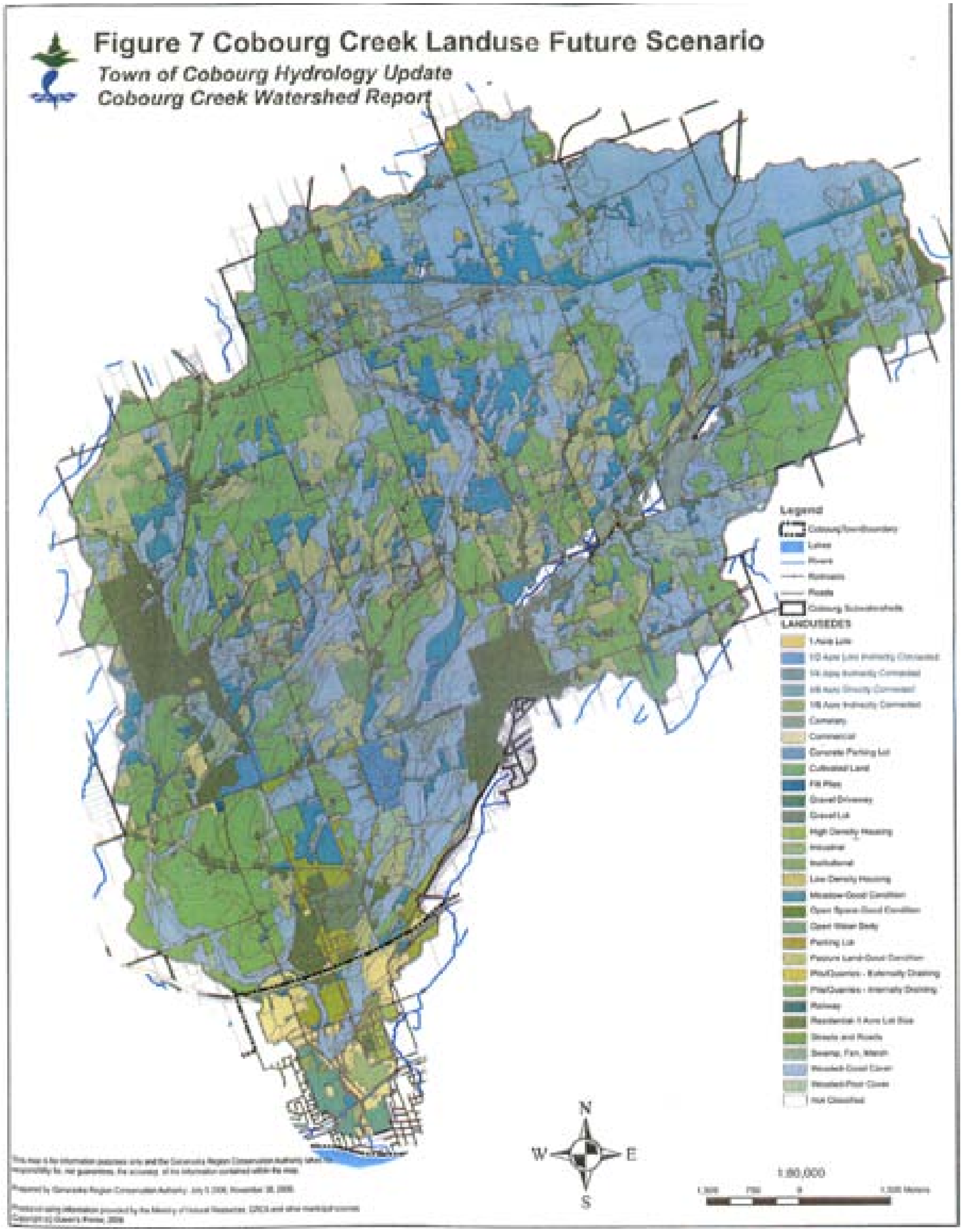


Figure 3.35: Future land use for hydrology study

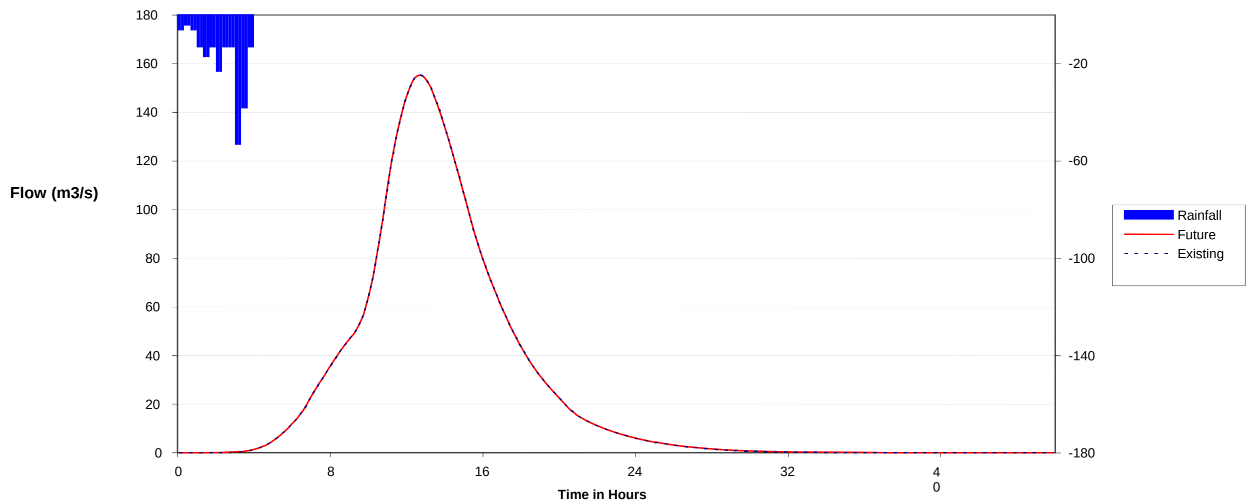


Figure 3.36: Comparison of existing and future flows in Cobourg Creek at Node 3010

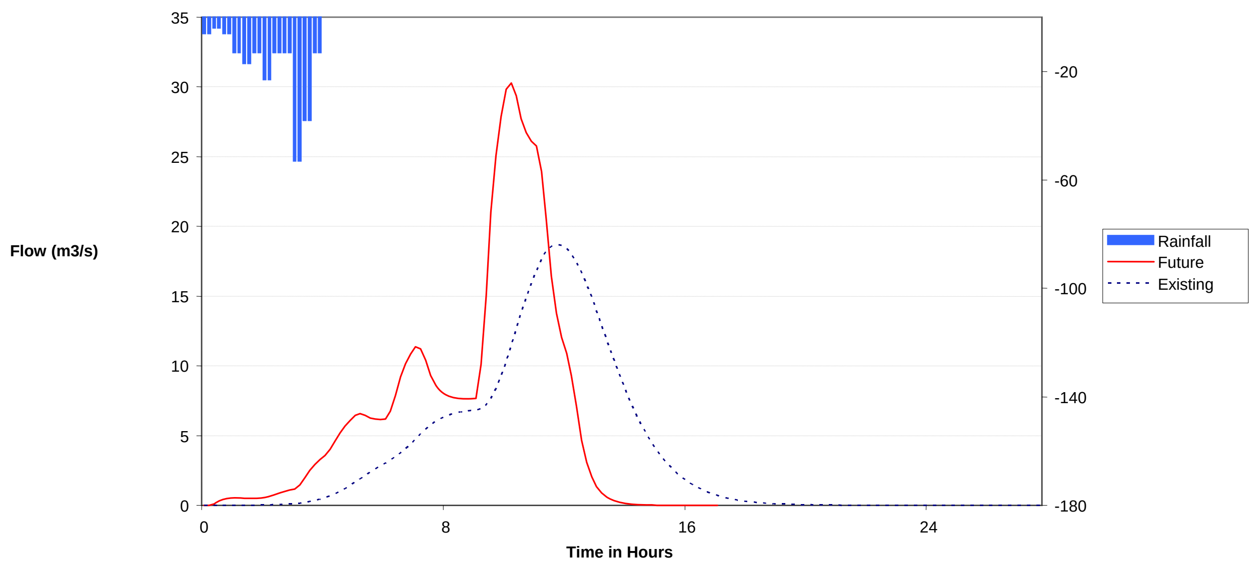


Figure 3.37: Comparison of existing and future flows in Cobourg Creek at Node 20

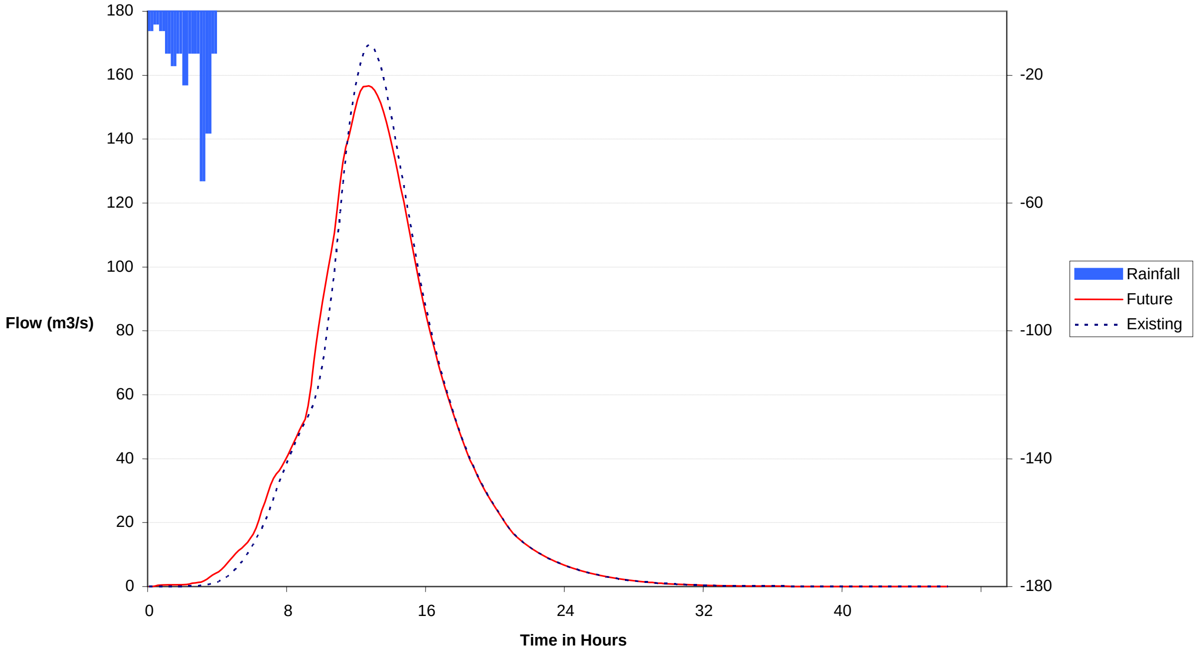


Figure 3.38: Comparison of existing and future flows in Cobourg Creek at Node 3011

As can be seen in Figure 3.38, the future scenario hydrograph has a lower peak. This is a direct result of the faster response rate of response for sub-catchment 20 to rainfall events under future development conditions. The peak flow rate is higher for the sub-catchment, but since it occurs earlier, when summed with the upstream node hydrograph, the resulting hydrograph has a lower peak flow rate. Since this is a Regional flow model, the construction of future stormwater management ponds will not change this phenomenon. This is consistent in the future scenario model for the hydrographs downstream of sub-catchments four, 13 and 20 (Ganaraska Region Conservation Authority 2007b).

Conclusions and Recommendations of Hydrology Analysis

The results of the new hydrologic model for Cobourg Creek are reasonable and are the best estimate of flow; therefore they were used in the establishment of new regulatory floodlines for Cobourg Creek within the Town of Cobourg boundaries. Ganaraska Region Conservation Authority (2007b) recommended that the calibrated peak flow rates for the 100-year AES 24-hour storm, as well as the calibrated peak flow rates from Hurricane Hazel, be used as input to the Cobourg Creek floodplain mapping.

It was further recommended that the future development scenario be used as input to the hydraulics model, as this model produces greater peaks than the peak flows generated from existing land use. Finally, it was recommended that the Town of Cobourg develop new flood plain policies to reflect these new flood lines. Policies developed will have to reflect the use of both the 100-year AES 24-hour storm, as well as the calibrated peak flow rates from Hurricane Hazel.

3.5.2 Hydraulics Analysis

Hydrology determines the amount of flow generated by a storm. Computer models use rainfall, land area and use, infiltration, and evaporation to determine the runoff associated with a rainfall (Section 3.0). Hydraulics models take runoff results from the hydrology models and convey it down the river system, estimating the extent of the area flooded by (or needed to carry) the flow.

Generally, development is regulated within the floodplain to limit the potential loss of life and damage to property. Within the Cobourg Creek watershed many settlement areas were historically 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.

There has been a long history of floodplain mapping work within the Cobourg Creek watershed. All steams with drainage areas larger than a quarter square mile have been floodplain mapped. The latest mapping for the majority of the watershed dates to 1977 with the completion of an extensive floodplain mapping project by M.M. Dillon (1977).

In 2006 the Ganaraska Region Conservation Authority in conjunction with the Town of Cobourg embarked on an endeavour to update the floodplain mapping for the four major creek systems within the municipal boundaries of the Town of Cobourg, including Cobourg Creek (Ganaraska Region Conservation Authority 2007b). The modeling for Cobourg Creek is based on work that was completed over 25 years ago for rural areas (M.M. Dillon 1977), and over 10 years ago for urban areas (R.V. Anderson Associates Limited 1992). The original mapping is still based on an imperial database and some of the original data is not available in digital form. Within the rural areas this mapping is sufficient to define flood hazards. It was realized that with the increased development pressures within the urban area of the Town of Cobourg, there was a need for a more accurate tool and mapping to assess the impacts of new development.

The Town of Cobourg update also incorporated the improvements available using current technologies, including the updated hydrology models using Visual OTTHYMO, updated topography using Light Detection and Ranging (LiDAR) technology, updated structure information, and hydraulic calculations using the most current HEC-RAS computer program. This enabled more accurate information to be used to put together the modeling tools that could also identify and quantify spills and impacts to flood-susceptible properties.

Flood Flows
As stated in the *Floodplain Management in Ontario Technical Guidelines* (Ontario Ministry of Natural Resources 1985), *"The Regulatory Floods selected for the Province are designed to accomplish the main objectives of floodplain management, to prevent loss of life and to minimize property damage and social disruption. The Regulatory Flood is the basis of which floodplains are delineated."*

The Cobourg Creek watershed lies within Zone 1, as defined by the MNR 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 within the Ganaraska Region Conservation Authority have their Regulatory Flood defined using a Hurricane Hazel-based event. As noted previously, all flood flow estimates to be used for hydraulic evaluations are described in Section 3.5.1.

Floodplain Calculations
The hydraulic models developed are based upon aerial photography and LiDAR field surveys. The in-field topographic survey required for this work was also an important element of the mapping exercise. The HEC-2 and HEC-RAS hydraulic models, from the U.S. Army Corps of Engineers, were used for computation of water surface elevations for floodplain mapping purposes. All aspects of the hydraulic modeling efforts will be consistent with guidelines published by the Hydrologic Engineering Center.

Hydraulic Model Results
The hydraulic analysis was completed using the HEC-RAS model, Version 3.13. The HEC-RAS model was run, assuming no obstructions (i.e., ice or debris) at any crossing structures, to calculate water surface profiles for the return period and Regional flood events. Water surface elevations were computed for the 100-year and Regional Storm. A summary of water surface elevations for the 100-year and Regional Storms at key crossings within the Town of Cobourg is provided in Table 3.11.

Table 3.11: Summary of water surface elevations at key crossings within the Cobourg Creek watershed

Crossing Location	River Station	100 Year water surface elevation (masl)	Regional Storm water surface elevation (masl)
Highway 401	4733.24	94.53	97.68
Elgin Street	3289.31	86.39	90.50
William Street	1960.00	82.96	86.73
Harden Street	1536.89	80.49	82.45
CP/CN Railroad	1339.10	79.73	94.00
University Avenue	1122.87	78.71	80.87
King Street	793.11	77.05	79.22

Hydraulics and Floodplain Summary

Floodplain mapping is available for all areas of Cobourg Creek including the historic built-up areas within the watershed. Development proposals must continue to address this issue in order to protect persons and property from flooding hazards.

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 that 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*" regulations, 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 *O. Reg. 168/06*, in the Cobourg 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 within the watershed (Figure 3.39). 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 that 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, that 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 potentially dangerous slopes
- To reduce soil erosion from valley slopes
- To regulate the draining or filling of wetlands that 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, and
- To make information available regarding erosion-prone areas to interested parties (Ganaraska Region Conservation Authority 2005).

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'.* 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 within the Cobourg Creek watershed.

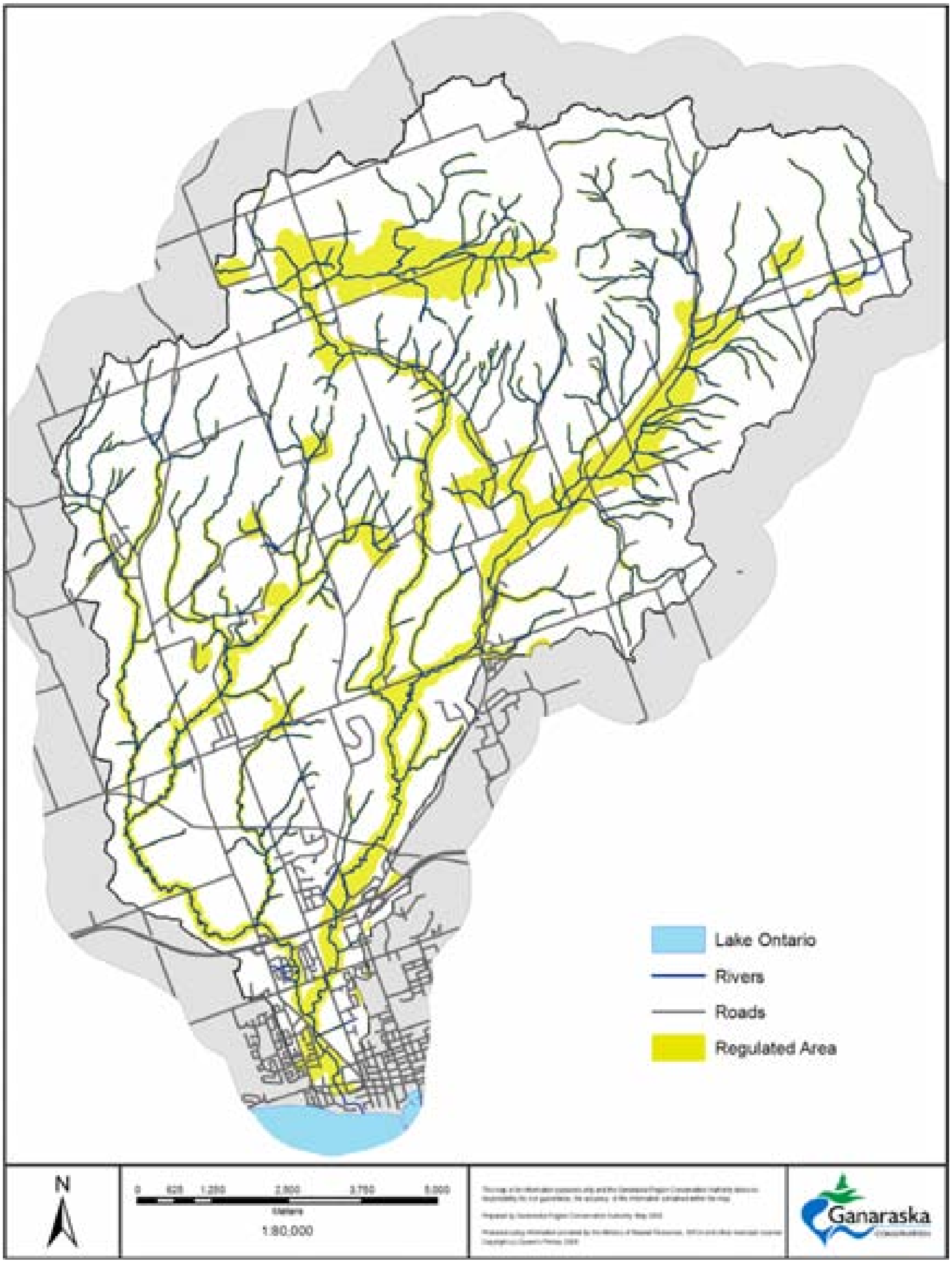


Figure 3.39: Regulated areas

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 Flood Line, 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 100 years.

The Regulatory Floodline is determined through a computer simulation of the specified storm centred over the watershed in question. This model takes into account watershed features including soils (type and degree of saturation), vegetation, grade and existing land uses, and it defines the water surface elevations that will be produced by the storm. Figures 3.40 and 3.41 displays the application of this model in delineating the Regulatory Floodline.

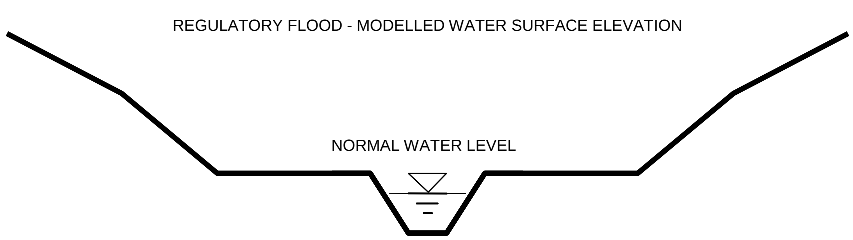


Figure 3.40: Watercourse cross-section with a Regulatory Floodline

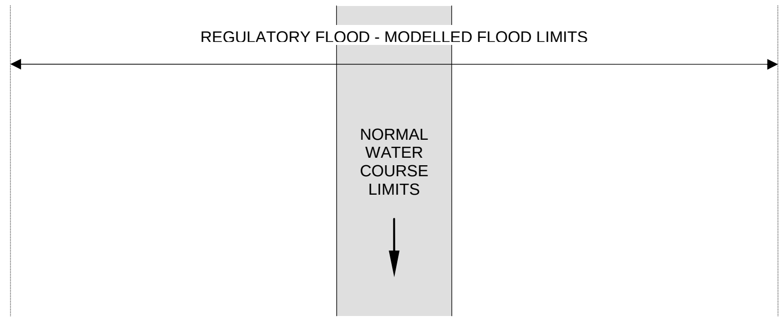


Figure 3.41: Plan view of a watercourse with a Regulatory Floodline

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 3.42.

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 3.42 and 3.43 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).

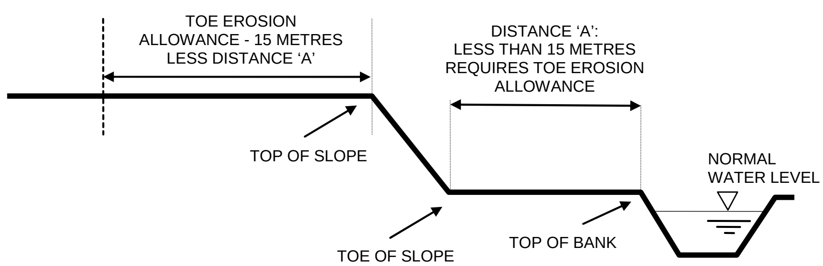


Figure 3.42: Watercourse cross-section with Toe Erosion Allowance

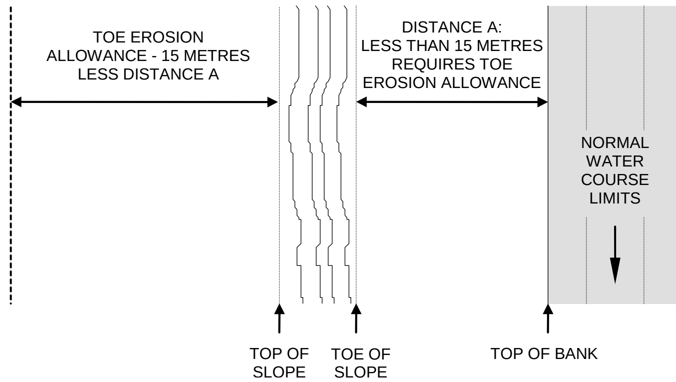


Figure 3.43: Plan view of watercourse with Toe Erosion Allowance

Slope Stability Allowance

Slopes are also naturally subject 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 3.44 shows the application of the Stable Slope Allowance.

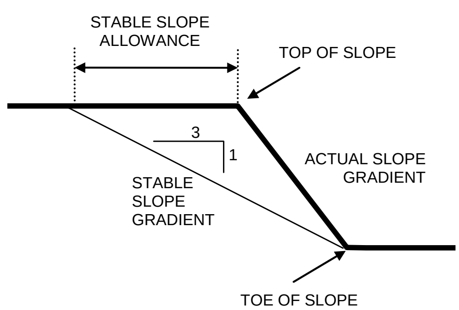


Figure 3.44: Stable Slope Allowance

Access Allowance

In addition to the above-mentioned Toe Erosion and Stable Slope Allowances, a minimum five 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 3.45 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).

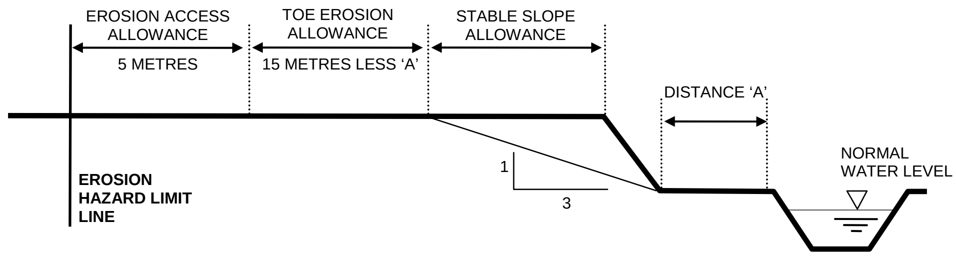


Figure 3.45: Erosion Hazards Limit (for a confined system)

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 within 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; instead 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, reaches are defined as areas of similar topography along the watercourse and regions between confluences.

The Meander Belt Allowance provides a limit to development within 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 six metre Erosion Access Allowance. Figure 3.46 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 five 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 3.46.

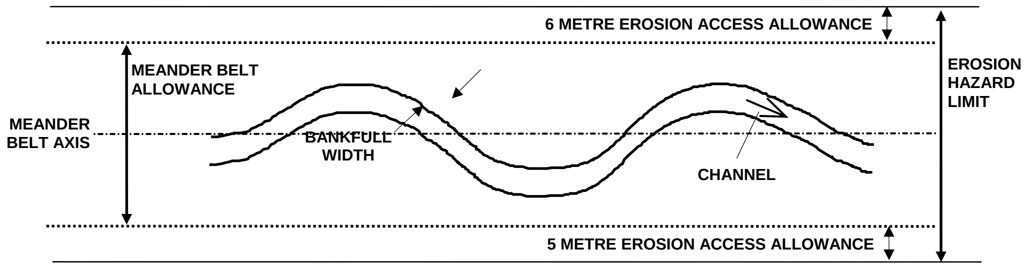


Figure 3.46: Erosion Hazard Limit (for an unconfined system)

Natural Hazard Limit - Riverine Hazards

The Toe Erosion Allowance, Stable Slope Allowance, Erosion Access Allowance, and the Meander Belt Allowance (where applicable) are applied in combination to every riverine system in the Cobourg 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 stated below. Section 28 under the *Conservation Authorities Act* acknowledges the same wetland definition as the *Provincial Policy Statement*.

> *Lands that are seasonally or permanently flooded by shallow water, as well as lands where the water table 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.*

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 ELC process) 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 2008c for further detail.

A water budget is a scientific 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. A water budget is not just a numeric model, but may contain a single model or a number of models. Water budgets will expand beyond the quantification of components in the water balance equation (precipitation, evapotranspiration, groundwater and surface water flow), and water use will be considered as part of the water budget.

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. Typically, the analysis includes the natural hydrologic cycle components and any human influences such as water takings. This type of analysis identifies the functional relationships between these 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. A water budget for a watershed 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, and surface or groundwater outflows, as well as any changes in storage within 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 indicated in Equation 1.

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)

(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, GIS layers were used in the model (Table 3.12), and the two stream gauges within Cobourg Creek were used to calibrate the model.

Table 3.12: 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 (Version 1.2) on the basis of DEM, Version 2 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 *Town of Cobourg Official Plan* (2002) and *Township of Hamilton Official Plan* (Ainley Group 2003).
Oak Ridges Moraine Hummocky Topography (MNR and YPDT-CAMC 2006)
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, 2004). Remove the permits of takings from large water bodies Ontario Lake and Rice Lake), together with temporary extractions. Remove the 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 Cobourg 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 of that watershed.

Surface Water Supply

The surface water supply in the Cobourg Creek watershed was evaluated using estimates of monthly values. 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 (HYDAT): Q_{p50} (Monthly median)
3. Stream flow monitoring (manual): monthly/bi-monthly measurements of base flow
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

Study Approach

The current study follows approaches 1 and 2 to estimate the surface water supply for the Cobourg Creek watershed. Since Cobourg Creek is gauged, the CANWET model was calibrated at the gauging location. The Q_{p50} of the simulated stream flows 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 for the Cobourg Creek watershed 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 for the Cobourg Creek watershed 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 Town of Cobourg and Township of Hamilton official plan designated lands (Figure 3.45). 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

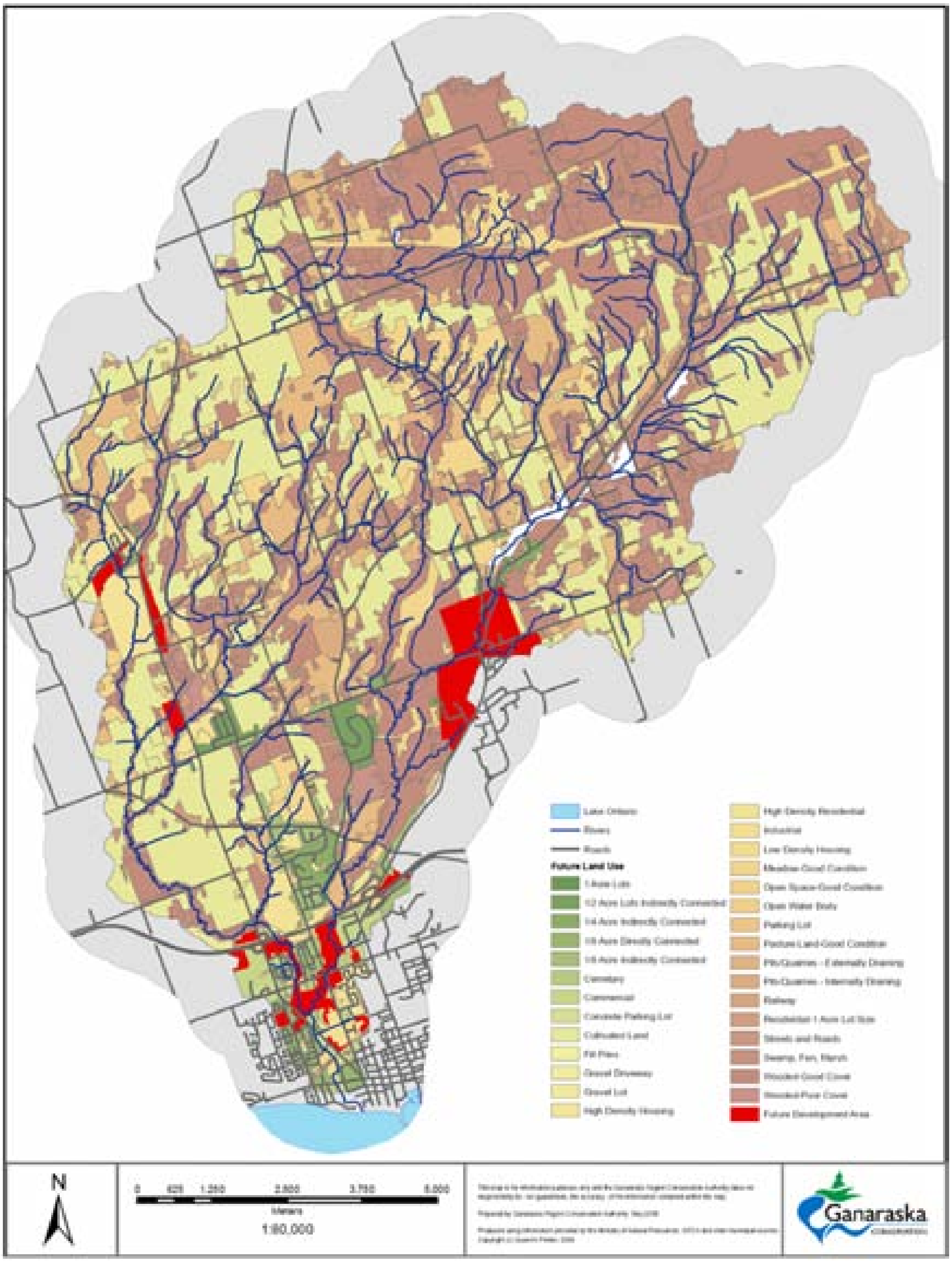


Figure 3.47: Future land use

The CGCM divides the globe into 3.75^o x 3.75^o grids and models climate data for each of these grids at varied time series. For this study, CGCM2 IPCC SRES "A2" GHG was used and future climate data was generated for 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 over-predict precipitation. The average annual precipitation for 20 years was 1276 mm, which is 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.

Groundwater Supply

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.”

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

- Base flow separation/water balance
- Calibrated continuous surface water model or groundwater model
- Calibrated soil moisture balance
- Experience

Study Approach

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 to 1995) and estimated annual groundwater recharge was then averaged to predict groundwater supply.

For the Cobourg Creek watershed, 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 Cobourg 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 base flow 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. These include 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’ uses, referring 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, which contains 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 the same unit within a reasonable time period (e.g., water bottling)

The locations of PTTW sites considered in the Cobourg Creek watershed water budget are shown in Figure 3.48, and detailed information regarding these takings is listed in Table 3.13. It is acknowledged that water is transferred from the Cobourg Creek watershed to the Midtown Creek watershed through the Creighton Heights Municipal Well. The well receives its water from the Cobourg Creek watershed and services residents outside of the watershed. However, given the limited amount of water used, these values are negligible for the purposes of this water budget and stress assessment.

Table 3.13: PTTW data for the Cobourg Creek watershed

Permit	Source	General Purpose	Specific Purpose	Demand Proportion	Consumptive Factor	Max Per Day (L/day)	Consumptive Annual Taking (m^3)
7578-6C5NRC	Surface	Commercial	Commercial	1	1	22,73,045	69,328
1652-645RX7	Ground	Commercial	Bottled Water	1	1	218,869	79,878
1652-645RX7	Ground	Commercial	Bottled Water	1	1	32,731	11,946
1652-645RX7	Ground	Commercial	Bottled Water	1	1	32,400	11,825
1711-6TVJ76	Ground	Water Supply	Municipal	0.5	0.2	245,000	887
1711-6TVJ76	Ground	Water Supply	Municipal	0.5	0.2	288,000	887
1711-6TVJ76	Ground	Water Supply	Municipal	0.5	0.2	274,000	887
1711-6TVJ76	Ground	Water Supply	Municipal	0.5	0.2	412,000	887
95-P-4019	Ground	Water Supply	Municipal	0.5	0.2	979,200	8,167

Non-permitted Water Use

In the Cobourg 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 recommends the use of 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, the non-serviced residential demand can be calculated using the typical water usage rate of 335 L/d/p (Litres per day per person).

Upon review of local water use, it has been determined that within the Cobourg 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.

Total population estimation

Statistics Canada Census data 2006 at DA level in the format of GIS database was obtained. The total population for the Cobourg Creek watershed is calculated by overlaying population DA polygons onto watershed polygons, breaking down by area and aggregating numbers. The population in the Cobourg Creek watershed is 9,427 people, based on Statistics Canada 2006, with a population density of 76.5 people/km^2. In the watershed 54% of population is serviced by municipal drinking water systems.

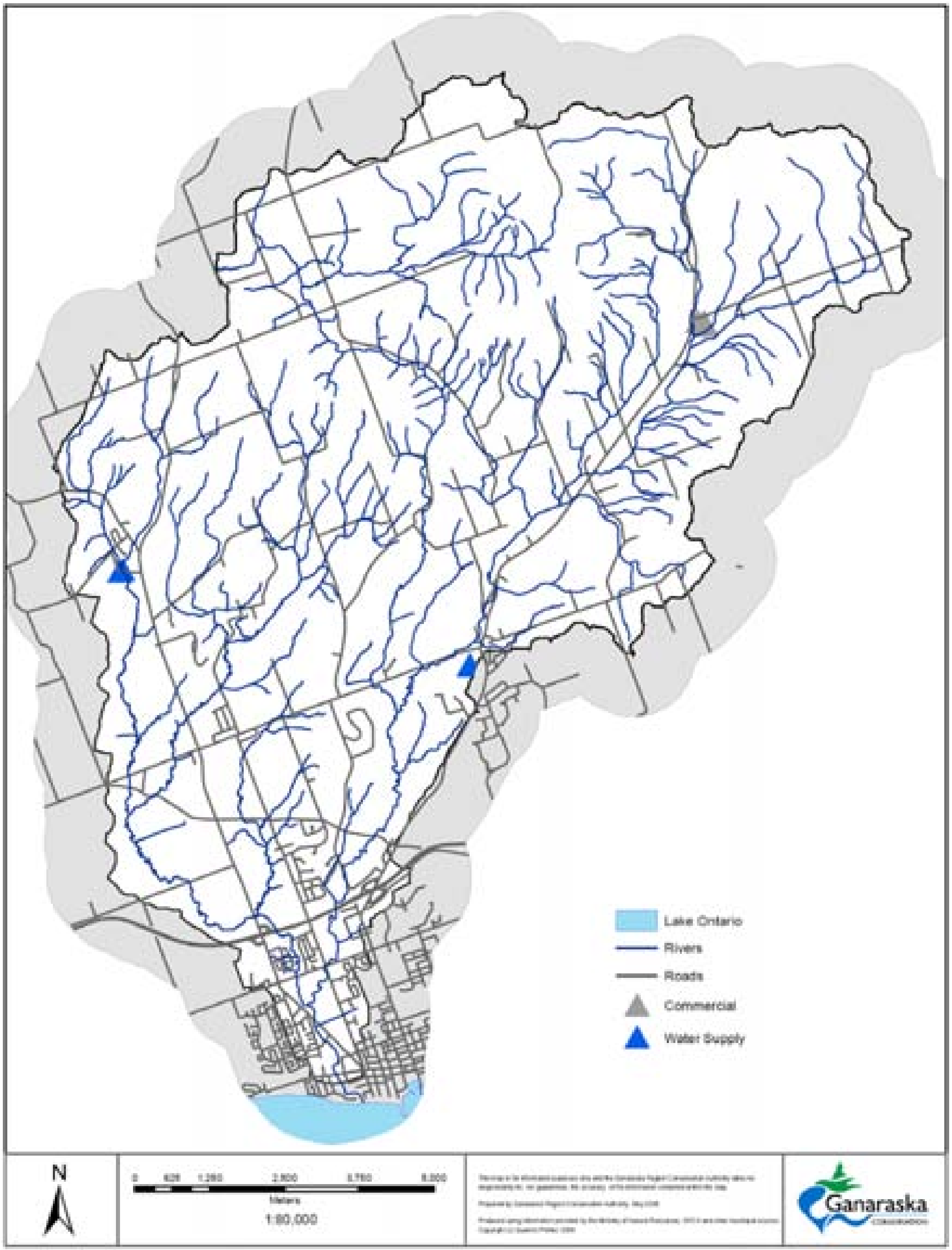


Figure 3.48: Permit to Take Water

Serviced population

Existing urban areas and urban development are located in and adjacent to the Town of Cobourg, and Creighton Heights and Camborne communities in the Township of Hamilton. These urban areas rely on municipal water supply systems. There are three municipal drinking water treatment plants that service populations within the Cobourg Creek watershed. One plant takes water from Lake Ontario and the other two systems withdraw water from groundwater.

The Cobourg Water Treatment Plant services a total municipal population of 18,000 people. The Camborne Municipal Well Field services a population of 200, and the Creighton Heights Municipal Well Field services a municipal population of 1,100 people. The serviced population data was broken down by overlaying the serviced area onto watershed population polygons.

Non-serviced water demand

Non-serviced water demand is calculated by combining non-serviced population and the recommended water usage rate 335 L/d/p. The results are presented in Table 3.14.

Table 3.14: Existing non-serviced residential water use

Watershed population	Serviced Population	Non-serviced Population	Percent Serviced	Non-serviced Residential Water Demand	
9,427	5123	4304	54	526,222	4.27 mm

Non-permitted Agricultural Water Demand

Ontario Ministry of the Environment (2007) recommends the use of De Loë (2002) methods which estimate agriculture water use based on the Statistics Canada 2001 agricultural census data at Census Consolidates Subdivision (CCS) level. The related GIS layer containing this information was obtained. Considering the fact that land use in the Cobourg Creek watershed has not experienced measurable changes in the past 5 years, the results from the De Loë method (2002) was used directly. This was done by overlaying the De Loë layer on the Cobourg Creek watershed polygons and aggregating the data. Non-permitted agricultural water use was estimated by subtracting permitted water takings 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 each GRCA watershed is reported in Table 3.15.

Table 3.15: Surface water non-permitted agriculture water use (m^3)

January to June	July	August	September to December	Annual
6,503 each month	43,098	43,098	6,503 each month	151,223

Future Scenario

For 25-year future scenarios, water demand was estimated by taking into account the increase in population serviced by the inland water source. The water demand for the municipal areas serviced by Lake Ontario is assumed to be a constant. 50.8% was estimated to represent the increases over 25 year time frame in the Township of Hamilton.

Water Reserve Estimation

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, 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 within the Cobourg 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 and kayaking, and navigation on local streams were assumed to be negligible. Therefore, the main function of reserved water within the Cobourg Creek watershed is to maintain the health of the natural ecosystem.

Surface Water Reserve

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 CANWET model were used for surface water reserve estimation. Both Q_{p90} and 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 reserves 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 is less reliable when this method was used in simulated streamflows instead of observed streamflows.

- Since Tessman method estimates water reserve based on mean values, the reserve values are less affected by simulation errors.

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 water supply. Due to this situation, Q_{p90} is utilized for estimation under future scenario with climate change. More investigation is required to determine the effect of climate change on water reserve.

Groundwater Reserve

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 within Ganaraska Region Conservation Authority watershed baseflow represents 40% to 60% of stream flow. Groundwater discharge to streams must be maintained to sustain base flow. The required reserve for the Cobourg 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 Cobourg 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. By the comparison between thresholds and estimated percent water demand, the Cobourg Creek watershed is 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.).

For the Cobourg Creek watershed stress assessments are undertaken on surface water and groundwater independently and evaluated for 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 3.16).

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

Table 3.16: 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 whether the watershed 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 climate change scenario uses the same methodology, equation and threshold table 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 3.17. Because groundwater sources and demand do not tend 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.

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

Table 3.17: 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 future scenario and future scenario with climate change. Finally, the stress level was classified by comparing results with the default stress thresholds in Table 3.17.

<u>Uncertainty</u>

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 analysis, 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” 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.

Water Budget Results for Cobourg Creek Watershed

The CANWET model was calibrated for the Cobourg Creek watershed for a two year period (2006 to 2007) against the observed streamflow data recorded at gauge 02HD019 on the Main Branch of Cobourg Creek at William Street. Figure 3.49 indicates a good agreement between observed and simulated stream flows. The calibrated model was therefore run for the three scenarios.

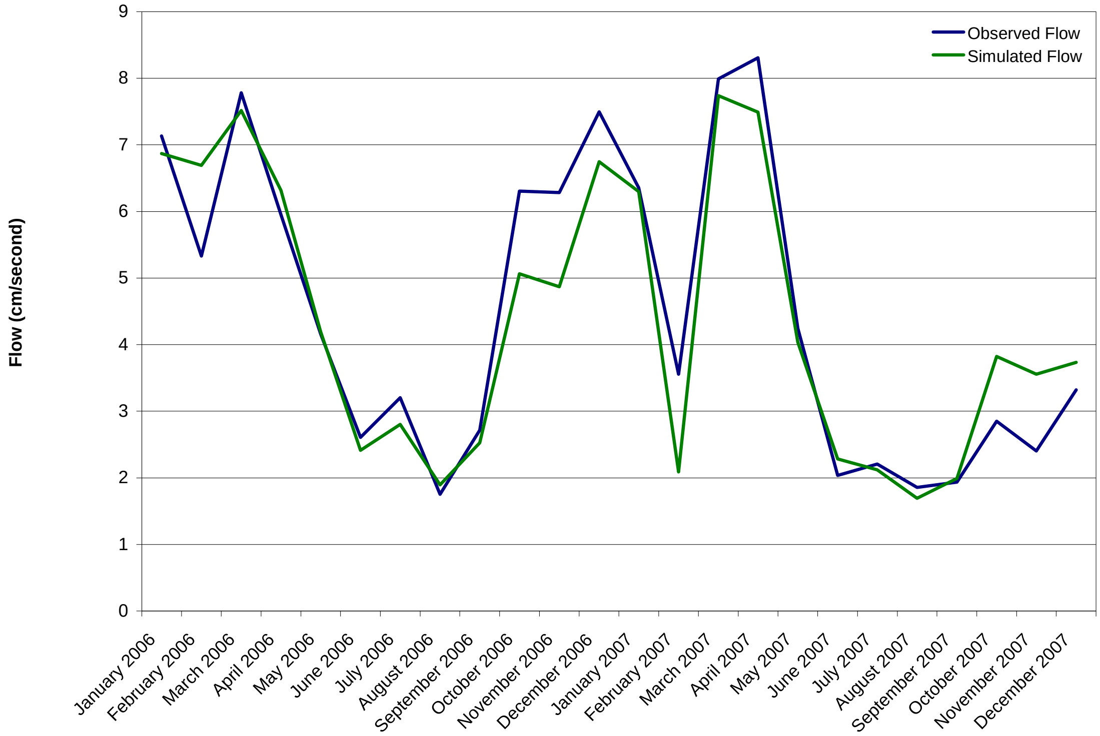


Figure 3.49: Simulated and observed monthly streamflow at the William Street gauge station

Existing Scenario

Figure 3.50 and Table 3.18 describe the elements of the water budget simulated by CANWET using long-term data for the Cobourg Creek watershed under the existing land use scenario.

Future Scenario

Figure 3.51 and Table 3.19 describe the elements of the water budget simulated by CANWET for the Cobourg Creek watershed using long-term existing climate data under the projected future land use scenario (Figure 3.47). The results showed negligible increase in streams flow compared to the existing land use scenario.

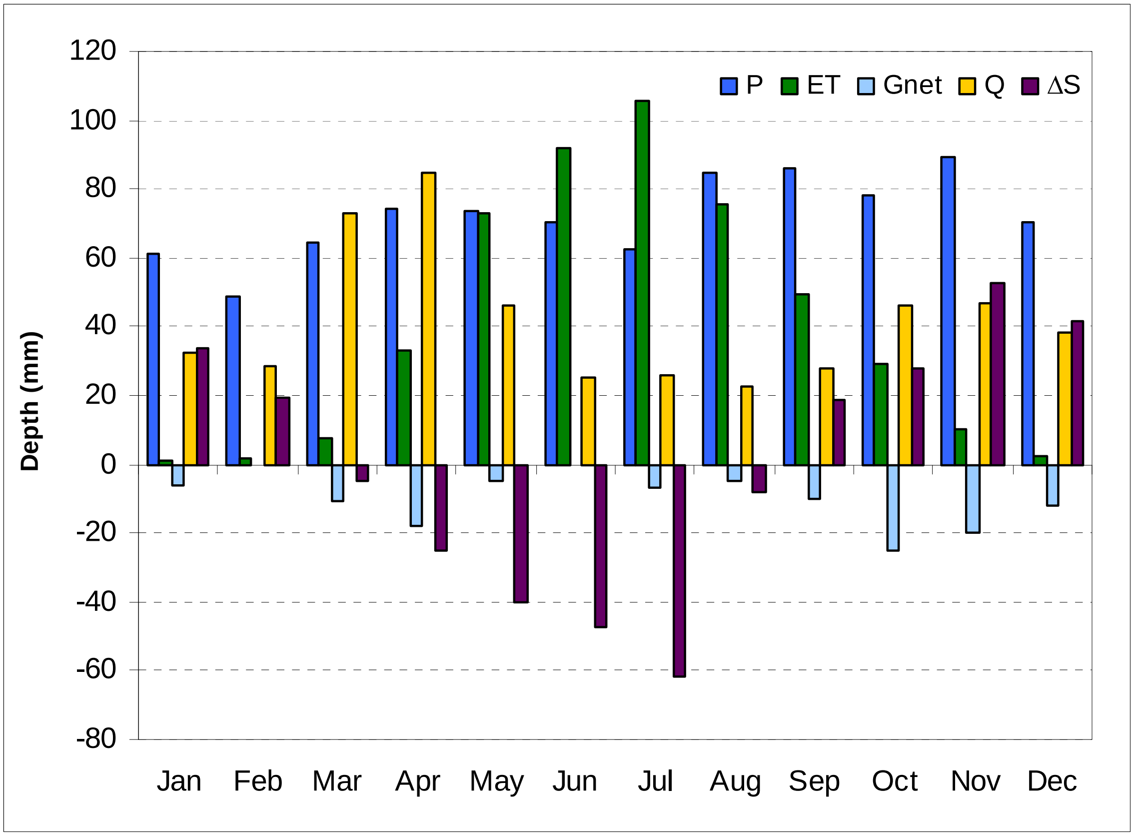


Figure 3.50: Cobourg Creek watershed under existing land use scenario

Table 3.18: Cobourg Creek watershed under 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	61.1	1	-6	32.8	33.3
February	49	1.6	0	28.6	18.8
March	64.7	7.6	-11	72.2	-4.1
April	74.5	32.8	-18	84.7	-25
May	73.8	73.1	-5	47.5	-41.8
June	70.1	91.9	0	25.8	-47.6
July	62.3	104.7	-7	25.6	-61
August	85	75.7	-5	22	-7.7
September	86	48.9	-10	27.3	19.8
October	78.1	28.9	-25	46.4	27.8
November	89.5	9.8	-20	46	53.7
December	70.5	2.3	-12	38.9	41.3
Annual	864.6	478.3	-119	497.8	

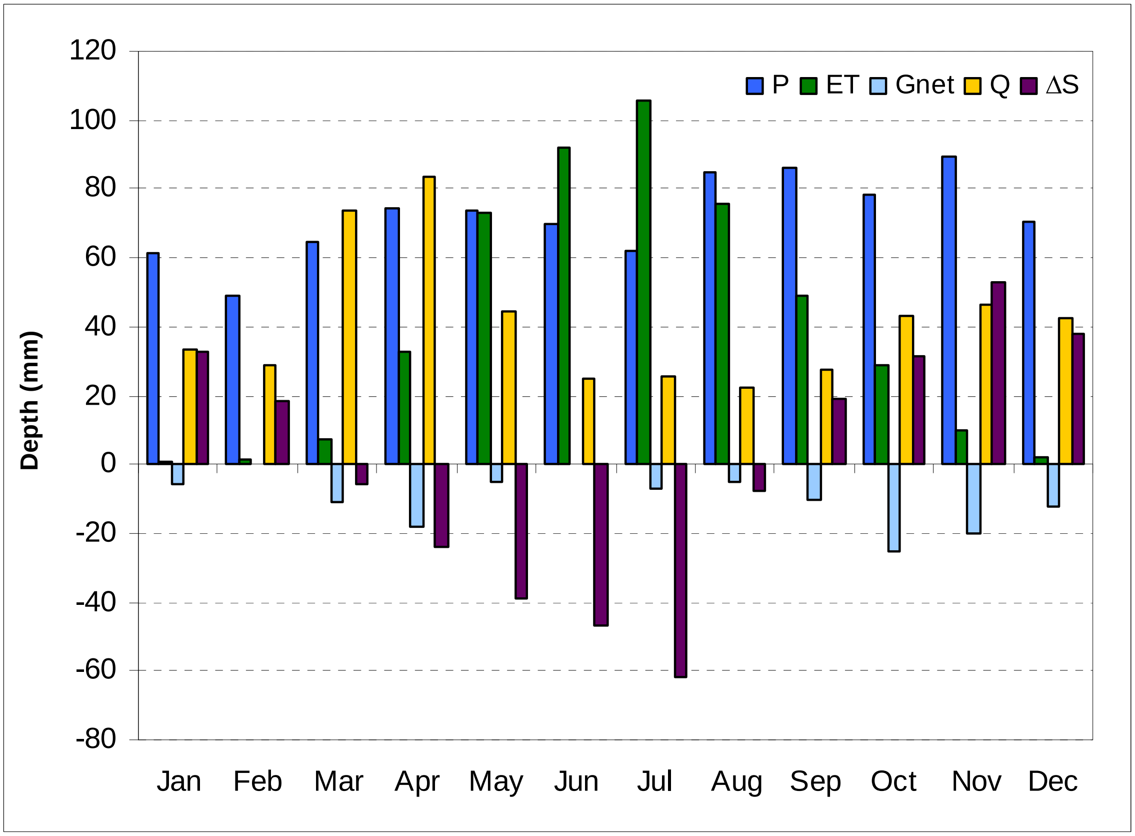


Figure 3.51: Cobourg Creek watershed under future land use scenario

Table 3.19: Cobourg Creek watershed under 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	61.1	0.9	-6	33.4	32.8
February	49	1.6	0	29.2	18.2
March	64.7	7.5	-11	73.7	-5.5
April	74.5	32.3	-18	84.7	-24.5
May	73.8	71.4	-5	46.8	-39.4
June	70.1	89	0	25.7	-44.6
July	62.3	104.7	-7	25.7	-61.1
August	85	76.2	-5	22.2	-8.4
September	86	48.7	-10	27.5	19.8
October	78.1	28	-25	46.8	28.3
November	89.5	9.6	-20	47.8	52.1
December	70.5	2.3	-12	40.5	39.7
Annual	864.6	472.2	-119	504	

Future Scenario with Climate Change

Figure 3.52 and Table 3.20 describe the elements of the water budget simulated by CANWET for the Cobourg Creek watershed using long-term climate data simulated by 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 CAWET model simulates significant increase in stream flow.

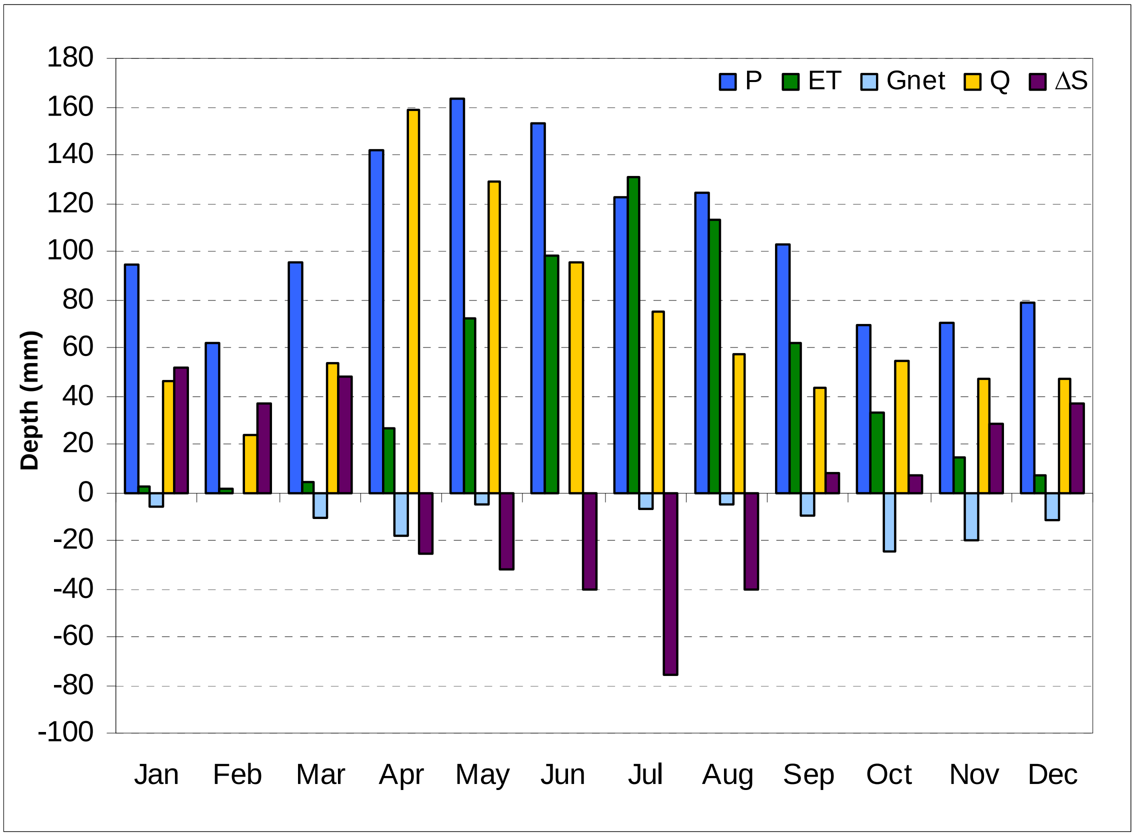


Figure 3.52: Cobourg Creek watershed under future land use scenario with climate change

Table 3.20: Cobourg Creek watershed under 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)	△S Change in Storage (mm)
January	94.5	2.6	-6	46.9	51
February	61.6	1.1	0	24.2	36.3
March	95.5	4.6	-11	53	48.9
April	141.6	26	-18	155	-21.4
May	163.1	70.1	-5	132	-34
June	153.2	95.2	0	97.7	-39.7
July	121.9	126.7	-7	76.4	-74.2
August	124	111.1	-5	58.2	-40.3
September	102.6	61.1	-10	44.5	7
October	69.3	32	-25	61.4	0.9
November	70.1	14	-20	48.1	28
December	78.9	7.2	-12	44.1	39.6
Annual	1276.3	551.7	-119	841.5	

Baltimore Creek Tributary Current Scenario

The CANWET model was set up and calibrated for the Baltimore Creek tributary for a two-year period (2006 to 2007) against the observed streamflow recorded at gauge station 02HD020, which is located in Baltimore. Figure 3.53 indicates good agreement between observed and simulated data. The calibrated model was run during the period of 1986 to 1995 under the current land use scenario. The elements of the water budget are described in Figure 3.54 and Table 3.21.

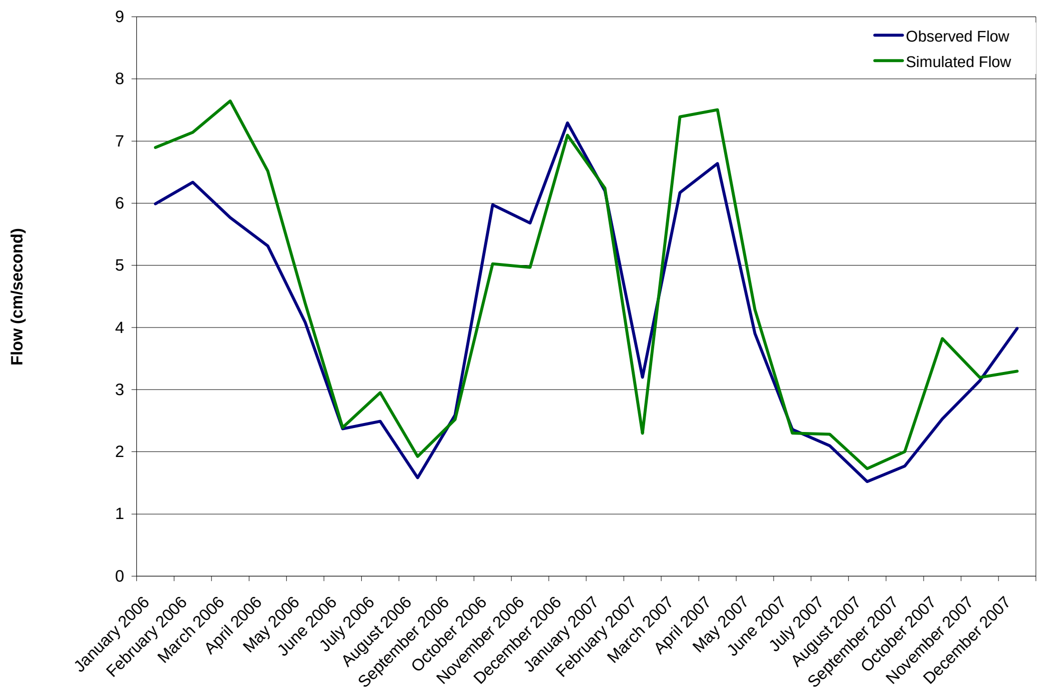


Figure 3.53: Simulated and observed monthly streamflow at the Baltimore gauge station

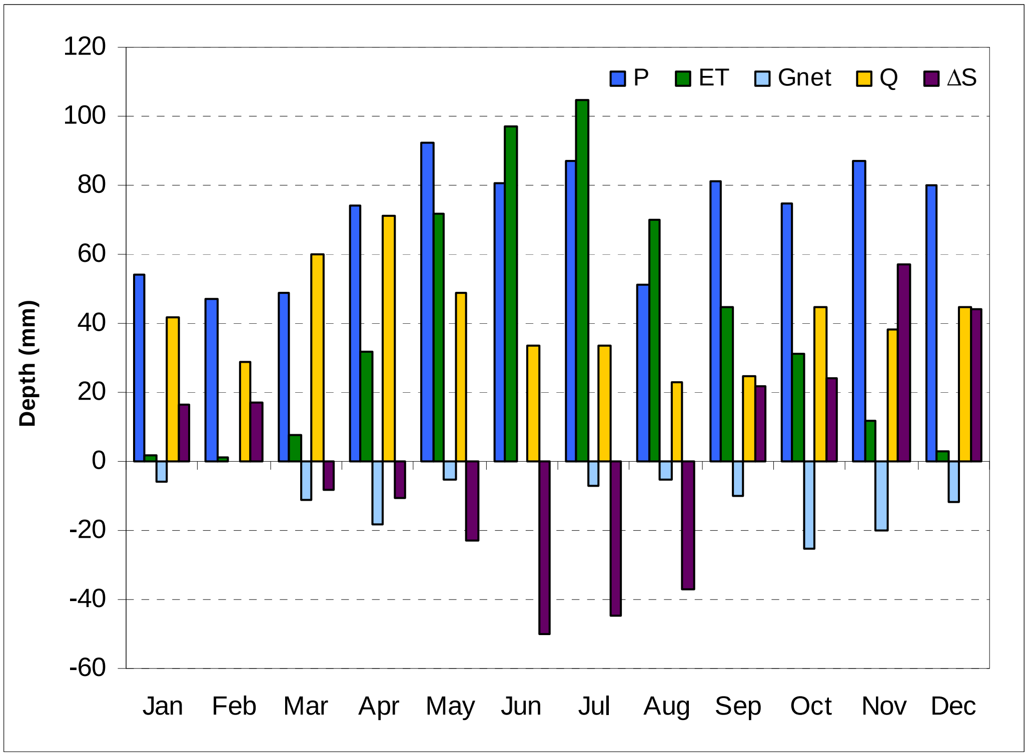


Figure 3.54: Baltimore Creek tributary under existing land use scenario

Table 3.21: Baltimore Creek tributary under 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	54.4	1.9	-6	41.9	16.6
February	46.8	1.3	0	28.6	16.9
March	48.9	7.9	-11	60.1	-8.1
April	74.2	31.9	-18	71.0	-10.7
May	92.6	71.7	-5	48.6	-22.7
June	80.6	97.0	0	33.5	-49.9
July	87.0	105.0	-7	33.6	-44.6
August	51.3	70.1	-5	23.1	-36.9
September	81.3	44.5	-10	24.8	22.0
October	74.7	31.1	-25	44.5	24.1
November	86.8	11.6	-20	38.4	56.8
December	79.8	3.1	-12	44.7	44.0
Annual	858.4	477.1	-119	492.8	

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 Tables 3.24 to 3.29.

Water Demand

The two municipal groundwater supply well fields are located at Camborne and Creighton Heights within the watershed. No reported water quantity issues have been identified with these wellfields. One PTTW location in the northeast is a multi-permit commercial water-taking targeting springs below the Oak Ridges Moraine for water bottling. In addition, one surface water source permit taking water from Baltimore Creek is issued to haul water in tankers primarily to fill or top up swimming pools.

Except for Camborne, Creighton Heights and the Town of Cobourg which are serviced by municipal water systems, other areas in the watershed are supported by private wells. The estimated pumped volume is 526,221 m^3 per year, with an estimated usage of 335 L/d/p.

The details of groundwater and surface water demand for each month are shown in Table 3.22. Groundwater use is uniform over the year, while for surface water there is a significantly higher summer usage due to water hauling for swimming pools, together with agricultural use. For the future scenario, the surface water demand is the same, and a 29% increase in groundwater demand is presented (Table 3.23).

Stress Assessment

Percent water demand calculation and stress assessment were conducted for the Cobourg Creek watershed. As shown in Tables 3.24 to 3.29 there is no indication that there are stresses under all three scenarios for both surface water and groundwater.

Uncertainty

The Cobourg Creek watershed is gauged with about 20 years of stream flow data. However, because the previous gauge station was influenced by the backwater of Lake Ontario, only two years of data of relatively good quality was used to set up the CANWET model. Several studies conducted, together with the regional groundwater model, enhance the understanding of the water system. The actual pumping records for the municipal water system at Camborne and Creighton Heights are provided by the Township of Hamilton. Other estimates of water demand are intended to be conservative. The limitations in the PTTW database, unknown consumptive factors and arbitrary assumptions in non-permitted demand calculations result in a significant uncertainty in water demand estimation. Because the watershed has been assigned a low stress level and the percent water demand estimate is far from the threshold of “moderate” stress, the uncertainty is not that important. The uncertainty can be evaluated as a “low” level.

Water Budget and Stress Assessment Summary

Three scenarios were run for the Cobourg Creek watershed—existing conditions, future conditions and future conditions under climate change effects. Both the existing and future conditions show that the Cobourg Creek watershed receives approximately 850 mm of precipitation a year. A large portion of this water is lost through evapotranspiration that increases in April and declines in October, with peak rates occurring in July. Groundwater recharge through stream inputs happen largely in March, April, October and November, and stream flow increases in March and April due to the spring freshet. Changes in storage occur from March to August, with the greatest loss occurring in July. This means that water stored in surface water, soil moisture and groundwater is being depleted through natural cycles and water use. Water is put back to storage in the period from September to February.

The Baltimore Creek tributary above the gauge station was analyzed on its own. This analysis revealed that the Baltimore Creek tributary has a larger change in storage than the Cobourg Creek watershed. This is shown with a change in storage of -7.7 mm in the Cobourg Creek scenario, compared to a change in storage of -36.9 mm in August in the Baltimore Creek tributary. Stream flow is more evenly distributed in Baltimore Creek tributary throughout the year due to a resilient groundwater contribution. Variability in storage can be in relation to an increase in groundwater inputs (as seen through increased flows) to the stream.

Under a scenario of future conditions with climate change effects, the Cobourg Creek watershed is expected to receive more precipitation, experience higher evapotranspiration rates, and experience more surface flows (due to increased precipitation). However, this provides a basic glimpse of a future with climate change. More work is required for modeling climate change.

Within the Cobourg Creek watershed, the surface water and groundwater stress assessment results in a “low” level of stress from water-taking reliability and water quantity perspective.

Table 3.22: Cobourg Creek watershed existing water demand estimation

Unit: m^3

Demand Type	Annual	January	February	March	April	May	June	July	August	September	October	November	December
PTTW	**192,861**	**10,609**	**9,421**	**10,272**	**10,015**	**45,698**	**44,557**	**10,554**	**10,811**	**10,000**	**10,351**	**10,104**	**10,469**
Groundwater	123,533	10,609	9,421	10,272	10,015	10,466	10,461	10,554	10,811	10,000	10,351	10,104	10,469
Surface Water	69,328	0	0	0	0	35,232	34,096	0	0	0	0	0	0
Non-Residential (G)	**105,244**	**8,770**	**8,770**	**8,770**	**8,770**	**8,770**	**8,770**	**8,770**	**8,770**	**8,770**	**8,770**	**8,770**	**8,770**
Non-Agriculture (S)	**138,942**	**5,975**	**5,975**	**5,975**	**5,975**	**5,975**	**5,975**	**39,598**	**39,598**	**5,975**	**5,975**	**5,975**	**5,975**
Total	**437,047**	**25,354**	**24,166**	**25,017**	**24,760**	**60,443**	**59,302**	**58,923**	**59,179**	**24,745**	**25,096**	**24,849**	**25,214**
Groundwater	228,777	19,380	18,191	19,042	18,785	19,236	19,232	19,325	19,581	18,771	19,121	18,874	19,240
Surface Water	208,270	5,975	5,975	5,975	5,975	41,207	40,070	39,598	39,598	5,975	5,975	5,975	5,975

Unit: mm

PTTW	**1.57**	**0.09**	**0.08**	**0.08**	**0.08**	**0.37**	**0.36**	**0.09**	**0.09**	**0.08**	**0.08**	**0.08**	**0.08**
Groundwater	1.00	0.09	0.08	0.08	0.08	0.08	0.08	0.09	0.09	0.08	0.08	0.08	0.08
Surface Water	0.56	0.00	0.00	0.00	0.00	0.29	0.28	0.00	0.00	0.00	0.00	0.00	0.00
Non-Residential (G)	**0.85**	**0.07**	**0.07**	**0.07**	**0.07**	**0.07**	**0.07**	**0.07**	**0.07**	**0.07**	**0.07**	**0.07**	**0.07**
Non-Agriculture (S)	**1.13**	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**	**0.32**	**0.32**	**0.05**	**0.05**	**0.05**	**0.05**
Total	**3.55**	**0.21**	**0.20**	**0.20**	**0.20**	**0.49**	**0.48**	**0.48**	**0.48**	**0.20**	**0.20**	**0.20**	**0.20**
Groundwater	1.86	0.16	0.15	0.15	0.15	0.16	0.16	0.16	0.16	0.15	0.16	0.15	0.16
Surface Water	1.69	0.05	0.05	0.05	0.05	0.33	0.33	0.32	0.32	0.05	0.05	0.05	0.05

Table 3.23: Cobourg Creek watershed future water demand estimation

Unit: m^3

Demand Type	Annual	January	February	March	April	May	June	July	August	September	October	November	December
PTTW	**192,861**	**10,609**	**9,421**	**10,272**	**10,015**	**45,698**	**44,557**	**10,554**	**10,811**	**10,000**	**10,351**	**10,104**	**10,469**
Groundwater	123,533	10,609	9,421	10,272	10,015	10,466	10,461	10,554	10,811	10,000	10,351	10,104	10,469
Surface Water	69,328	0	0	0	0	35,232	34,096	0	0	0	0	0	0
Non-Residential (G)	**169,135**	**14,095**	**14,095**	**14,095**	**14,095**	**14,095**	**14,095**	**14,095**	**14,095**	**14,095**	**14,095**	**14,095**	**14,095**
Non-Agriculture (S)	**138,942**	**5,975**	**5,975**	**5,975**	**5,975**	**5,975**	**5,975**	**39,598**	**39,598**	**5,975**	**5,975**	**5,975**	**5,975**
Total	**500,938**	**30,678**	**29,490**	**30,341**	**30,084**	**65,767**	**64,626**	**64,247**	**64,503**	**30,070**	**30,420**	**30,173**	**30,539**
Groundwater	292,668	24,704	23,515	24,366	24,110	24,560	24,556	24,649	24,905	24,095	24,445	24,199	24,564
Surface Water	208,270	5,975	5,975	5,975	5,975	41,207	40,070	39,598	39,598	5,975	5,975	5,975	5,975

Unit: mm

PTTW	**1.57**	**0.09**	**0.08**	**0.08**	**0.08**	**0.37**	**0.36**	**0.09**	**0.09**	**0.08**	**0.08**	**0.08**	**0.08**
Groundwater	1.00	0.09	0.08	0.08	0.08	0.08	0.08	0.09	0.09	0.08	0.08	0.08	0.08
Surface Water	0.56	0.00	0.00	0.00	0.00	0.29	0.28	0.00	0.00	0.00	0.00	0.00	0.00
Non-Residential (G)	**1.37**	**0.11**	**0.11**	**0.11**	**0.11**	**0.11**	**0.11**	**0.11**	**0.11**	**0.11**	**0.11**	**0.11**	**0.11**
Non-Agriculture (S)	**1.13**	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**	**0.32**	**0.32**	**0.05**	**0.05**	**0.05**	**0.05**
Total	**4.07**	**0.25**	**0.24**	**0.25**	**0.24**	**0.53**	**0.52**	**0.52**	**0.52**	**0.24**	**0.25**	**0.24**	**0.25**
Groundwater	2.38	0.20	0.19	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Surface Water	1.69	0.05	0.05	0.05	0.05	0.33	0.33	0.32	0.32	0.05	0.05	0.05	0.05

Table 3.24: Cobourg Creek watershed surface water stress calculation (existing 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	mm/month	% Water Demand		
January	1.32	27.70	0.78	16.37	0.54	11.33	5975	0.048	0.43%	Low	Low
February	1.14	24.00	0.78	16.37	0.36	7.63	5975	0.048	0.64%	Low	Low
March	3.39	71.35	1.37	28.88	2.02	42.47	5975	0.048	0.11%	Low	Low
April	4.05	85.30	1.61	33.89	2.44	51.41	5975	0.048	0.09%	Low	Low
May	2.30	48.35	0.90	19.00	1.39	29.35	41207	0.334	1.14%	Low	Low
June	1.24	26.00	0.78	16.37	0.46	9.63	40070	0.325	3.38%	Low	Low
July	1.19	25.10	0.78	16.37	0.41	8.73	39598	0.321	3.68%	Low	Low
August	1.06	22.30	0.78	16.37	0.28	5.93	39598	0.321	5.42%	Low	Low
September	1.25	26.35	0.78	16.37	0.47	9.98	5975	0.048	0.49%	Low	Low
October	2.16	45.35	0.88	18.55	1.27	26.80	5975	0.048	0.18%	Low	Low
November	1.92	40.45	0.87	18.41	1.05	22.04	5975	0.048	0.22%	Low	Low
December	1.69	35.55	0.78	16.37	0.91	19.18	5975	0.048	0.25%	Low	Low

Table 3.25: Cobourg Creek watershed 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	mm/month	% Water Demand		
January	1.35	28.30	0.79	16.57	0.56	11.73	5975	0.048	0.41%	Low	Low
February	1.16	24.40	0.79	16.57	0.37	7.83	5975	0.048	0.62%	Low	Low
March	3.42	71.90	1.40	29.48	2.02	42.42	5975	0.048	0.11%	Low	Low
April	4.06	85.40	1.61	33.87	2.45	51.53	5975	0.048	0.09%	Low	Low
May	2.25	47.40	0.89	18.73	1.36	28.67	41207	0.334	1.17%	Low	Low
June	1.21	25.55	0.79	16.57	0.43	8.98	40070	0.325	3.62%	Low	Low
July	1.20	25.35	0.79	16.57	0.42	8.78	39598	0.321	3.66%	Low	Low
August	1.07	22.45	0.79	16.57	0.28	5.88	39598	0.321	5.47%	Low	Low
September	1.26	26.55	0.79	16.57	0.47	9.98	5975	0.048	0.49%	Low	Low
October	2.16	45.35	0.89	18.71	1.27	26.64	5975	0.048	0.18%	Low	Low
November	1.99	41.80	0.91	19.13	1.08	22.67	5975	0.048	0.21%	Low	Low
December	1.82	38.25	0.79	16.57	1.03	21.68	5975	0.048	0.22%	Low	Low

Table 3.26: Cobourg Creek watershed surface water stress calculation (future scenario with climate change)

Month	Water Supply (Q_{p50})		Water Reserve (Q_{p10})		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	2.17	45.65	0.86	18.17	1.31	27.48	5975	0.048	0.18%	Low	Low
February	0.98	20.55	0.33	6.93	0.65	13.62	5975	0.048	0.36%	Low	Low
March	2.28	47.90	1.01	21.33	1.26	26.57	5975	0.048	0.18%	Low	Low
April	6.96	146.45	4.44	93.46	2.52	52.99	5975	0.048	0.09%	Low	Low
May	5.61	118.10	3.44	72.47	2.17	45.63	41207	0.334	0.73%	Low	Low
June	4.63	97.50	2.72	57.32	1.91	40.18	40070	0.325	0.81%	Low	Low
July	3.46	72.75	2.20	46.21	1.26	26.54	39598	0.321	1.21%	Low	Low
August	2.37	49.85	1.60	33.62	0.77	16.23	39598	0.321	1.98%	Low	Low
September	1.95	41.10	1.36	28.56	0.60	12.54	5975	0.048	0.39%	Low	Low
October	2.40	50.40	2.03	42.68	0.37	7.72	5975	0.048	0.63%	Low	Low
November	1.90	39.95	1.71	36.01	0.19	3.94	5975	0.048	1.23%	Low	Low
December	1.90	40.00	1.11	23.36	0.79	16.64	5975	0.048	0.29%	Low	Low

Table 3.27: Cobourg Creek watershed 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	1.74	36.58	0.174	3.66	1.56	32.93	19380	0.157	0.48%	Low	Low
February	1.74	36.58	0.174	3.66	1.56	32.93	18191	0.148	0.45%	Low	Low
March	1.74	36.58	0.174	3.66	1.56	32.93	19042	0.155	0.47%	Low	Low
April	1.74	36.58	0.174	3.66	1.56	32.93	18785	0.152	0.46%	Low	Low
May	1.74	36.58	0.174	3.66	1.56	32.93	19236	0.156	0.47%	Low	Low
June	1.74	36.58	0.174	3.66	1.56	32.93	19232	0.156	0.47%	Low	Low
July	1.74	36.58	0.174	3.66	1.56	32.93	19325	0.157	0.48%	Low	Low
August	1.74	36.58	0.174	3.66	1.56	32.93	19581	0.159	0.48%	Low	Low
September	1.74	36.58	0.174	3.66	1.56	32.93	18771	0.152	0.46%	Low	Low
October	1.74	36.58	0.174	3.66	1.56	32.93	19121	0.155	0.47%	Low	Low
November	1.74	36.58	0.174	3.66	1.56	32.93	18874	0.153	0.47%	Low	Low
December	1.74	36.58	0.174	3.66	1.56	32.93	19240	0.156	0.47%	Low	Low
Annual	20.86	439.00	2.086	43.90	18.78	395.10	228777	1.857	0.47%	Low	Low

Table 3.28: Cobourg Creek watershed 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	1.73	36.33	0.173	3.63	1.55	32.70	24704	0.201	0.61%	Low	Low
February	1.73	36.33	0.173	3.63	1.55	32.70	23515	0.191	0.58%	Low	Low
March	1.73	36.33	0.173	3.63	1.55	32.70	24366	0.198	0.60%	Low	Low
April	1.73	36.33	0.173	3.63	1.55	32.70	24110	0.196	0.60%	Low	Low
May	1.73	36.33	0.173	3.63	1.55	32.70	24560	0.199	0.61%	Low	Low
June	1.73	36.33	0.173	3.63	1.55	32.70	24556	0.199	0.61%	Low	Low
July	1.73	36.33	0.173	3.63	1.55	32.70	24649	0.200	0.61%	Low	Low
August	1.73	36.33	0.173	3.63	1.55	32.70	24905	0.202	0.62%	Low	Low
September	1.73	36.33	0.173	3.63	1.55	32.70	24095	0.196	0.60%	Low	Low
October	1.73	36.33	0.173	3.63	1.55	32.70	24445	0.198	0.61%	Low	Low
November	1.73	36.33	0.173	3.63	1.55	32.70	24199	0.196	0.60%	Low	Low
December	1.73	36.33	0.173	3.63	1.55	32.70	24564	0.199	0.61%	Low	Low
Annual	20.72	436.00	2.072	43.6	18.65	392.40	292668	2.376	0.61%	Low	Low

Table 3.29: Cobourg Creek watershed 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	2.83	59.62	0.283	5.96	2.55	53.66	24704	0.201	0.37%	Low	Low
February	2.83	59.62	0.283	5.96	2.55	53.66	23515	0.191	0.36%	Low	Low
March	2.83	59.62	0.283	5.96	2.55	53.66	24366	0.198	0.37%	Low	Low
April	2.83	59.62	0.283	5.96	2.55	53.66	24110	0.196	0.36%	Low	Low
May	2.83	59.62	0.283	5.96	2.55	53.66	24560	0.199	0.37%	Low	Low
June	2.83	59.62	0.283	5.96	2.55	53.66	24556	0.199	0.37%	Low	Low
July	2.83	59.62	0.283	5.96	2.55	53.66	24649	0.200	0.37%	Low	Low
August	2.83	59.62	0.283	5.96	2.55	53.66	24905	0.202	0.38%	Low	Low
September	2.83	59.62	0.283	5.96	2.55	53.66	24095	0.196	0.36%	Low	Low
October	2.83	59.62	0.283	5.96	2.55	53.66	24445	0.198	0.37%	Low	Low
November	2.83	59.62	0.283	5.96	2.55	53.66	24199	0.196	0.37%	Low	Low
December	2.83	59.62	0.283	5.96	2.55	53.66	24564	0.199	0.37%	Low	Low
Annual	34.00	715.40	3.400	71.54	30.60	643.86	292668	2.376	0.37%	Low	Low

3.5.5 Duration of Flows

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

Flow duration curves are generated by graphing the length of time a stream maintains a specific flow. This in turn shows the percentage of time a stream flows at a certain rate. As noted below, this simple graph can be interpreted to provide information on the resilience of a stream.

<u>Ecological Flow Modeling Results</u>

Baltimore Creek Gauge

Figure 3.55 shows the percentage of time flow is higher than the minimum required flows for ecological needs, calculated as the reserve value in the stress assessment process. This value has been calculated at 0.26 cubic metres per second (cms). This means that 85.8% of the time, Baltimore Creek above the gauge is experiencing flows that meet or exceed the minimum requirements of the aquatic ecology. Table 3.30 shows monthly flows and modeled ecological flow requirements.

As described in Section 3.4.5, because only two years of monitoring data are available for Cobourg Creek and Baltimore Creek gauge stations, the simulated streamflows from CANWET were used to set required flows for ecological needs. Table 3.30 lists streamflow characteristics at Baltimore Gauge based on simulated monthly streamflows from 1976 to 1995. Also, the daily flow duration curve was plotted based on two-year monitoring data to test the occurrence of ecological flow requirements calculated from Tessman.

William Street Gauge

Figure 3.56 shows the percentage of time flow is higher than the minimum required flows for ecological needs at the William Street gauge. This value has been calculated at 0.85 cms. This means that 79% of the time, Cobourg Creek above the William Street gauge is experiencing flows that meet or exceed the minimum requirements of the aquatic ecology. Table 3.31 shows monthly flows and modeled ecological flow requirements.

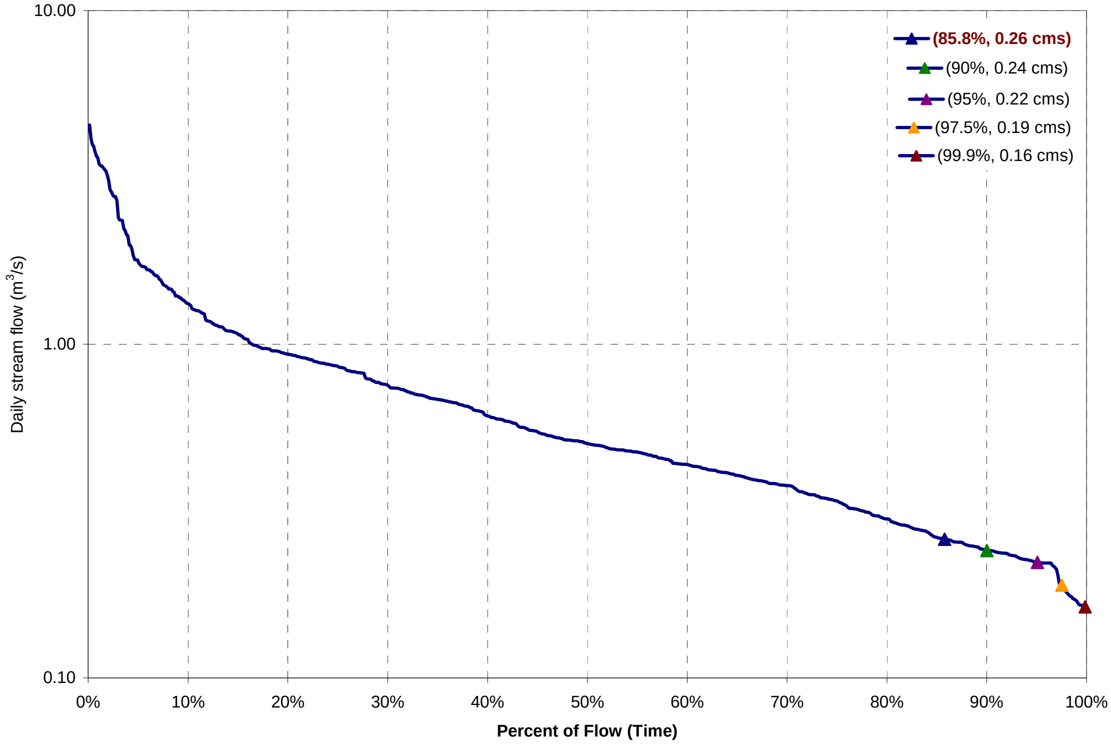


Figure 3.55: Flow duration curve at Baltimore Gauge 2006 to 2007

Table 3.30: Monthly flow characteristics at the Baltimore Gauge

Month	Monthly Mean Flow (cms)	Q50	Q90*	Tessman
January	0.52	0.45	0.19	0.26
February	0.45	0.37	0.10	0.26
March	1.11	1.10	0.82	0.44
April	1.36	1.36	0.77	0.54
May	0.79	0.81	0.52	0.32
June	0.42	0.43	0.27	0.26
July	0.41	0.40	0.33	0.26
August	0.35	0.35	0.26	0.26
September	0.43	0.42	0.34	0.26
October	0.73	0.72	0.62	0.29
November	0.69	0.59	0.49	0.28
December	0.61	0.54	0.35	0.26

* Ranked average monthly discharges for the period of simulation (1976 to 1995)

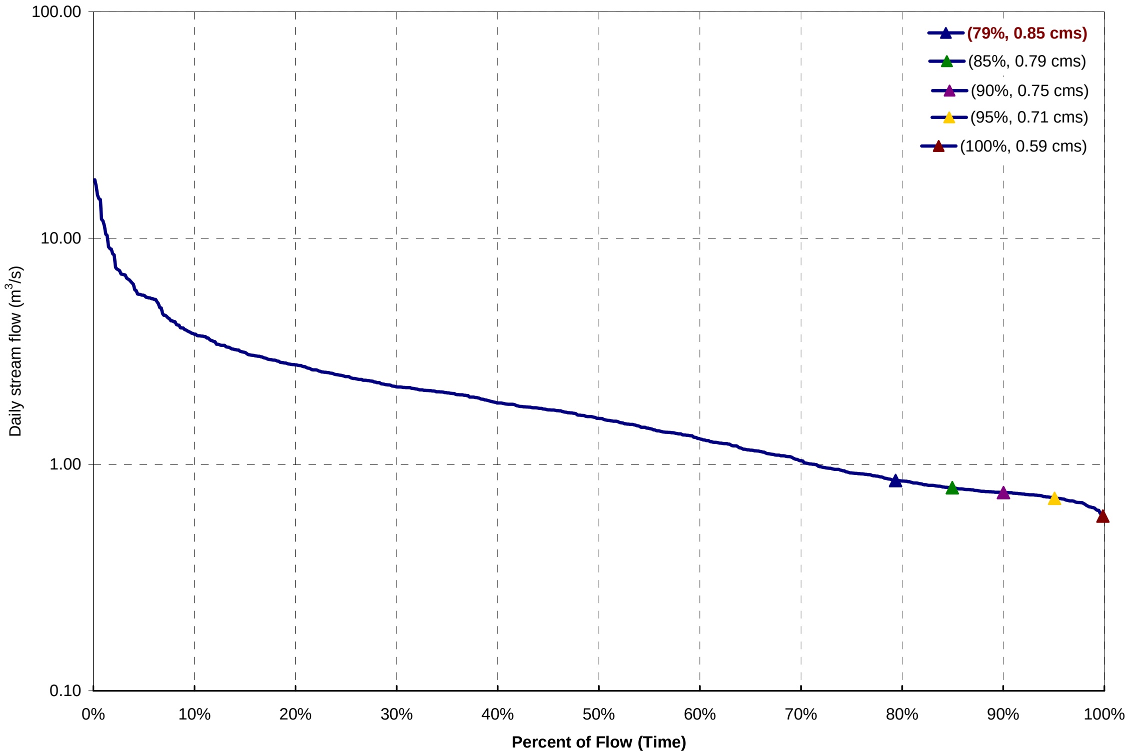


Figure 3.56: Flow duration curve at the William Street Gauge

Table 3.31: Monthly flow characteristics at the William Street Gauge

Month	Monthly Mean Flow (cms)	Q50	Q90*	Tessman
January	1.68	1.43	0.61	0.85
February	1.47	1.27	0.24	0.85
March	3.77	3.72	2.72	1.51
April	4.38	4.44	2.35	1.75
May	2.38	2.41	1.59	0.95
June	1.32	1.31	0.84	0.85
July	1.33	1.33	1.06	0.85
August	1.17	1.20	0.85	0.85
September	1.45	1.39	1.12	0.85
October	2.41	2.36	2.01	0.96
November	2.44	2.19	1.67	0.98
December	2.00	1.78	1.18	0.85

* Ranked average monthly discharges for the period of simulation (1976 to 1995)

This analysis has also been undertaken for the Ganaraska River and Wilmot Creek. The analysis shows that both the Ganaraska River and Wilmot Creek are able to produce minimum flows (reserve values) a greater percentage of the time (Ganaraska River 98% and Wilmot Creek 94%). The analysis on Cobourg Creek might indicate that there is more variance in flows, particularly low flows, and as such, the creek has a harder time maintaining aquatic and ecological functions. However, studies reveal that aquatic ecological functions are generally not stressed (Section 4.0). It is believed that flow duration issues demonstrated here may be removed as more data becomes available from the gauging stations.

3.6 GROUNDWATER QUALITY

Groundwater quality naturally varies from place to place, is affected by seasonal changes and local climate, and is affected by the types of soils and rocks through which water moves. When water from rain or snowmelt moves overland and through the ground, the water may dissolve minerals found in rocks and soils, percolate through organic material such as roots and leaves, and react 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.

Within the Cobourg Creek watershed, the most common dissolved substances in surface or groundwater are minerals and salts, which as a group are 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 2004b). 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 within the Cobourg Creek watershed. Adequate oxygen levels in water are a necessity for fish and other aquatic life. The following sections provide detailed information about the status of groundwater quality within the Cobourg Creek watershed.

Groundwater quality data for the Cobourg Creek watershed is potentially available from a wide variety of sources including the MOE 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, spatially (vertically in aquifer/aquitard units and horizontally within an individual aquifer) and temporally 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 the water wells in the Cobourg Creek watershed are private except for municipally-operated wells. Many of these private wells supply water to permanent residents, whereas other wells are used for agricultural purposes including livestock watering and 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 in the area based on data from private wells. A key understanding of these aquifers comes from the analysis of the information in the MOE Water Well Record Database. The sand and gravel deposits of glaciofluvial and glaciolacustrine origins are the main aquifers in the area. Within the Cobourg 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 Cobourg Creek watershed where overburden is relatively thin.

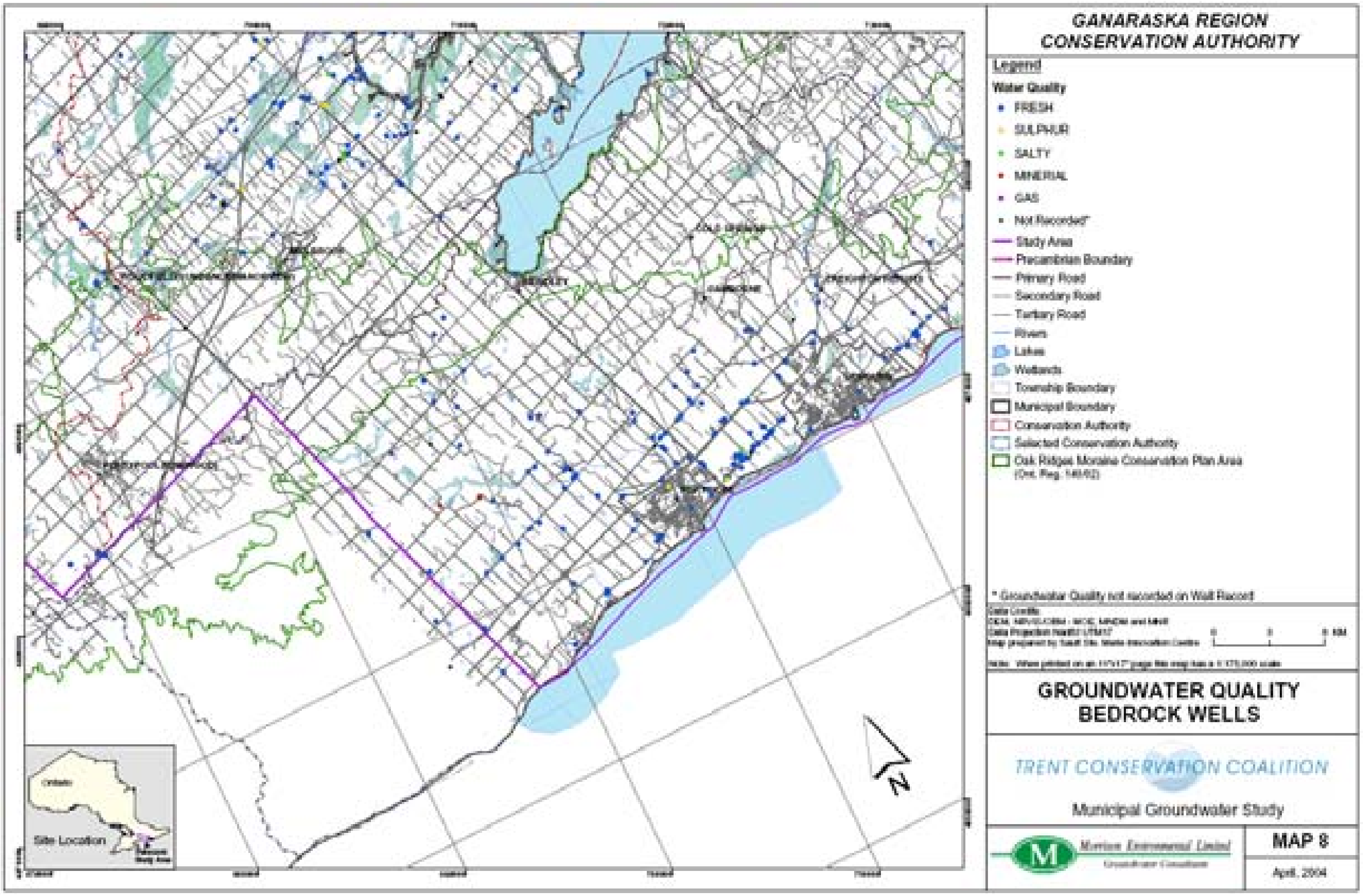
General information related to the quality of groundwater is available from the MOE Water Well Record Database. A considerable number of wells are reported to have some natural water quality problems. For example, some bedrock wells have been reported to have salty, sulphurous or mineral water, and other well water contains gas (Singer et al. 2003). Faced with major difficulties in assessing the considerable data available, Singer et al. (2003) have not provided a detailed description of groundwater quality in the overburden aquifers. The description of groundwater quality within 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 MOE Water Well Record Database includes information related to groundwater quality types encountered 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 MOE. 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. The driller’s observations are subjective and are therefore inadequate for determining the suitability of groundwater for drinking purposes.

To provide an indication of the Cobourg Creek watershed groundwater quality, well records were compiled in the Trent Conservation Coalition groundwater study report using an unfiltered database (Morrison Environmental Limited 2004b). Figure 3.57 and Figure 3.58 present groundwater quality data for bedrock and overburden wells for the Ganaraska Region Conservation Authority study area. Wells screened in bedrock (Figure 3.5) were observed to produce fresh water. Fresh water was interpreted to be water that has acceptable taste and odour, and is usable as a drinking water supply. Although not noted on the well records, water in this category may still require treatment such as softening or iron removal to meet Ontario Drinking Water Standards. The presence of contaminants that do not usually produce a notable taste or odour (such as bacteria and nitrate) would not normally be noted on the well records. Salty water is not frequently reported, and it is expected that these occurrences might be a result of activities at the ground's surface. Road salting and dust control can result in chloride contamination, as can salt/sand stockpiles and landfills.

For the majority of the wells screened in the overburden (Figure 3.58), few were reported poor regarding groundwater quality (Morrison Environmental Limited 2004b). Of the wells with reliable information, the vast majority indicated that groundwater is fresh. The report concluded that groundwater in the area is naturally low in chloride, nitrate and most metals. Iron and manganese are more variable, and on occasion exceed the Ontario Drinking Water Standards. The occurrence of these metals is usually natural, but on occasion can be a result of human activity. Quality can often be managed by treating the water using available technologies.

Due to the limited data availability at this time, the above sections provide general information about regional groundwater quality within the Cobourg Creek watershed. In addition, it is known that site-specific groundwater quality issues occur within the Cobourg 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.



(Morrison Environmental Limited 2004b)

Figure 3.57: Groundwater quality in bedrock wells

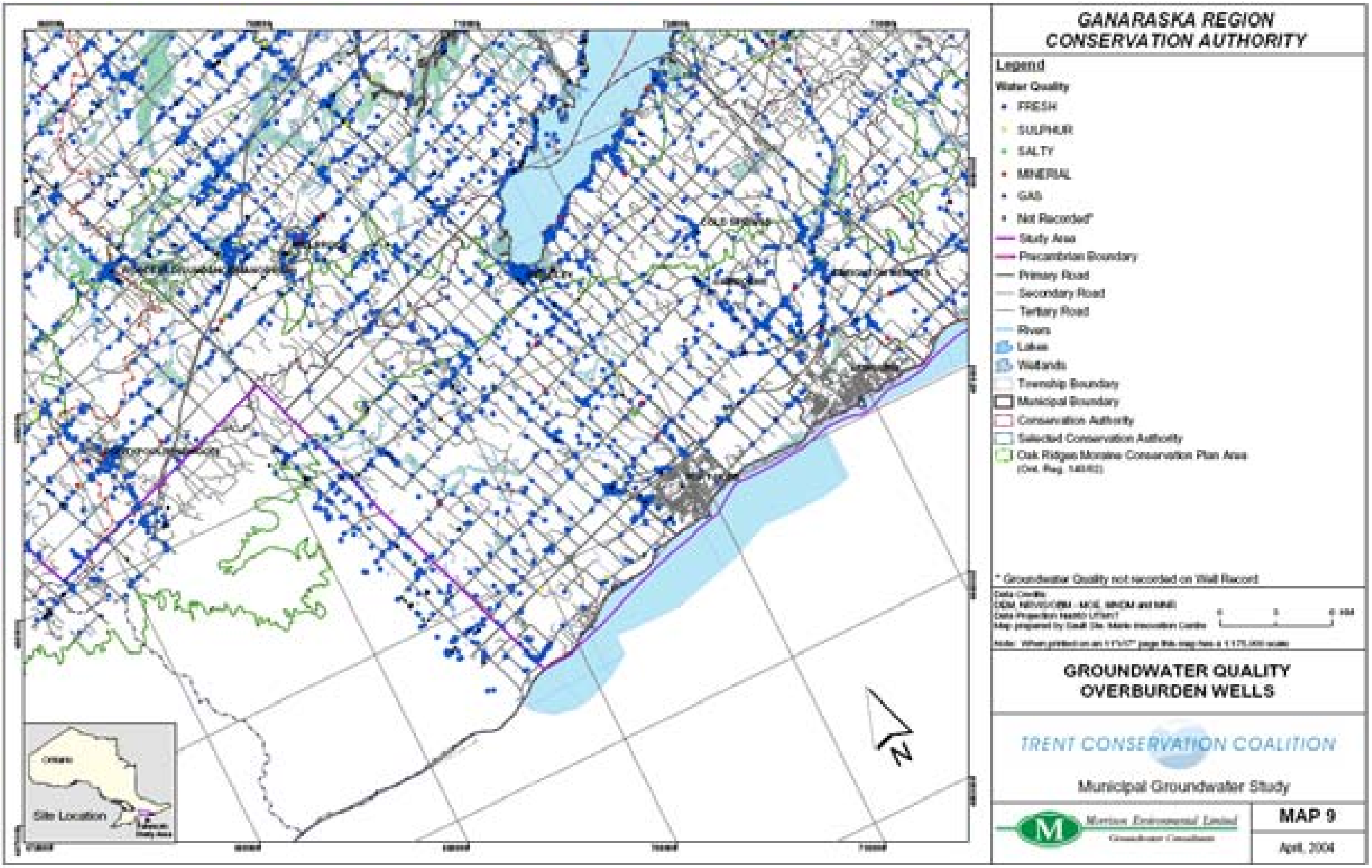


Figure 3.58: Groundwater quality in overburden wells

(Morrison Environmental 2004b)

3.6.2 Municipal Well Field Groundwater Quality

Groundwater quality information is available for the two municipal systems in the Township of Hamilton, and was summarized by Jagger Hims Limited 2007. The measured water quality was compared to the Ontario Drinking Water Standards (ODWS). In general, the raw water quality at both the Camborne and Creighton Heights wellfields is maintained at a high quality standard and is typically suitable for human consumption without treatment (Jagger Hims Limited 2007, Ganaraska Region Conservation Authority 2008b).

At the Creighton Heights wellfield, hardness, turbidity, iron and manganese are present in the water supply prior to treatment (Jagger Hims Limited 2007). At the Camborne wellfield, hardness, turbidity, and iron are present in the water supply prior to treatment (Jagger Hims Limited 2007). No volatile organic compounds, pesticides or herbicides were detected in either water supply. Chloride and sodium concentrations at both wellfields showed variability, however the variability is considered to be related to natural aquifer water quality variability (Jagger Hims Limited 2007). Table 3.32 shows the water quality of the Creighton Heights wellfield, and Table 3.33 shows the water quality of the Camborne wellfield as summarized by Jagger Hims Limited 2007.

Table 3:32: Creighton Heights wellfield summarized raw water quality

Parameter	Units	Ontario Drinking Water Standards		RDL	MDL	Number of Tests Reported	Minimum Concentration	Maximum Concentration	Average Concentration	Number of Exceedences
		MAC/IMAC	AO/OG Limits				10-Feb-03	24-Apr-06		
Membrane Filtration: Total coliform	cfu/100mL	0	-	-	-	28	0	0	0	0
Membrane Filtration: E.coli	cfu/100mL	0	-	-	-	29	0	0	0	0
Nitrite NO2 (as Nitogen)	mg/L	1	-	0.1	0.011	35	0.011	0.011	0.011	0
Nitrate NO3 (as Nitogen)	mg/L	10	-	1	0.021	35	0.021	0.144	0.059	0
Nitrate+Nitite (as Nitogen)	mg/L	10	-	1	0.021	35	0.021	0.144	0.059	0
Total Ammonia (N)	mg/L	-	-	-	0.04	27	1.51	2.37	1.86	0
Free Ammonia (unpreserved)	mg/L	-	-	-	0.04	29	1.38	2.58	1.73	0
Iron	ug/L	-	300	150	90	37	**344**	**500**	**405.0**	37
Manganese	ug/L	-	50	25	2	36	33	**218**	**157.6**	35
Dissolved Organic Carbon	mg/L	-	5	-	0.4	35	0.7	3.8	2.4	0
Total Organic Carbon	mg/L	-	-	-	-	35	1.7	4	2.6	0
pH	none	-	6.5-8.5	-	0.05	19	7.56	8.35	8.1	0
Alkalinity	mg/L as $CaCO_3$	-	30-500	-	0.30	17	199	263	213.8	0
Fluoride	mg/L	1.5	-	0.15	0.04	2	0.25	0.27	0.260	0
Chloride	mg/L	-	250	-	0.10	2	10 RDS	20 RDS	15.0	0
Sulphate	mg/L	-	500	-	0.22	2	< MDL	< MDL	< MDL	0
Colour	TCU	-	5	5	3	**15**	**9**	**17**	**12.3**	**14**
Turbidity	NTU	1	5	0.25	0.20	2	1.02	1.58	1.3	2
Hardness	mg/L as $CaCO_3$	-	80-100	-	5.8	2	155RDS	194RDS	174.5	2
Calcium	mg/L	-	-	-	2	2	34 RDS	43 RDS	38.5	0
Copper	ug/L	-	1000	500	64	2	< MDL	< MDL	< MDL	0
Sodium	mg/L	*20	200	2	0.7	2	23.1 RDS	30.0 RDS	26.6	0
Lead	ug/L	10	-	2	20	2	< MDL	< MDL	< MDL	0
Zinc	ug/L	-	5000	2500	100	2	< MDL	< MDL	< MDL	0
Total Dissolved Solids (calculated)	mg/L	-	-	-	-	2	213	247	230.0	0

(Jagger Hims Limited 2007)

Table 3:33: Camborne wellfield summarized raw water quality

PARAMETER	UNITS	Ontario Drinking Water Standards			Well PW 1a		Well PW 2a	
		MAC/IMAC	AO/OG Limits	RDL	MDL	Concentration	MDL	Concentration
Membrane Filtration: Total coliform	cfu/100mL	0	-	-	-	-	-	-
Membrane Filtration: E.coli	cfu/100mL	0	-	-	-	-	-	-
Nitrite NO2 (as Nitogen)	mg/L	1	-	0.1	0.06	< 0.06	0.005	< 0.005
Nitrate NO3 (as Nitogen)	mg/L	10	-	1	0.06	< 0.06	0.013	< 0.013
Nitrate+Nitite (as Nitogen)	mg/L	10	-	1	0.1	< 0.1	0.013	< 0.013
Total Ammonia (N)	mg/L	-	-	-	-	-	-	-
Free Ammonia (unpreserved)	mg/L	-	-	-	-	-	-	-
Iron	ug/L	-	300	150	90	270	10	256
Manganese	ug/L	-	50	25	2	0.016	1	16
Dissolved Organic Carbon	mg/L	-	5	-	-	-	-	-
Total Organic Carbon	mg/L	-	-	-	-	-	-	-
pH	none	-	6.5-8.5	-	0.05	7.98	0.05	6.22
Alkalinity	mg/L as $CaCO_3$	-	30-500	-	0.30	198	2.00	194
Fluoride	mg/L	1.5	-	0.15	0.1	< 0.1	0.06	0.15
Chloride	mg/L	-	250	-	0.10	4.8	0.03	5.30
Sulphate	mg/L	-	500	-	0.22	39	0.06	33
Colour	TCU	-	5	5	4	< 4	3	< 3
Turbidity	NTU	1	5	0.25	0.20	**3.8**	0.1	**1.54**
Hardness	mg/L as $CaCO_3$	-	80-100	-	5.8	227	0.1	223
Calcium	mg/L	-	-	-	-	-	0.01	52.3
Copper	ug/L	-	1000	500	-	0.5	0.5	< 0.5
Sodium	mg/L	*20	200	2	0.05	4.91	0.05	5.58
Lead	ug/L	10	-	2	0.002	< 0.002	0.1	< 0.1
Zinc	ug/L	-	5000	2500	-	0.02	1	16
Total Dissolved Solids (calculated)	mg/L	500	-	-	30	236	30	257

(Jagger Hims Limited 2007)

3.6.3 PGMN Groundwater Quality

Groundwater quality sampling within the Ganaraska Region Conservation Authority is being conducted as part of the MOE Provincial Groundwater Monitoring Network (PGMN). Provincial Groundwater Monitoring Network wells across the Ganaraska Region Conservation Authority are not used for private or public drinking water supplies; however they 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 is one PGMN well within the Cobourg Creek watershed. This well is PGMN Well number GA 393, at Ball's Mill Conservation Area, and has a depth of 21.56 m. Groundwater quantity and quality sampling occurs as part of the monitoring program. The location of the PGMN well is shown in Figure 3.59. Groundwater quality sampling has been completed in 2004, 2006 and 2007. Samples were tested for most parameters specified in the Ontario Drinking Water Quality Standards Regulation (O. Reg. 169/03). All of the sampling procedures, storage and laboratory testing are carried out according to MOE guidelines.

Table 3.34 shows the laboratory results as well as the comparison of these results with the Ontario Drinking Water Standards at the PGMN well. Bolded results indicate samples exceeded the Ontario Drinking Water Standards for non-health related parameters. Red bolded results indicate samples exceeding the Ontario Drinking Water Standards for health related parameters. Laboratory results of groundwater samples collected to date showed no major variations from the Ontario Drinking Water Standards (Table 3.34).

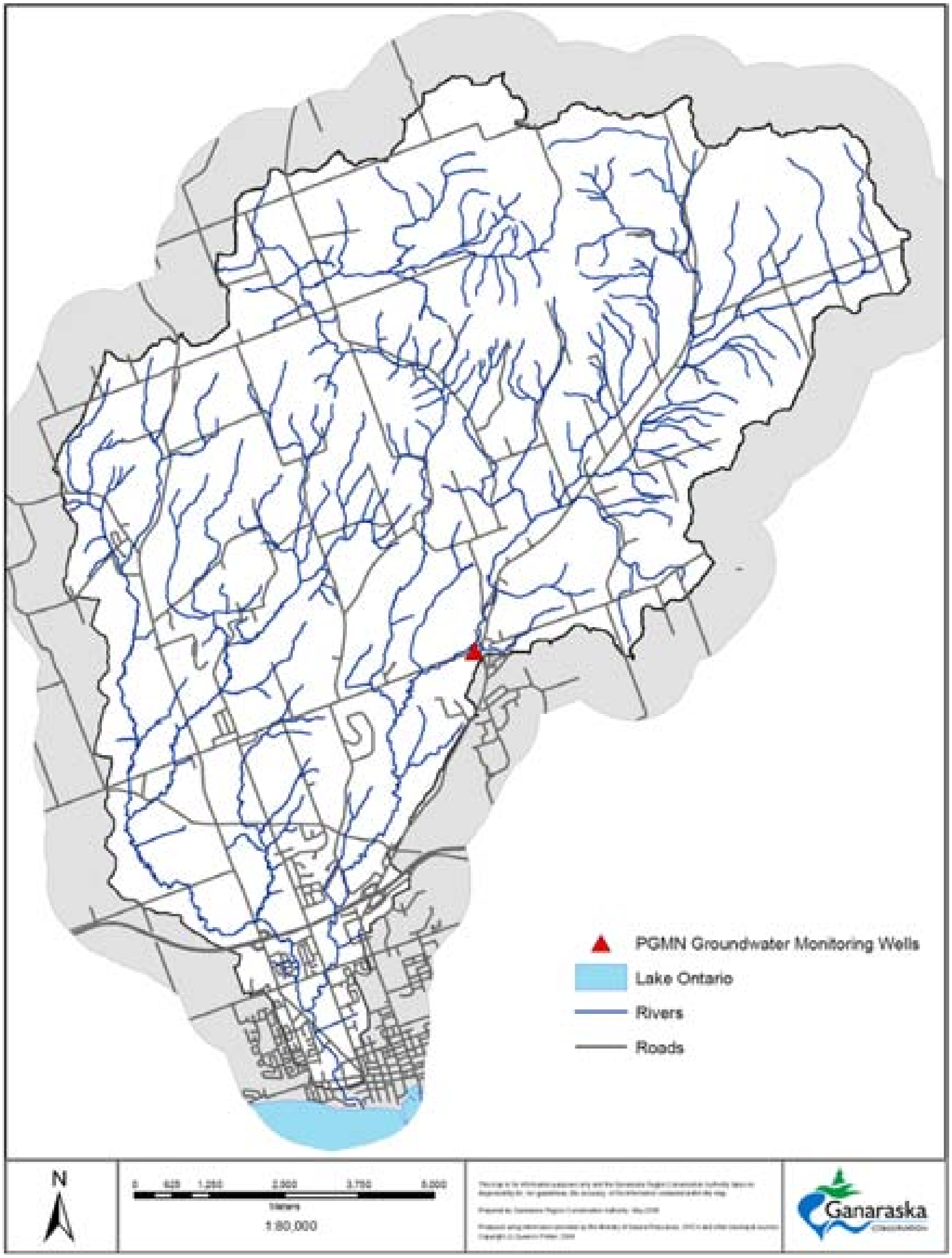


Figure 3.59: Provincial Groundwater Monitoring Network well

Table 3.34: Groundwater Quality at the Ball’s Mill Conservation Area PGMN Well

Parameter	Units	Ontario Drinking Water Standard	June 3, 2004	November 7, 2006	October 31, 2007
pH	None	6.5 to 8.5	7.89	7.99	7.98
Alkalinity	mg/L as CaCO3	30 to 500	351	395	372
Conductivity	μS/cm	800	**925**	**1030**	**852**
Carbonate	mg/L as CaCO3		--	< 2	< 2
Bicarbonate	mg/L as CaCO3		428	395	372
Total Dissolved Solids	mg/L	500	**599**	**586**	494
Chloride	mg/L	250	89.7	100	75
Nitrite	as N mg/L	1.0	0.01	< 0.005	0.005 <MDL
Nitrate	as N mg/L	10.0	0	< 0.013	0.013 <MDL
Nitrate + nitrite	as N mg/L	10.0	0.05	< 0.013	0.013 <MDL
Sulphate	mg/L		15.9	9.5	11
Fluoride	mg/L	1.5	0.09	0.12	0.12
Total Reactive Phosphorus	mg/L			0.04	0.02 <MDL
Dissolved Organic Carbon	mg/L	5.0	4.1	3.4	3.3
Dissolved Inorganic Carbon	mg/L		105	94.8	83.3
Organic Nitrogen	mg/L	0.15	**0.77**	**0.22**	**0.22**
Ammonia + ammonium	as N mg/L		0.27	0.41	0.37
Total Kjeldahl Nitrogen	as N mg/L		1.04	0.63	0.59
Hardness	mg/L as CaCO3	80 to 100	**302**	**353**	**373**
Aluminum	mg/L	0.1	0.0306	0.0065	0.0022
Antimony	mg/L	0.006	0.00065	0.0003	< 0.0002
Arsenic	mg/L	0.025	0.0021	0.0014	0.0025
Barium	mg/L	1	0.192	0.164	0.146
Beryllium	mg/L		0.00002	< 0.00004	< 0.00002
Boron	mg/L	5	0.026	0.031	0.038
Calcium	mg/L		99	121	129
Cadmium	mg/L	0.005	-0.00001	< 0.00006	< 0.000003
Cobalt	mg/L		0.00015	0.000603	0.000349
Chromium	mg/L	0.05	0.0023	< 0.0003	0.0006
Copper	mg/L	1	0.0008	0.0004	0.0006
Iron	mg/L	0.3	**3.6**	< 0.01	**2.89**
Lead	mg/L	0.01	0.00008	< 0.00002	0.00004
Magnesium	mg/L		13.2	12.3	12.2
Manganese	mg/L	0.05	**0.299**	**0.278**	**0.252**
Molybdenum	mg/L		0.0011	0.00207	0.00734
Nickel	mg/L		0.0009	< 0.0007	0.0010
Phosphorus	mg/L		0.88	0.02	0.03
Potassium	mg/L		5.20	4.17	4.79
Selenium	mg/L	0.01	0.00	< 0.003	< 0.001
Silver	mg/L		0.00002	< 0.00003	< 0.00001
Sodium	mg/L	200	80	69.7	65.3
Strontium	mg/L		0.535	0.414	0.430
Titanium	mg/L		0.0017	0.0009	0.0003
Thallium	mg/L		0	< 0.0001	< 0.0001
Uranium	mg/L	0.02	0.00012	0.00022	0.000089
Vanadium	mg/L	0.1	0.00058	0.00013	0.00095
Zinc	mg/L	5	0.0016	0.0010	0.004

Bold signifies parameters exceeding the Ontario Drinking Water Standard for non-health related parameters.
Red Bold signifies parameters exceeding the Ontario Drinking Water Standard for health related parameters.

3.7 SURFACE WATER QUALITY

The quality of surface water is influenced by the surrounding landscape and instream transformations. Land use and cover within a watershed can influence water chemistry and integrity of the stream environment. Non-point sources 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 contributes to surface water quality. Surface water quality modeling is not yet available for the Cobourg Creek watershed. It is anticipated that a model will be available in 2009/2010 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 which set out limits for certain parameters as they relate to aquatic life toxicity levels, unsafe use of water for recreational activities, unfit water use for agricultural purposes and non-potable water 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 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 levels of government 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 analysing the surface water quality of Cobourg 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 surface water quality of Cobourg 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, four surface water quality programs exist within Cobourg Creek the Ganaraska Region Water Quality Monitoring Network, the Ganaraska Region

Conservation Authority Municipal Salt Monitoring Program, the Baseflow Water Quality Monitoring Program, and the Provincial Water Quality Monitoring Network.

Ganaraska Region Conservation Authority staff conducts the Ganaraska Region Water Quality Monitoring Network (GRWQMN) on a yearly basis. Within the Cobourg Creek watershed, 12 GRWQMN sample sites exist. Combinations of these sites were sampled once a month in 2002, 2003 and 2005, ranging in months from May to October. Table 3.35 outlines the GRWQMN sample sites and Figure 3.60 shows their locations.

Table 3.35: Locations and sampling times of GRWQMN stations

Location	**Sample Frequency Dates**
Corner of Elgin Street and Ontario Street, Cobourg	July 21, August 19 and September 26, 2002 May 29, June 18, July 16 August 20 and October 08 2003 July 19, August 30 and September 27 2005
Elgin Street at Cobourg Conservation Area	July 21, August 19 and September 26, 2002 May 29, June 18, July 16 August 20 and October 08 2003 July, August and September 2005
William Street, Cobourg at Gauge Station	May 29, June 18, July 16 August 20 and October 08 2003
Dale Road, first crossing west of County Road 45	July 19, August 30 and September 27 2005 July 21, August 19 and September 26, 2002
Dale Road, first crossing east of Williamson Road	July 21, August 19 and September 26, 2002 July 19, August 30 and September 27 2005
Dale Road, second crossing east of Williamson Road	July 21, August 19 and September 26, 2002 July 19, August 30 and September 27 2005
County Road 45, crossing south of Centreton Road	July, July 21, August 19 and September 26, 2002
Dale Road, crossing east of Racetrack Road	July 19, August 30 and September 27 2005
Crossen Road	July 21, August 19 and September 26, 2002
Hayden Road	July 21, August 19 and September 26, 2002
Albert’s Alley	July 21, August 19 and September 26, 2002
Harwood Road	July 21, August 19 and September 26, 2002

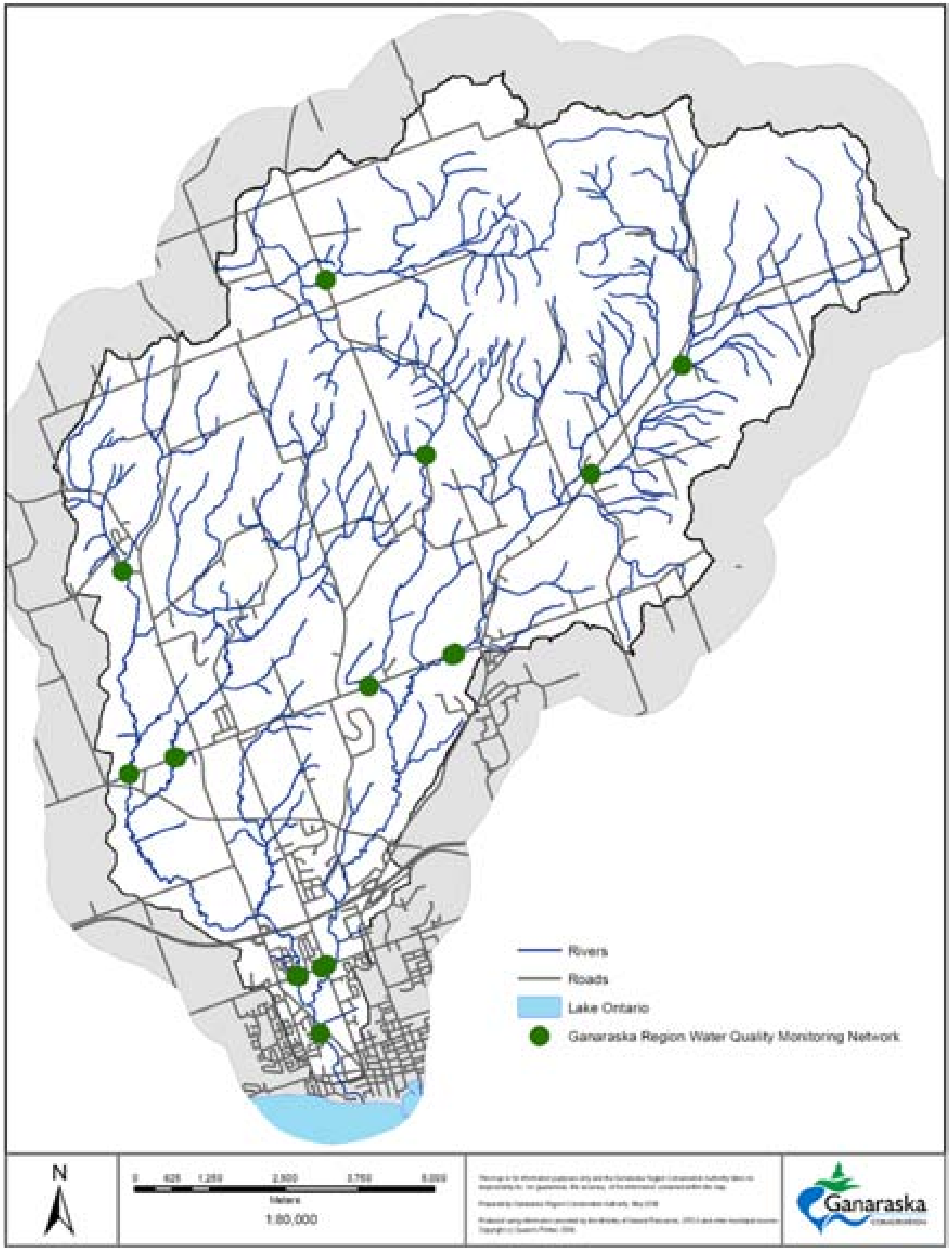


Figure 3.60: Ganaraska Region Water Quality Monitoring Network sites

A Municipal Salt Monitoring Program is also conducted by Ganaraska Region Conservation Authority staff within Cobourg Creek. Starting in December 2005 water quality samples were taken from five sites south of Highway 401. Samples were taken biweekly from December to March 2006, June to August 2006 and December to March 2007. Eight additional sites were added to this program and sampled once per month in April, May, October, November and December 2007 along with the original five sites (Figure 3.61).

The largest surface water data set exists through the Provincial Water Quality Monitoring Network (PWQMN), operated in partnership by the Ontario Ministry of Environment (MOE) and the Ganaraska Region Conservation Authority. Throughout the existence of the program, 46 parameters have been analyzed at one time or another. Two active and two historic PWQMN sample stations are located in Cobourg Creek in the lower half of the watershed (Telephone Road south). Figure 3.62 shows the locations of the active PWQMN stations and Table 3.36 outlines the years of data available.

Table 3.36: PWQMN station and sampling frequency in Cobourg Creek

Station	**PWMQN Station ID**	**Years Sampled**	**Status**
Cobourg Creek at Telephone Road	6013300502	2002 to 2007**	Active
Cobourg Creek at Fourth Street*	6013300102	1964 to 1996	Active
Cobourg Creek at King Street*	6013300402	2002 to 2007	
Cobourg Creek at Ontario Street	6013300302	1965 to 1969	Inactive
Cobourg Creek at Danforth Road	6013300202	1965 to 1969	Inactive

- In 1980 the King Street station was moved to the Fourth Street station. However these sites are combined since there is a small distance between the two.
- ** Metal sampling stopped in December 2006
- Turbidity sampling stopped at both stations in December 2006

In 2007 a baseflow water quality monitoring program was carried out in Cobourg 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. Forty-six sites were sampled between July 31 and August 1, 2007 (Figure 3.63), during a period of no rain and baseflow conditions.

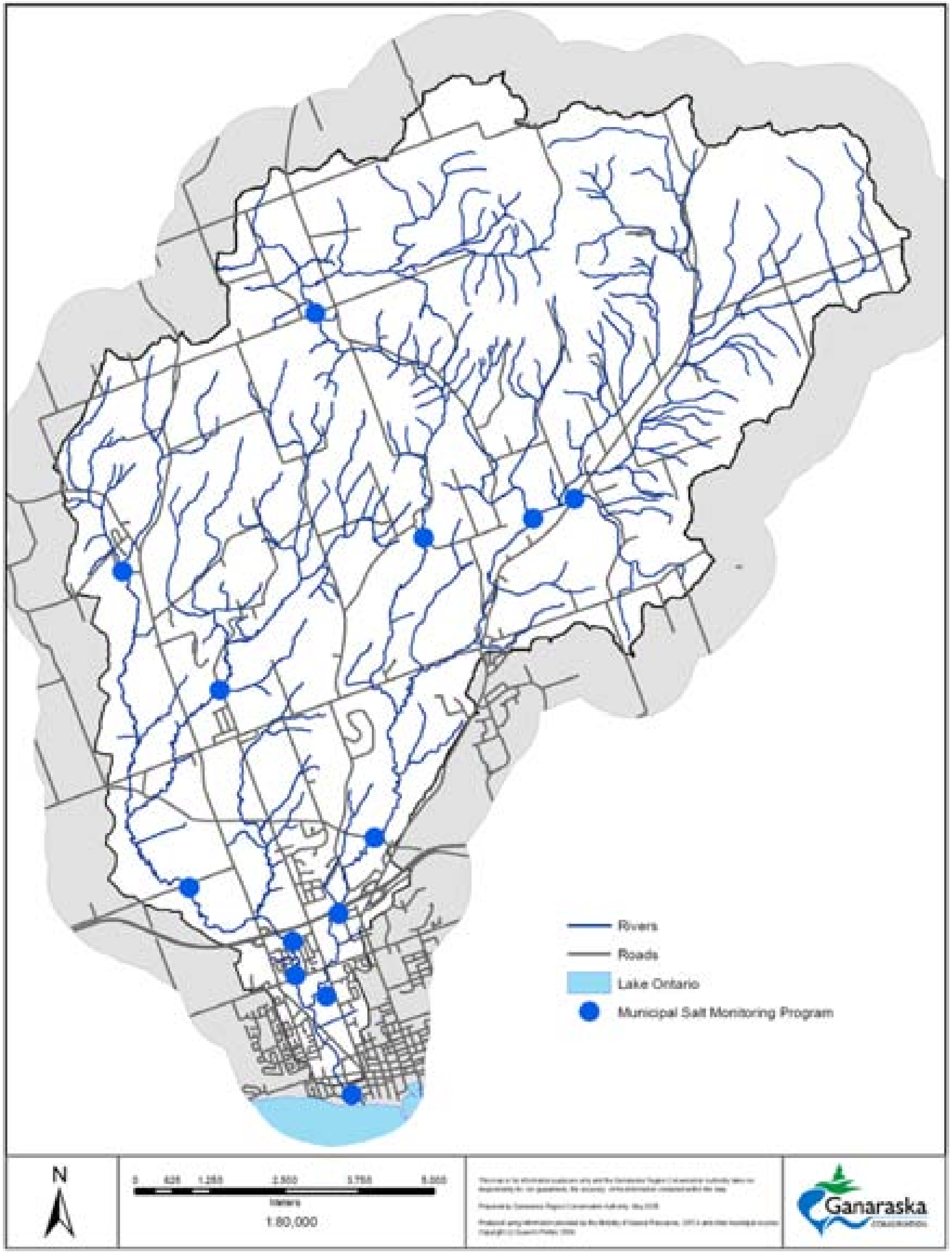


Figure 3.61: Municipal Salt Monitoring Program sites

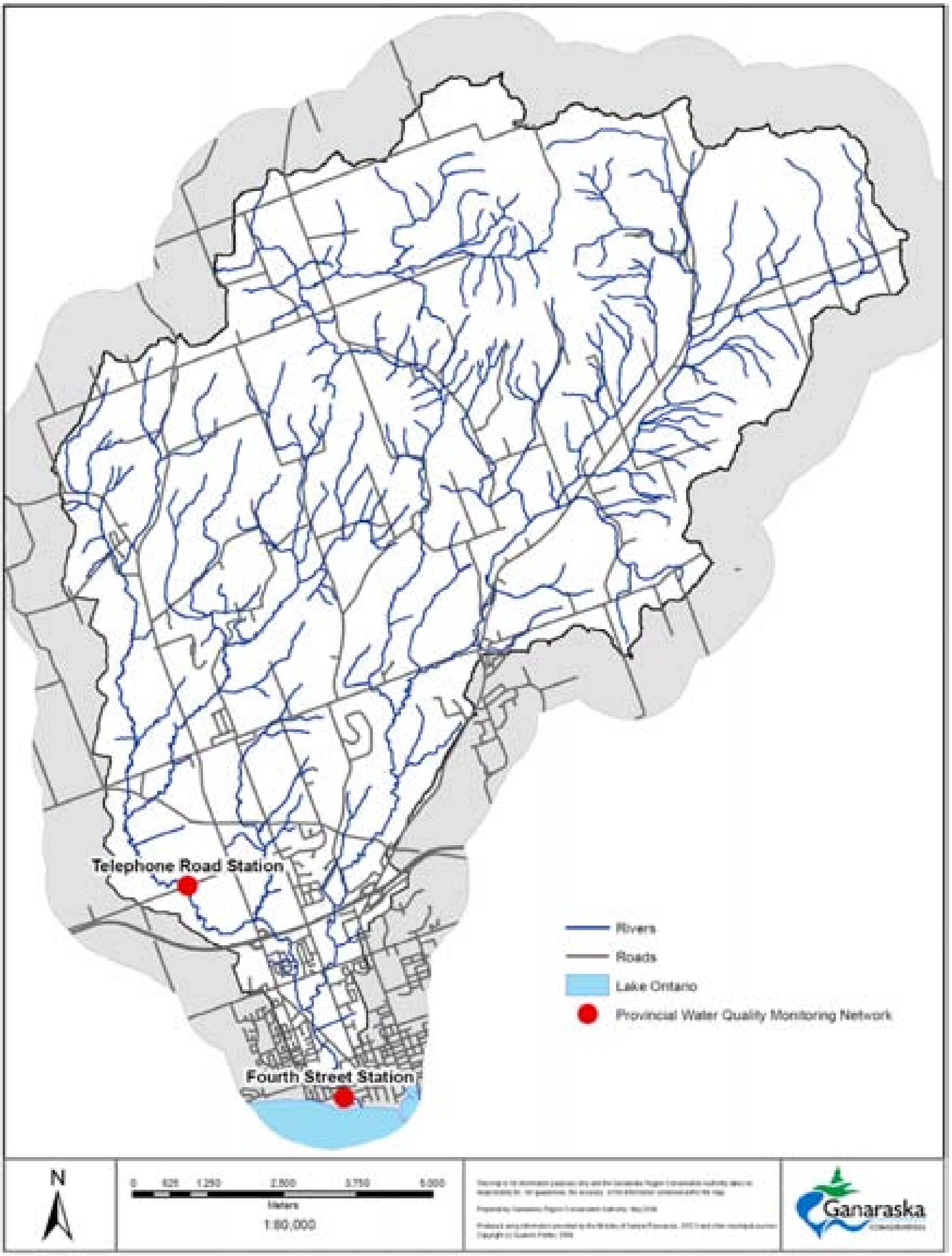


Figure 3.62: Provincial Water Quality Monitoring Network sites

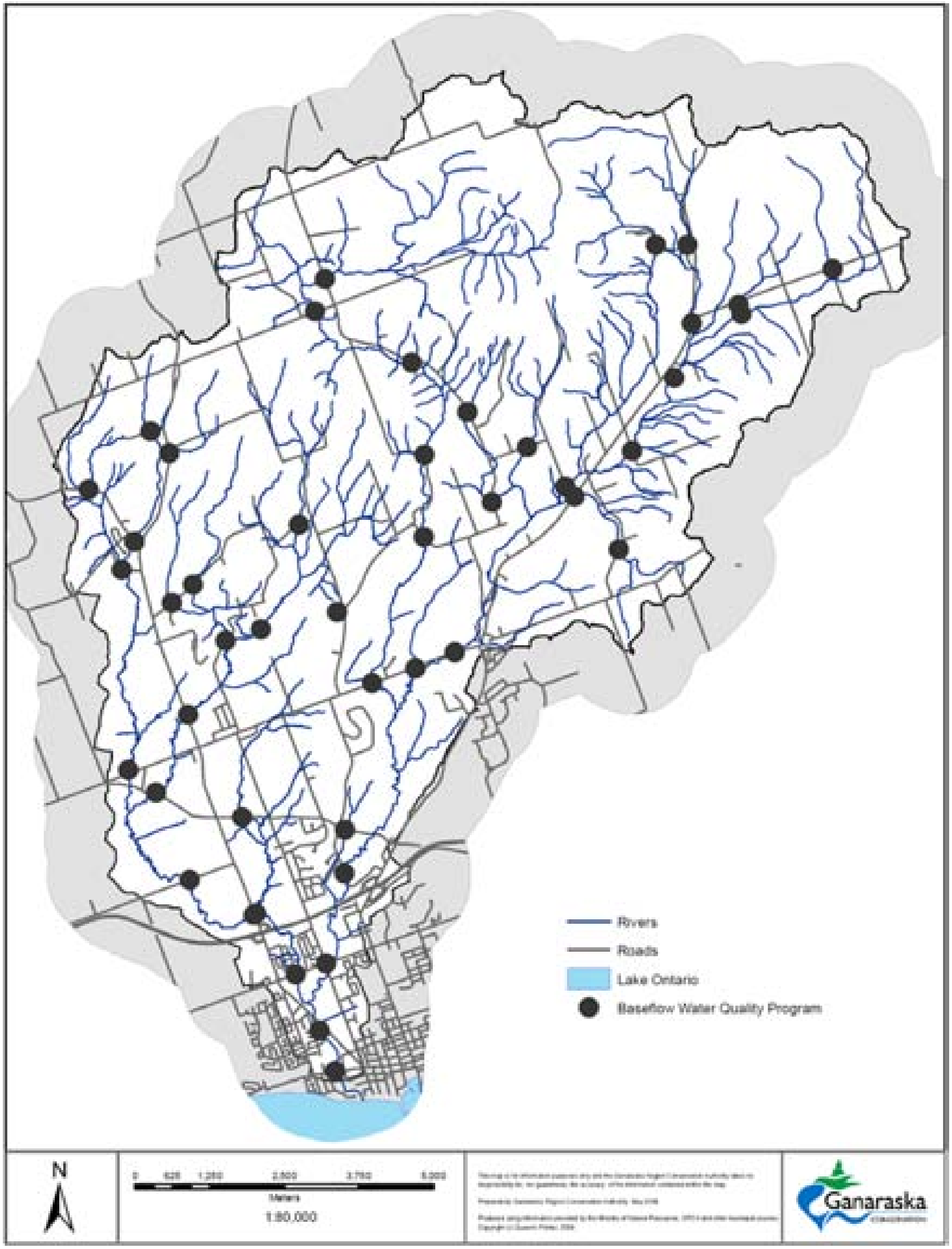


Figure 3.63: Baseflow Water Quality Program sites

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 taken from the sample site in a 500ml bottle and analyzed for alkalinity, total suspended solids, nitrate, nitrite and chloride concentrations in-house using a HACH DR/2010 Portable Datalogging Spectophotometre. The Spectophotometre 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 in 2002 and 2003 and Caduceon Environmental Laboratories in 2005 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 500 ml bottle and analyzed in-house using the HACH DR/2010 Portable Datalogging Spectophotometre with the Mercuric Thiocyanate method (HACH Company 1989).

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 1965 include those outlined in Table 3.37.

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

Table 3.37: List of water quality parameters sampled through PWQMN

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

The baseflow water quality monitoring analysis was conducted by Caduceon Environmental Laboratories in 2007 for analysis of 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.

Water Quality Data Screening

Although the PWQMN data contains the most surface water quality data, not all of the 46 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 1996. Therefore certain parameters and sample sites have been removed from the water quality analysis.

Both Ontario Street and Danforth Road stations have been removed from the data analysis since they were only sampled from 1965 to 1969, 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 1995) or there are less than 30 sample points making them statistically invalid. As a result of these conditions the following parameters will not be analyzed.

- Cyanide: Only one sample in 1980
- Arsenic: Five samples in 1980 and 1994
- Sulphate: Fifteen samples in 1997
- Phenolics: Sampled prior to 1993
- Turbidity reported in JTU: Sampled prior to 1972
- Filtered Iron: Three samples
- Any nitrite or nitrate sampled prior to 1994 due to differences in analysis
- Total Residue: Sampled prior to 1994
- Filtered Residue: Sampled prior to 1994
- Colour: Two samples in 1968 and 1969
- Dissolved Organic Carbon: Sampled in 1972 and 1973
- Biological Oxygen Demand: Sampled from 1965 to 1968
- *Pseudonom Aeruginosa* MF: Four samples in 1995
- Fecal Streptococcus MF: Sampled prior to 1995
- Fecal Coliform MF: Sampled prior to 1994
- *Escherichia coli*: Four samples in 1995
- 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.

Surface Water Quality Guidelines

Surface water quality guidelines were used to evaluate measured water quality parameters. Table 3.38 outlines the guidelines used and the source.

Table 3.38: 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-N ⍭	2.9 mg/L	Molybdenum*	40 µg/L
Nitrite-N ⍭	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
Chloride ⍭	250 mg/L	Atrazine ⍭	1.8 µg/L
Aluminum*	75 µg/L	Glyphosate ⍭	65 µg/L
Beryllium*	11 µg/L	Metolachlor *	3 µg/L
Cadmium*	0.2 µg/L	2,4-D ⍭	4 µg/L
Copper*	5 µg/L		

* Ontario Ministry of Environment and Energy (1999)

⍭ Canadian Council of Ministers of the Environment (2006)

† Pawlisz et al. (1997)

➸ Department of Fisheries and Oceans Canada (2000)

Water Quality Sampling Flows

Stream flows were measured in Cobourg Creek at the William Street stream gauge during sampling events for both the GRWQMN (Figure 3.64) and the PWQMN (Figure 3.65). The flows at the William Street gauge station were compared against parameter concentrations using non-parametric Spearman's Ranks Correlation.

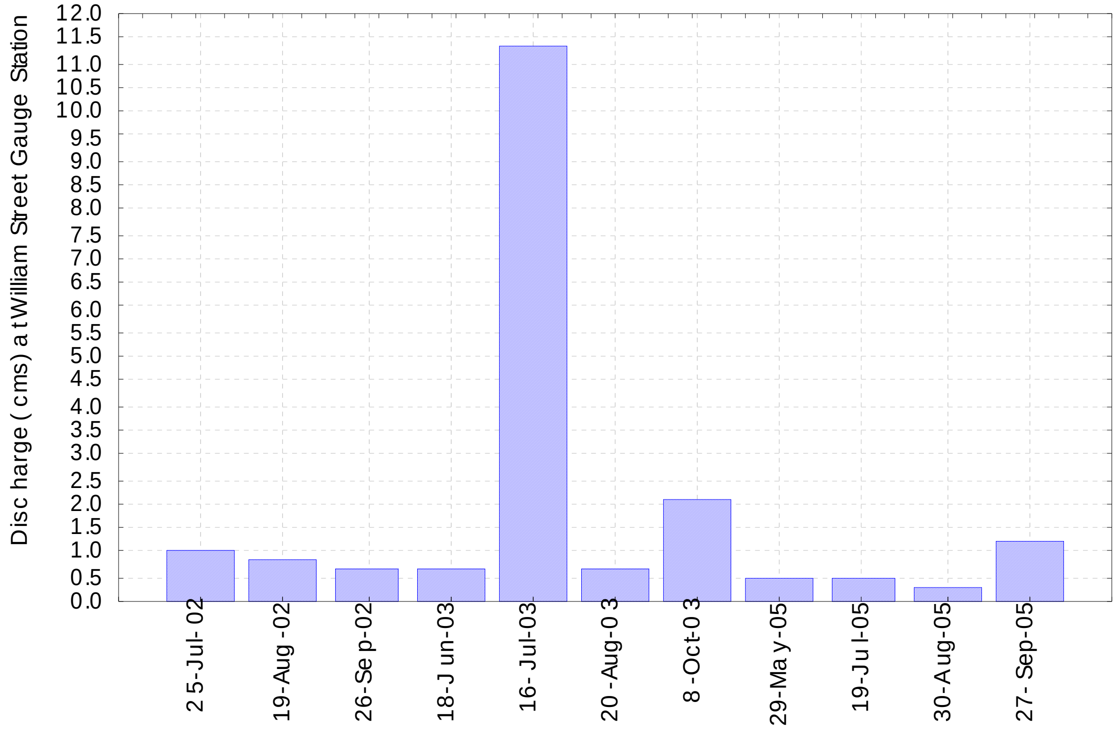


Figure 3.64: Stream flow of Cobourg Creek measured at the William Street gauge station during GRWQMN sampling

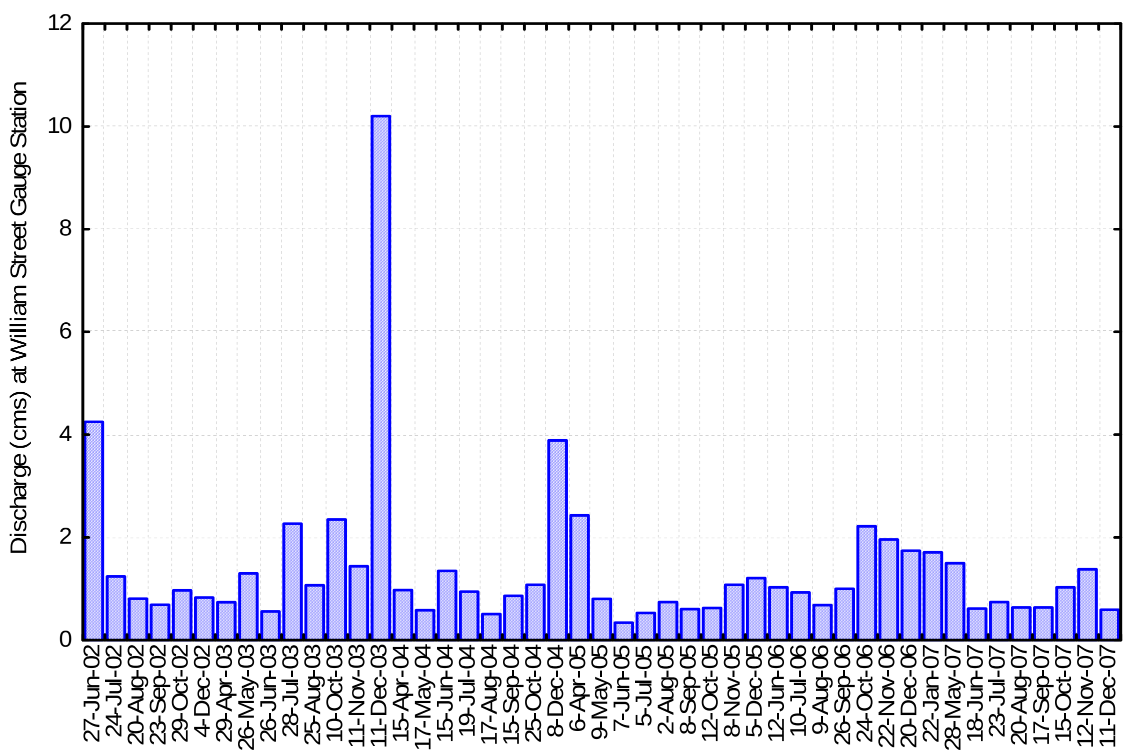


Figure 3.65: Stream flow in Cobourg Creek measured at the William Street gauge station during PWQMN sampling

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 were 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 between 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[2]

The Ganaraska Region Water Quality Monitoring Network allows a watershed-wide analysis of water quality. All but one station is upstream of the PWQMN stations allowing for greater representation of the upper tributaries of Cobourg Creek. Given the small data set of each GRWQMN station, all stations will be grouped to give an overall picture of water quality in Cobourg Creek.

Physical Parameters

The physical parameters of the surface water within Cobourg Creek indicate the base conditions water quality. Table 3.39 describes the physical conditions of the Cobourg 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 3.39: Range of physical parameters through the GRWQMN

Variable	n*	Median	Minimum	Maximum	10th Percentile	90th Percentile
pH	60	8.32	7.22	8.58	8.11	8.49
Dissolved Oxygen (mg/L)	44	10.5	1.3	17.2	6.3	15.9
Conductivity (µs/cm)	59	475	0.3	806	324	585
Salinity (%)	56	0.22	0.16	0.40	0.20	0.29
TDS (g/L)	38	0.24	0.18	0.44	0.18	0.35
Alkalinity (mg/L as CaCO3)	60	186.5	119.0	260.0	154.0	229.0
TSS (mg/L)	60	6	0	219	2	20
Turbidity (mg/L)	63	1.68	0.58	72.50	0.92	6.00

*n represents the number of samples

Results show the following:

- pH levels are within the acceptable range of 6.5 to 8.5.
- Total suspended solids (TSS) rarely (90th percentile = 20 mg/L, maximum = 219 mg/L) exceeded the recommended 25 mg/L.
- The median TSS concentration of 6 mg/L reflects the usual condition without influences of high flows.
- TSS and turbidity are affected by high flows (discharge), increasing as flows increase (n=60, r^2=0.12, r_s=0.34, p=<0.05; n=63, r^2=0.26, r_s=0.51, p=<0.05 respectively).
- Dissolved oxygen ranging between 1.3 and 17.2 mg/L are within acceptable ranges during sampling.
- Dissolved oxygen is noted to decline as stream temperatures increase (n=44, r_s = -0.5012, p = 0.0005) (Figure 3.66)

[2] Please note, a complete discussion of all results are found in Section 3.7.6

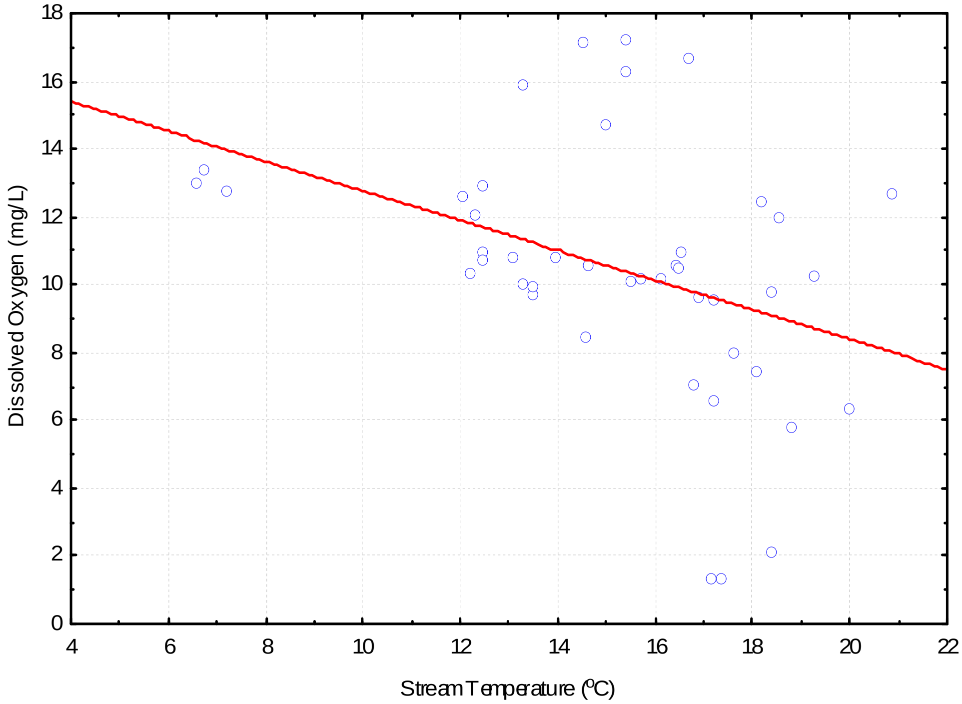


Figure 3.66: Dissolved oxygen concentrations in relation to stream temperature in Cobourg Creek

Nutrients

Five nutrient parameters have been sampled through the GRWQMN and concentration ranges are found in Table 3.40.

- Nitrate-N and Nitrite–N concentrations have never exceeded the CWQG of 2.9 mg/L and 0.197 mg/L respectively 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 31% of the time.
- Total phosphorus has also exceeded the PWQO of 0.03 mg/L 16% of the time.
- Both unionized ammonia and total phosphorus median values are below the respective PWQO (Table 3.40).
- Ammonia-ammonium and total phosphorus are affected by high flows, increasing as flows increase ($n=63$, $r^2=0.13$, $r_s=0.36$, $p=<0.05$; $n=63$, $r^2=0.06$, $r_s=0.25$, $p=0.05$ respectively).

Table 3.40: Nutrient concentrations within Cobourg Creek through the GRWQMN

Variable	n	Median	Min	Max	10th Percentile	25th Quartile	75th Quartile	90th Percentile
Nitrate-N (mg/L) (CWQG = 2.9 mg/L)	60	0.7	0.1	1.3	0.4	0.6	0.9	1.1
Nitrite-N (mg/L) (CWQG = 0.197 mg/L)	60	0.004	0	0.03	0.002	0.003	0.007	0.009
Ammonia-ammonium (mg/L)	63	0.10	0.01	1.0	0.003	0.070	0.200	0.3
Unionized Ammonia (mg/L) (PWQO = 0.02 mg/L)	48	0.015	0	0.11	0.009	0.009	0.023	0.05
Total Phosphorus (mg/L) (PWQO = 0.03 mg/L)	63	0.019	0.011	0.14	0.019	0.019	0.030	0.05

Bacteria

Ranges of *Escherichia coli* and total coliforms frequently exceed their respective PWQO as sampled through the GRWQMN (Table 3.41). These concentrations give an idea of bacteria concentrations within Cobourg 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 Cobourg Creek watershed.
- Total coliform and *Escherichia coli* are affected by high flows, increasing as flows increase (n=63, r^2=0.10, r_s=0.31, p=<0.05; n=63, r^2=0.14, r_s=0.38, p=<0.05 respectively).

Table 3.41: Bacteria concentrations within Cobourg Creek through the GRWQMN

Variable	n	Geometric Mean	Min	Max	10th Percentile	90th Percentile
Escherichia coli (cfu/100ml)(PWQO = 100cfu/100ml)	63	248	20	11000	40	1780
Total Coliform (cfu/100ml)	63	1929	80	23000	640	7900

3.7.3 Cobourg Creek Municipal Salt Monitoring Program Results

Chloride concentrations within Cobourg Creek, as sampled from 2005 to 2007, ranged from 2.4 to 122 mg/L with a median concentration of 16 mg/L. None of the samples exceeded the CEQG of 250 mg/L. During months that received snow/mixed precipitation and snowmelt runoff (November to April), chloride concentrations were higher than in the months that are dominated by rain (May to October) ($z=3.98$, $p = 0.00$, $n=168$).

Differences were found between sample sites, with Cobourg East White having lower concentrations than Cobourg at Peace Park and Cobourg West ($H(12, n = 168) = 42.05557$ $p = 0.0000$) (Figure 3.67). There is also a difference in chloride concentrations in relation to Highway 401, with sites below the 401 having higher chloride concentrations than those above ($z = 2.64$, $p = 0.008$).

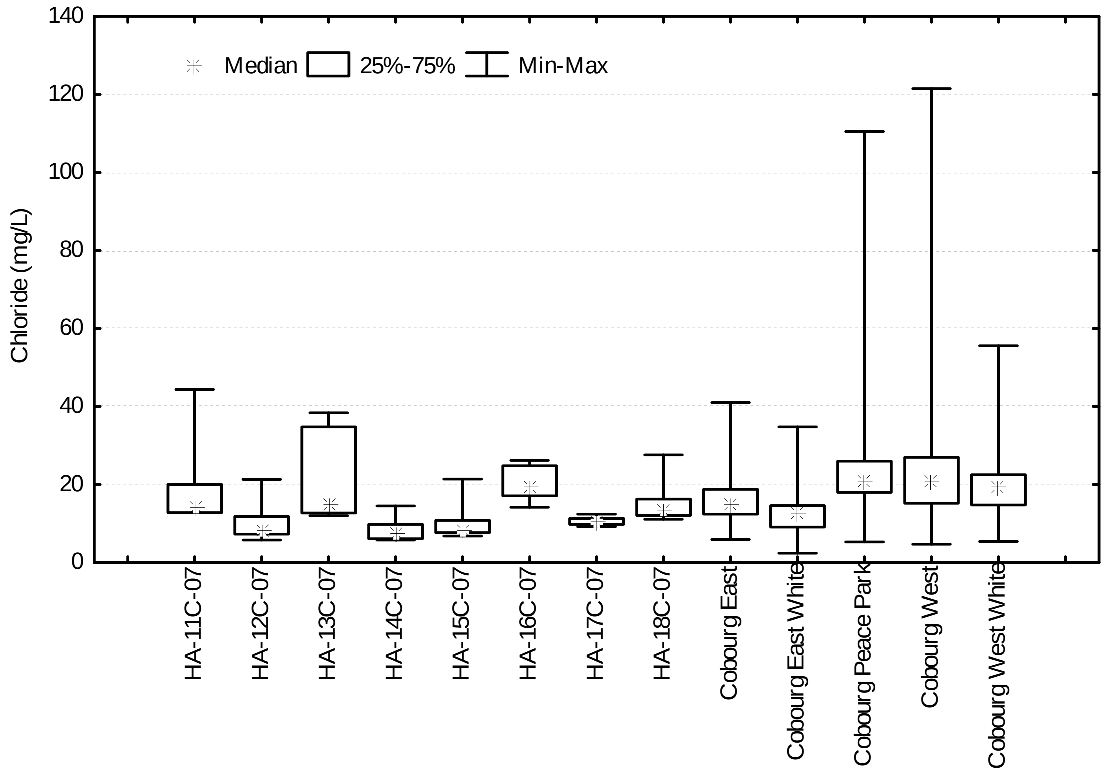


Figure 3.67: Differences in chloride concentrations at Cobourg Creek sample sites

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 (i.e., point source contamination). By sampling numerous sites in the Cobourg Creek watershed, 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 Cobourg Creek suggest the background conditions of the quality of water. Table 3.42 describes the physical conditions of the Cobourg 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.

Table 3.42: Range of physical parameters through the baseflow water quality monitoring program

Variable	n	Median	Minimum	Maximum	10th Percentile	90th Percentile
pH	46	8.34	7.47	8.62	8.10	8.51
Dissolved Oxygen (mg/L)	46	13.2	6.37	19.10	10.79	14.57
Conductivity (μs/cm)	46	433	281	1123	393	570
Salinity (%)	46	0.21	0.13	0.52	0.19	0.28
TSS (mg/L)	46	5.00	0.9	109	1.00	11.00
Turbidity (mg/L)	46	1.68	0.31	6.40	0.44	3.59

The pH levels are within the acceptable range of 6.5 to 8.5. TSS rarely (90th percentile = 11 mg/L, maximum = 109 mg/L) exceeded the recommended 25 mg/L; the median concentration of 5 mg/L reflects the usual condition of Cobourg Creek.

Nutrients

Five nutrient parameters were sampled through the baseflow water quality monitoring program and concentration ranges are found in Table 3.43.

- Nitrate–N exceeded the CWQG of 2.9 mg/L at three sites, or 6% of the time.
- Nitrite–N exceeded the CWQG of 0.197 mg/L at two of the sample sites, or 4% of the time.
- Unionized ammonia concentrations at sample sites were always below analytical detection limits, and therefore below the PWQO.
- Total phosphorus exceeded the PWQO of 0.03 mg/L at eight sites, or 17% of the time at sampled baseflow water quality monitoring stations.
- Nitrite-N, nitrate-N and total phosphorus median values were below the respective PWQO (Table 3.43).

Table 3.43: Nutrient concentrations within Cobourg Creek through the baseflow water quality monitoring program

Variable	n	Median	Min	Max	10th Percentile	25th Quartile	75th Quartile	90th Percentile
Nitrate-N (mg/L) (CWQG = 2.9 mg/L)	46	0.90	0	5.4	0	0	0	1.8
Nitrite-N (mg/L) (CWQG = 0.197 mg/L)	46	0	0	0.2	0	0	0	0.1
Ammonia-ammonium (mg/L)	46	0	0	0.27	0	0	0	0.02
Unionized Ammonia (mg/L) (PWQO = 0.02 mg/L)	46	0	0	0	0	0	0	0
Total Phosphorus (mg/L) (PWQO = 0.03 mg/L)	46	0.017	0.002	0.062	0.007	0.011	0.024	0.037

Bacteria

Ranges of *Escherichia coli* and total coliforms frequently exceed respective PWQO as sampled through the baseflow water quality monitoring program (Table 3.44). These concentrations give an idea of bacteria concentrations within Cobourg 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 22 sites, or 48% of the time.

Table 3.44: Bacteria concentrations within Cobourg Creek through the baseflow water quality monitoring program

Variable	N	Geometric Mean	Min	Max	10th Percentile	90th Percentile
Escherichia coli (cfu/100ml)(PWQO = 100cfu/100ml)	46	58	<2	516	4	290
Total Coliform (cfu/100ml)	46	769	150	> 2001	320	>2001

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 above the sample sites. Of the 46 sample sites, 22 sites were dominated by natural areas (i.e., forests, meadows, thickets, wetlands, open areas and open water), 3 sites were dominated by development (i.e., roads, rail, urban areas, rural development or aggregates), and 21 sites were dominated by agricultural land use (intensive and non-intensive agriculture). Within these catchment classifications 16 sites that were dominated by agriculture also had concentrations of total coliform (nine sites), *Escherichia coli* (11 sites), total phosphorus (four sites), and nitrite (one site) above the PWQO or CEQG. Of the 22 natural area dominated catchments, 10 of these sites had concentrations of total coliform (four sites), *Escherichia coli* (four sites), total phosphorus (two sites), and nitrite (one site) above the PWQO or CEQG.

Although this coarse analysis of land use on water quality provides an indication that land uses associated with human disturbances (i.e., 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 five sites where catchment areas 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, however further investigation into causes of higher concentrations of bacteria and nutrients needs to occur.

3.7.5 Provincial Water Quality Monitoring Network (PWQMN) Results

<u>Physical Parameters</u>

Table 3.45 describes the physical conditions as sampled at the two PWQMN sites in Cobourg 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. Turbidity measured at the Telephone Road station is related to increases in discharge, as measured at the William Street gauge station ($n=36$, $r_s = 0.3411$, $p<0.05$).

Table 3.45: Physical parameters as sampled at the PWQMN stations

PWQMN Station	n	Median	Minimum	Maximum	10th Percentile	90th Percentile
			Turbidity (FTU)			
Telephone Road	36	1.99	0.91	174	1.23	11.7
Fourth Street	280	5.50	0.01	200	2.00	26.0
			Particulate Residue (mg/L)			
Telephone Road	47	3.8	0.6	404	1.2	15.2
Fourth Street	381	15.0	0.0	356	3.7	63.0
			pH (infield and laboratory readings)			
Telephone Road	93	8.32	5.02	9.00	7.82	8.52
Fourth Street	438	8.25	4.92	9.50	7.70	8.51
			Dissolved Oxygen (mg/L)			
Telephone Road	46	12.93	5.85	19.75	9.00	15.94
Fourth Street	376	10.64	1.00	20.18	10.84	13.70
			Alkalinity (mg/L) as $CaCO_3$			
Telephone Road	47	240	179	277	227	264
Fourth Street	236	208	65	418	194	236
			Conductivity (μs/cm)			
Telephone Road	93	509	0.3	1271	456	748
Fourth Street	423	524	110	1269	447	675

Other Parameters

As previously mentioned, 46 water quality parameters have been sampled since 1965 through the PWQMN, however some parameters have been removed from analysis. 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 3.46).

Table 3.46: PWQMN samples 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	**Nitrite-N**	**Chloride**	Total Ammonium
Cadmium	Copper	**Nitrate-N**		Barium
Cobalt	Molybdenum	**Total Chromium**		Calcium
Iron	Nickle			Carbon
Lead	Vandium			Hardness
Phosphorus	Zinc			Magnesium
				Manganese
				Phosphate
				Potassium
				Sodium
				Strontium
				Titanium
				Total Kjeldahl N

Bold signifies parameters to be further analyzed

Metal Concentrations

Six metal parameters exceeded PWQO or CWQG within Cobourg Creek between 2002 and 2006 at the Telephone Road Station and between 2002 and 2007 at the Fourth Street Station. Table 3.47 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.

Table 3.47: Metal concentrations in Cobourg Creek from 2002 to 2007

Parameter	**Telephone Road Station (2002 to 2006)**						
	n	**Median**	**Min***	**Max**	**10^{th} Percentile***	**90^{th} Percentile**	**% of Samples Exceeding Objective**
Aluminum μg/L (PWQO = 75 μg/L)	38	40.1	14.7	1300	18.1	191	13
Cadmium μg/L (PWQO = 0.2μg/L)	38	0.15	-1.22	1.61	-0.76	0.79	42
Total Chromium μg/L (adapted CWQG = 2 μg/L (Pawlisz et al. 1997))	38	0.22	-1.52	11.6	-0.69	0.96	5
Cobalt μg/L (PWQO = 0.9 μg/L)	38	0.15	-1.58	1.92	-0.52	0.74	9
Iron μg/L (PWQO = 300 μg /L)	38	94.1	58.6	1650	64.2	235	3
Lead μg/L (PWQO = 5 μg/L)	38	0.04	-9.83	6.34	-4.95	4.72	5
	Fourth Street Station (2002 to 2007)						
Aluminum μg/L	47	44.7	-0.13	895	31.5	127	23
Cadmium μg/L	47	0.20	-1.09	1.32	-0.71	0.76	47
Total Chromium μg/L	47	0.22	-2.67	12.90	-1.03	0.91	4
Cobalt μg/L	47	0.17	-1.01	1.47	-0.52	0.92	11
Iron μg/L	47	79.8	7.35	1140	48.3	180	4
Lead μg/L	47	0.88	-9.58	12.20	-4.10	7.51	15

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

Metal Trends

There is no linear relationship between time and aluminum, cadmium, chromium, iron or lead concentrations at the Telephone Road station (Table 3.48). Cobalt concentrations have decreased between 2002 and 2006 at the Telephone Road station. At the Fourth Street station there is no linear relationship between time and aluminum, cadmium, chromium, cobalt, iron or lead (Table 3.48).

Table 3.48: Metal trends at PWQMN stations in Cobourg Creek

Parameter	Telephone Road Station			
	r^2	r_s	p	N
Aluminum	0.0945	-0.3074	0.0604	38
Cadmium	0.0050	-0.0710	0.6718	38
Chromium	0.0519	0.2279	0.1687	38
Cobalt	0.1108	-0.3328	0.0412*	38
Iron	0.0022	0.0474	0.7776	38
Lead	0.0192	-0.1384	0.4072	38
	Fourth Street Station			
Aluminum	0.0140	-0.1185	0.4227	47
Cadmium	0.0276	0.1661	0.2646	47
Chromium	0.0524	0.2288	0.1219	47
Cobalt	0.0012	0.0350	0.8154	47
Iron	0.0375	-0.1936	0.1922	47
Lead	0.0387	-0.1966	0.1853	47

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

Chloride Concentration and Trend

Chloride concentrations at the Fourth Street station have decreased since 1965 and there is no linear relationship between chloride concentrations and time at the Telephone Road station (Table 3.49, Figures 3.68 and 3.69). Chloride concentrations have never exceeded the CWQG of 250 mg/L at either station except once in 1977 when the maximum sample concentration exceeded the CWQG at the King Street station (replaced by the Fourth Street station).

Table 3.49: Chloride trends at PWQMN stations in Cobourg Creek

Station	r^2	r_s	p	n
Telephone Road	0.0104	0.1020	0.4951	47
Fourth Street	0.0552	-0.2286	<0.0001*	393

* indicates a significance of $p < 0.05$

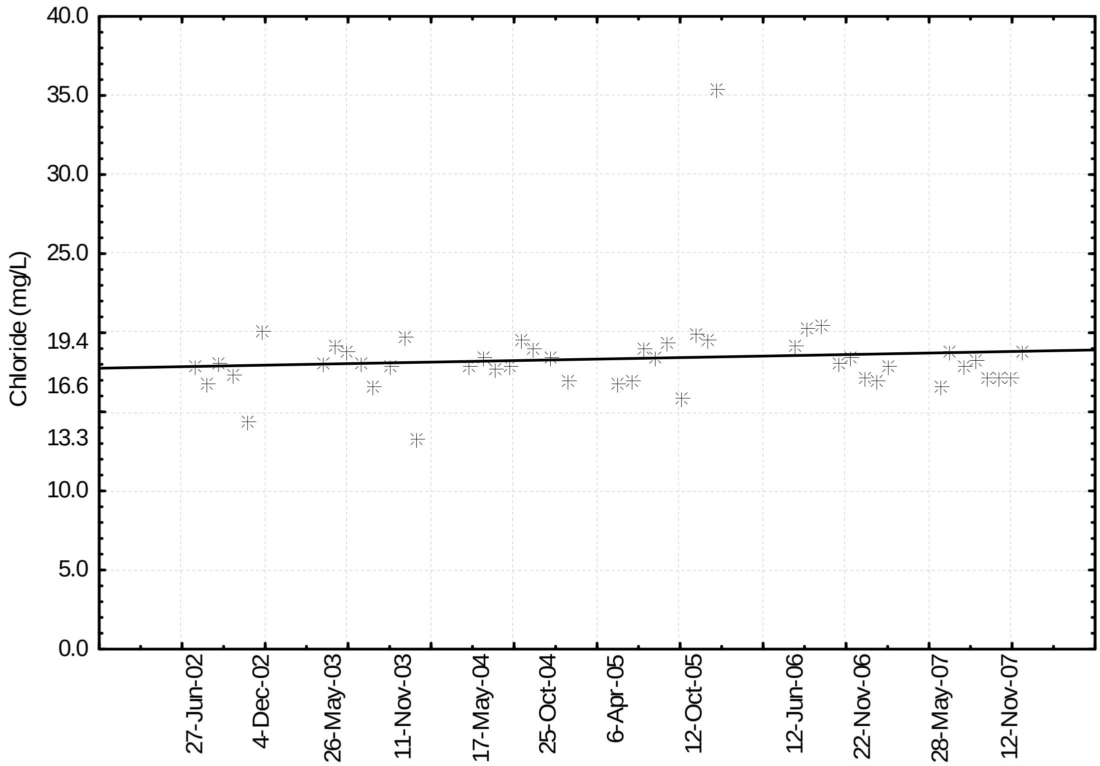


Figure 3.68: Chloride trend at the Telephone Road station, 2002 to 2007

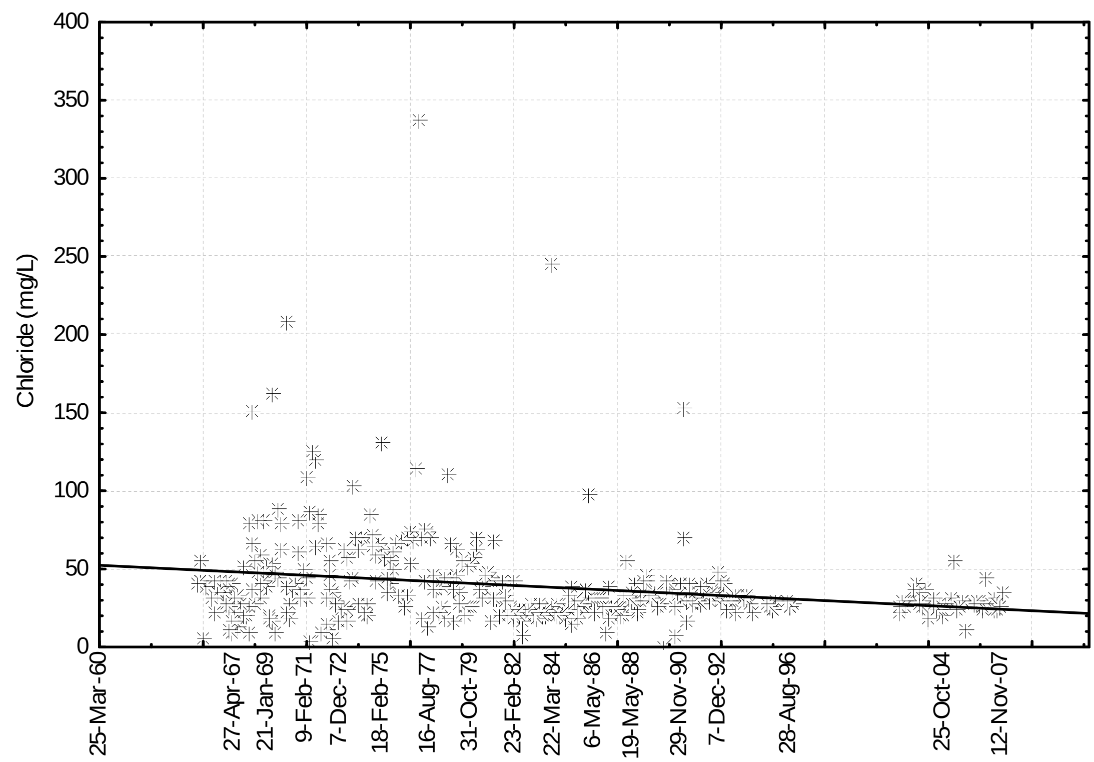


Figure 3.69: Chloride trend at the Fourth Street station, 1965 to 2007

Nutrient Concentrations

Since 2002 sampled total phosphorus has exceeded PWQO 23% of the time at Telephone Road and 32% of the time at Fourth Street (Table 3.50), however median concentrations are below the PWQO at the Telephone Road station and the Fourth Street station. Unfiltered nitrate-N has never exceeded CWQG at either station since 2002. Sampled nitrite-N did not exceed CWQG at either station, except twice at the Fourth Street station, or 4% of the time since 2002.

Table 3.50: Nutrient concentrations at PWQMN stations 2002 to 2007

Parameter	Telephone Road Station						
	n	Median	Min	Max	10^{th} Percentile	90^{th} Percentile	% of samples exceeding
Total Phosphorus mg/L (PWQO = 0.03 mg/L)	47	0.02	0.005	0.68	0.01	0.06	23
Nitrate-N Unfiltered mg/L (CWQG = 2.9 mg/L)	47	1.00	0.71	2.35	0.80	1.89	0
Nitrite-N mg/L (CWQG = 0.197 mg/L)	47	0.008	0.002	0.055	0.004	0.016	0
	Fourth Street Station						
Total Phosphorus mg/L	47	0.026	0.01	0.42	0.01	0.08	32
Nitrate-N Unfiltered mg/L	47	1.00	0.71	2.35	0.75	1.50	0
Nitrite-N mg/L	47	0.014	0.005	0.28	0.005	0.066	4

Nutrient Trends

Although total phosphorus concentrations have exceeded the PWQO at both stations, there is no linear trend in total phosphorus at the Telephone Road station, and there is a decline in total phosphorus concentrations at the Fourth Street station since 1964 (Table 3.51). Total phosphorus measured at the Telephone Road station and the Fourth Street station between 2002 and 2007 is not related to increases in discharge, as measured at the William Street gauge station (Telephone Road = n =47, r_s = 0.24, p = 0.11; Fourth Street = n=47, r_s = 0.03, p = 0.820).

There is no linear trend in nitrate-N concentrations at the Telephone Road station, although the concentrations have never exceeded the PWQO. At the Fourth Street station there is no linear trend in nitrate-N (unfiltered) concentrations since 2002 (Table 3.51). Nitrate-N measured at the Telephone Road and Fourth Street stations between 2002 and 2006 is related to increases in discharge, as measured at the William Street gauge station (Telephone Road: n=47, r_s = 0.3410, $p<0.05$; Fourth Street: n=47, r_s = 0.3016, $p<0.05$). There is no linear trend in nitrite-N concentrations at the Fourth Street station, but there has been a decline in nitrite-N concentrations at the Telephone Road station since

2002 (Table 3.51). There is no relationship between discharge and nitrite-N concentrations.

Table 3.51: Nutrient trends at PWQMN stations in Cobourg Creek

Parameters	Telephone Road Station			
	r^2	r	p	n
Total Phosphorus	0.0149	-0.1222	0.4132	47
Nitrate-N Unfiltered	0.0218	0.1477	0.3218	47
Nitrite-N	0.0920	-0.3003	0.0403*	47
	Fourth Street Station			
Total Phosphorus	0.0962	-0.3102	0.0000*	397
Nitrate-N Unfiltered	0.0616	0.2481	0.0927	47
Nitrite-N	0.0278	-0.1667	0.2627	47

* indicates a significance of $p < 0.05$

<u>Pesticides</u>

Out of the six samples each for 2,4-D, Atrazine, Metolachlor and Glyphosate, only 2,4-D was not found in concentration. Table 3.52 shows the concentrations of pesticides that were detected in Cobourg Creek. Metolachlor is below the PWQO of 3 µg/L, and Atrazine and Glyphosate are below respective federal guidelines.

Table 3.52: Pesticide concentrations

Date Sampled	Pesticide	Guideline (µg/L)	Concentration (µg/L)
June 22, 2007	Atrazine	1.8	0.11
June 22, 2007	Glyphosate	65	0.15
August 1, 2007	Metolachlor	3	0.17

3.7.6 Discussion of Cobourg Creek Surface Water Quality

<u>Physical Parameters</u>

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

Quantifying dissolved and suspended solids within Cobourg 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 turbidity and suspended solids can be attributed to higher flows. Total suspended solids rarely exceeded the recommended 25mg/L, and when exceedances occur it is during high flows.

Dissolved oxygen concentrations at sample sites are also within acceptable ranges as related to *Provincial Water Quality Objectives*. This indicates that instream 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 they rarely declined below acceptable concentrations. The maintenance of dissolved oxygen is important for aquatic organisms and their sustainability (Section 4.0.2).

The physical parameters of Cobourg 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 waters, in harder water, or in water that has a high buffering capacity such as Cobourg Creek. Therefore, Cobourg 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 to the 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 within Cobourg Creek are not currently an immediate issue as seen through the Chloride Monitoring Program and the PWQMN. In fact, chloride concentrations have decreased at the Fourth Street PWQMN station since the 1960s. This decline, among other factors, may be attributed to upgrades at the Cobourg Waste Water Treatment Plant #1 throughout the sampling time frame. However, site-specific chloride concentrations, although below the CEQG of 250 mg/L, do experience spikes during the winter season. Snow/mixed precipitation and snowmelt runoff months do have higher chloride concentrations than rain dominated months in Cobourg Creek, and sample sites below Highway 401 have higher chloride concentrations than sites above the 401. Although the 401 may be influencing the differences in chloride concentrations below the highway, this area is also urbanized, with more roads per unit area and storm drain influences.

Chloride concentrations may also be higher in the winter and snowmelt season in Cobourg 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). Winter stream conditions have increased flow over summer baseflow conditions. This increase in flow can cause chloride to be diluted, yet months that receive snow/mixed precipitation and snowmelt runoff (November to April) have higher chloride concentrations than months that receive rain (May to October), leading one to believe that chloride loadings outweigh the effects of dilution in the stream. The only way chloride can leave a river in winter is by water leaving the system.

One option for lowering 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 from 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 Cobourg Creek may be achieved.

Metals

Six metal parameters have exceeded PWQO or CWQG at the PWQMN stations between 2002 and 2007, however median concentrations of the six metals are below the respective PWQO or CWQG. Metals sampled within Cobourg Creek are not an immediate concern but should be continually monitored to ensure concentrations do not become elevated. In addition, proper urban landscape management (i.e., storm water management and industrial discharge) should occur to reduce the potential risk of metals within Cobourg Creek.

Aluminum concentrations have exceeded the PWQO 13% of the time at the Telephone Road station and 23% of the time at the Fourth Street 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 potential of being toxic 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 have 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 32% of the time. Since 1964 total phosphorus has declined at the Fourth Street/King Street station. Unionized ammonia has been sampled in concentrations greater than the PWQO of 0.02 mg/L 31% of the time as sampled through the GRWQMN, but unionized ammonia never exceeded the PWQO during baseflow water quality monitoring sampling.

Nitrate-N exceeded the CWQG only during baseflow water quality monitoring sampling (6% of the time). Nitrite-N rarely exceeds the CWQG during baseflow water quality monitoring sampling (4% of the sites), and GRWQMN sampling (3% of the sites). At the Telephone Road PWQMN station, nitrite-N concentrations have been declining since 2002. 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.

The Town of Cobourg Waste Water Treatment Plant #1 releases its treated effluents into Cobourg Creek, approximately 1.2 km upstream of Lake Ontario. The release of effluent results in a small increase of total phosphorus concentrations in all seasons except autumn (Greenland International Consulting Limited 2004). Therefore, it is possible that the effluents from the Waste Water Treatment Plant #1 play a role in elevated total phosphorus concentrations at the Fourth Street PWQMN station, especially when there are already elevated levels within Cobourg Creek from upstream sources. Within the next few years however, there are plans to add a tertiary treatment system to the Waste Water Treatment Plant #1, which will further address the issue of nutrient discharge.

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) that 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 manure or fertilizer was incorporated, and how soon before a rainfall event that manure or fertilizer was applied (Sharpley et al. 1996).

Aquatic systems can benefit from phosphorus that makes a system productive. Addition of phosphorus can cause change in a system by increasing plant and algal growth that in turn alters the number and types of plants and animals, increases animal growth and size, increases turbidity, creates more organic matter, and 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 that 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 Cobourg Creek during high flows or storm events, and direct methods such as storm drains and field tile drains are useful. 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 for reducing the amount of nutrients entering Cobourg 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 Cobourg Creek have been analyzed. Eight samples 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 Cobourg Creek are either nonexistent 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 Cobourg Creek watershed and total coliforms range between 80 and 23000 cfu/100ml. The presence of *Escherichia coli* in surface water indicates that fecal material from humans or other warm-blooded animals is present in the water. However, it is natural to have concentrations of coliforms in any river system. Sources of *Escherichia coli* include municipal wastewater spills, septic leachate, agricultural or storm runoff, wildlife populations, or nonpoint sources of human or animal waste (An et al. 2002). Total coliform includes all coliform species (*Escherichia coli* and its variants). Sources of total coliform are the same sources as *Escherichia coli*, however they are not necessarily from fecal matter, but also plant and organic material.

Fecal coliforms are bacteria, which are single-celled living organisms. These bacteria can decay under certain environmental factors. 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/100ml is in place in the Province of Ontario (Ontario Ministry of the Environment 2003) and a recreational guideline of 100 cfu/100ml.

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 effects of fecal coliform on aquatic organisms is uncertain, proper management of sources of fecal coliforms need to be addressed in the Cobourg Creek watershed. In addition, surface water that serves as sources of drinking water for human or livestock consumption needs to be protected from fecal coliform contamination.

Chapter 4 - Biotic Features

4.0 AQUATIC RESOURCES

Aquatic resources within Cobourg Creek include instream habitat and the aquatic organisms that rely on aquatic habitats, and riparian areas. The forms and functions of these resources rely on 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 a healthy environment. The Cobourg Creek watershed has long been recognized for its excellent trout and salmon fishery. The Cobourg Creek historically supported healthy brook trout and Atlantic salmon populations. Through the efforts of the Ontario Ministry of Natural Resources stocking programs, the river now supports a diverse coldwater fishery. Cobourg Creek hosts a significant salmonid spawning run from the Lake Ontario basin. Currently, a major effort is being undertaken to reintroduce a self-sustaining Atlantic salmon population into Cobourg Creek.

In conjunction with the Cobourg Creek Watershed Background Document and Plan, a Fisheries Management Plan for Cobourg is being created in partnership with the Ontario Ministry of Natural Resources. The *"Fisheries Background Report for Cobourg Creek Fisheries Management Plan"* (Ontario Ministry of Natural Resources and Ganaraska Region Conservation Authority 2008) has been created to assist in the development of the Fisheries Management Plan. Information pertaining to the Cobourg Creek fisheries presented in this document has been summarized from the background document prepared for the Fisheries Management Plan. Please refer to this document for detailed information on fisheries analysis and results.

Methods

Fisheries data was collected using a one-pass backpack electrofishing method (Stanfield 2005). Data was used from a variety of agencies, all of which was collected using similar methods. Data was standardized to avoid error from inconsistent methods, and data from the period of 2002 to 2007 was used to reduce the effects of temporal variation. As a result, 79 sites were used to characterize the fisheries of Cobourg Creek. Atlantic salmon (*Salmo salar*) were not analyzed within fish communities as their presence is a result of stocking, not natural populations (Ontario Ministry of Natural Resources and Ganaraska Region Conservation Authority 2008). In addition, species that were only found in more than 10% of the sampling sites were included in fish community analysis.

Fish density (fish/m^2) and biomass (grams/m^2) were calculated for all species observed in each sample site, and sites were described using percentiles. Site area was calculated from site length and average site width.

The Cobourg Creek watershed was divided into nine sub-catchments for the purpose of reporting and analyzing fisheries and instream data. The sub-catchments were divided using tributary boundaries and sections of tributaries where fish barriers existed (i.e., dams or water structures), and/or where shifts in dominant surficial geology or land use were present (Ontario Ministry of Natural Resources and Ganaraska Region Conservation Authority 2008). The resulting nine sub-catchments are found in Figure 4.0.

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 10% of the sampling sites, Atlantic salmon and Chinook salmon. Please refer to Ontario Ministry of Natural Resources and Ganaraska Region Conservation Authority 2008 for details on these methods.

Cobourg Creek Fisheries

Cobourg Creek fisheries have been summarized from "Fisheries Background Report for Cobourg Creek Fisheries Management Plan" Ontario Ministry of Natural Resources and Ganaraska Region Conservation Authority 2008. Maps presented in this section are from Ontario Ministry of Natural Resources and Ganaraska Region Conservation Authority 2008. Please refer to this document for additional information.

Thirty-six fish species have been identified within Cobourg Creek (Table 4.0). Of these species, 21 were found during backpack electrofishing from 1997 to 2007. These species were found within different sub-catchments, and are shown with abundance and diversity in each sub-catchment (Table 4.1). The species listed in Table 4.1 were subjected to further analysis as these species were found in more than 10% of the sample sites. The following represents a summary of the distribution patterns of the species. Please refer to Ontario Ministry of Natural Resources and Ganaraska Region Conservation Authority 2008 for further detailed information.

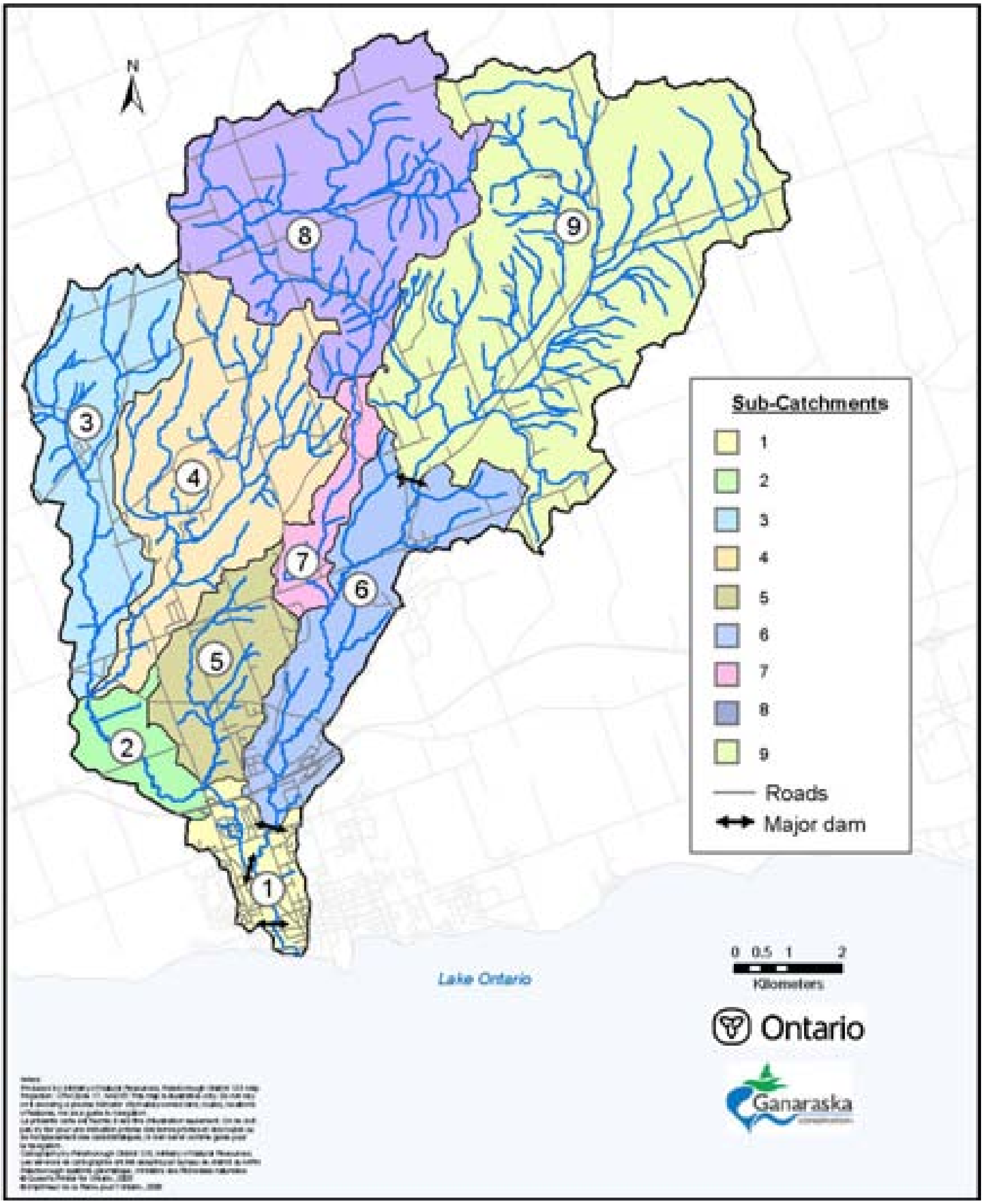


Figure 4.0: Fisheries sub-catchments

Table 4.0: Fish species observed in Cobourg Creek

Common Name	Scientific Name	Origin and Designation
Atlantic salmon	*Salmo salar*	Native and Extirpated
brook trout	*Salvelinus fontinalis*	Native
rainbow trout	*Oncorhynchus mykiss*	Introduced
brown trout	*Salmo trutta*	Introduced
Chinook salmon	*Oncorhynchus tshawytscha*	Introduced
longnose dace	*Rhinichthys cataractae*	Native
blacknose dace	*Rhinichthys atratulus*	Native
Northern redbelly dace	*Phoxinus eos*	Native
finescale dace	*Phoxinus neogaeus*	Native
emerald shinner	*Notropis atherinoides*	Native
common shinner	*Luxilus cornutus*	Native
creek chub	*Semotilus atromaculatus*	Native
horneyhead chub	*Nocomis biguttatus*	Native
white sucker	*Catostomus commersonii*	Native
brassy minnow	*Hybognathus hankinsoni*	Native
bluntnose minnow	*Pimephales notatus*	Native
fathead minnow	*Pimephales promelas*	Native
Johnny darter	*Etheostoma nigrum*	Native
fantail darter	*Etheostoma flabellare*	Native
logperch	*Percina caprodes*	Native
slimy sculpin	*Cottus cognatus*	Native
mottled sculpin	*Cottus bairdii*	Native
brook stickleback	*Culaea inconstans*	Native
pumpkinseed	*Lepomis gibbosus*	Native
bluegill	*Lepomis macrochirus*	Native
brown bullhead	*Ameiurus nebulosus*	Native
round goby	*Neogobius melanostomus*	Introduced
Sea lamprey	*Petromyzon marinus*	Native*
American brook lamprey	*Lampetra appendix*	Native
rock bass	*Ambloplites rupestris*	Native
smallmouth bass	*Micropterus dolomieu*	Native
threespine stickleback	*Gasterosteus aculeatus*	Native
rainbow smelt	*Osmerus mordax*	Introduced*
common carp	*Cyprinus carpio*	Introduced
banded killifish	*Fundulus diaphanous*	Native
longnose sucker	*Catostomus catostomus*	Native

* Some scientists believe that rainbow smelt are native to Lake Ontario. Sea lamprey is also believed to be native to Lake Ontario due to the connection to the Atlantic Ocean. Sea Lamprey is non-native to the upper Great Lakes.

Table 4.1: Fish species diversity and richness per sub-catchment

Sub-catchment	brook trout *(Salvelinus fontinalis)*	brown trout *(Salmo trutta)*	Chinook salmon *(Oncorhynchus tshawytscha)*	rainbow trout *(Oncorhynchus mykiss)*	white sucker *(Catostomus commersonii)*	northern redbelly dace *(Phoxinus eos)*	brassy minnow *(Hybognathus hankinsoni)*	Hornyhead chub *(Nocomis biguttatus)*	common shiner *(Luxilus cornutus)*	bluntnose minnow*(Pimephales notatus)*	fathead minnow *Pimephales promelas)*	blacknose dace *(Rhinichthys atratulus)*	longnose Dace *(Rhinichthys cataractae)*	creek chub *(Semotilus atromaculatus)*	brook stickleback *(Culaea inconstans)*	pumpkinseed *(Lepomis gibbosus)*	johnny darter *(Etheostoma nigrum)*	fantail darter *(Etheostoma flabellare)*	sculpin family *(Cottidae)*	round goby (*Neogobius melanostomus)*	juvenile lamprey *(Petromyzontidae)*	**Species Richness (number of species)**
1		X	X	X	X				X	X		X	X	X		X	X	X	X	X	X	**15**
2			X	X	X				X	X	X	X	X	X	X	X	X	X	X		X	**15**
3	X	X		X	X	X			X	X		X	X	X			X	X	X		X	**14**
4	X			X	X						X	X	X	X	X		X		X		X	**11**
5				X	X				X	X		X		X			X		X			**8**
6	X	X		X	X	X					X	X	X	X	X		X	X	X		X	**14**
7	X	X		X	X	X					X	X	X	X					X		X	**11**
8	X	X		X	X	X	X	X			X	X	X	X	X				X		X	**14**
9	X	X		X		X						X	X	X					X		X	**9**

Brook Trout (Salvelinus fontinalis)

Brook trout are a valued native sport fish and have been stocked intensively because of their visual appeal and economic value. Requiring cold water, brook trout are sensitive to habitat alteration and their presence is indicative of a coldwater stream. Approximately 50,000 brook trout were stocked in Cobourg Creek by the Ontario Ministry of Natural Resources from 1946 to 1976. Private stocking most likely occurred prior to 1946, however the earliest private stocking recorded was in 1970. Evidence from other geographically-proximate tributaries (e.g., Ganaraska River) indicates that stocking of provincial hatchery brood stock has resulted in introgression of genotypes in stream-resident brook trout.

Cobourg Creek brook trout densities ranged from 0.001 to 0.345 fish/m^2 and biomass ranged from 0.006 to 6.932 g/m^2. The highest densities and biomass of brook trout were observed in the northern half of the watershed within or close to the Oak Ridges Moraine boundary (Figure 4.1). Brook trout were only found in three sites south of Dale Road in lower densities and biomass. Sites supporting the largest populations of brook trout were found in the headwaters of the West and East Branch.[3].

Rainbow Trout (Oncorhynchus mykiss)

Rainbow trout are native to the Pacific Ocean, the west coast of North America, and East Asia. Rainbow trout were first introduced into Lake Ontario in the late 1800s and 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 nearby tributaries has occurred since 1961. Straying from the nearby populations was likely the first adfluvial rainbow trout to spawn in Cobourg Creek, although 4,300 rainbow trout have been stocked in Cobourg Creek between 1968 and 1984. Since 1979, approximately 200 adult rainbow trout have been manually transferred over Pratt's Dam each spring by the Ontario Ministry of Natural Resources, the Ganaraska Region Conservation Authority and local volunteers.

[3] When referencing locations of fish species, the East Branch includes all areas and tributaries above the confluence where the West Branch joins. Within the rest of the document this branch is referred to as the Central Branch and Baltimore Creek Tributary respectively.

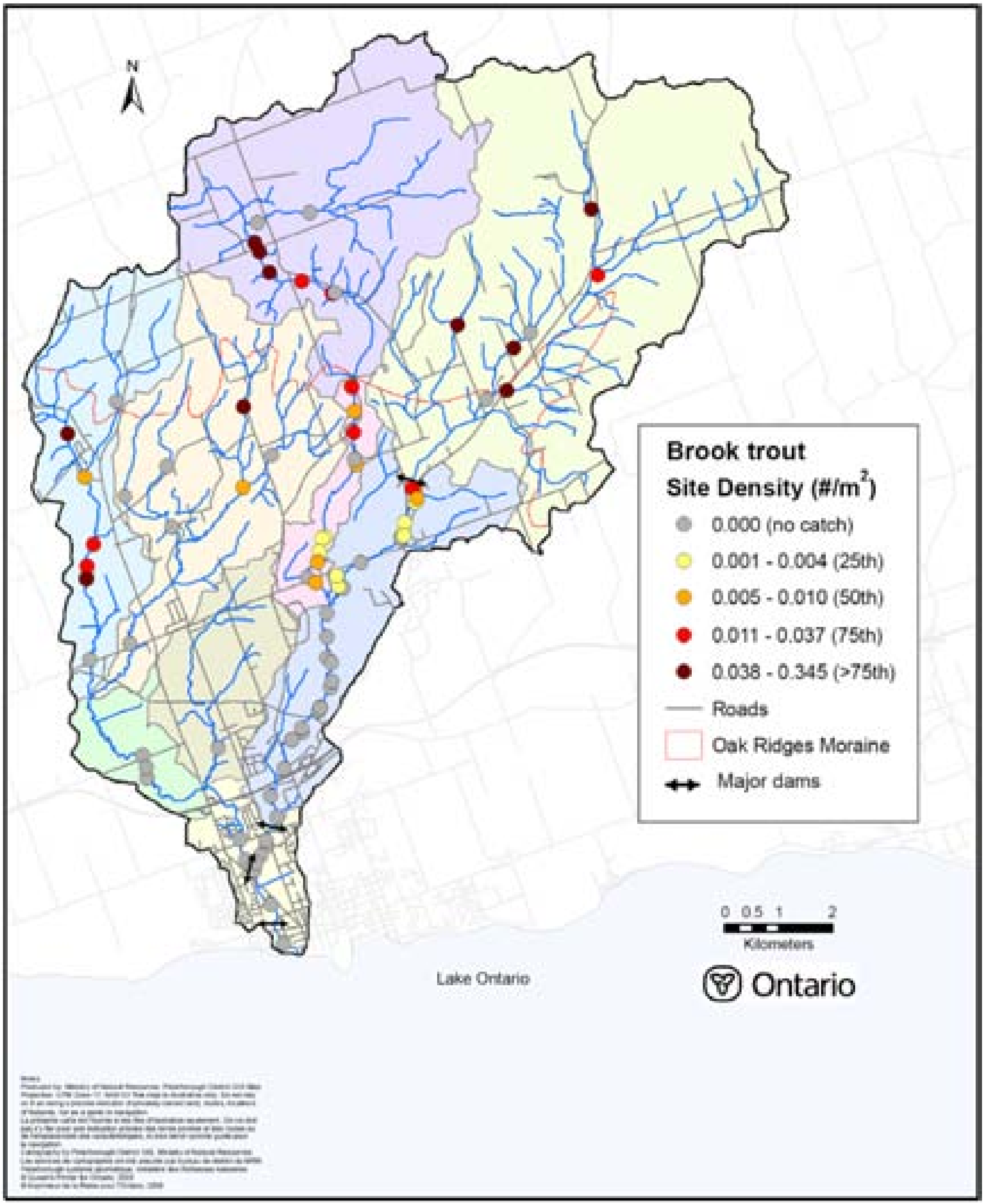


Figure 4.1: Brook trout July/August distribution

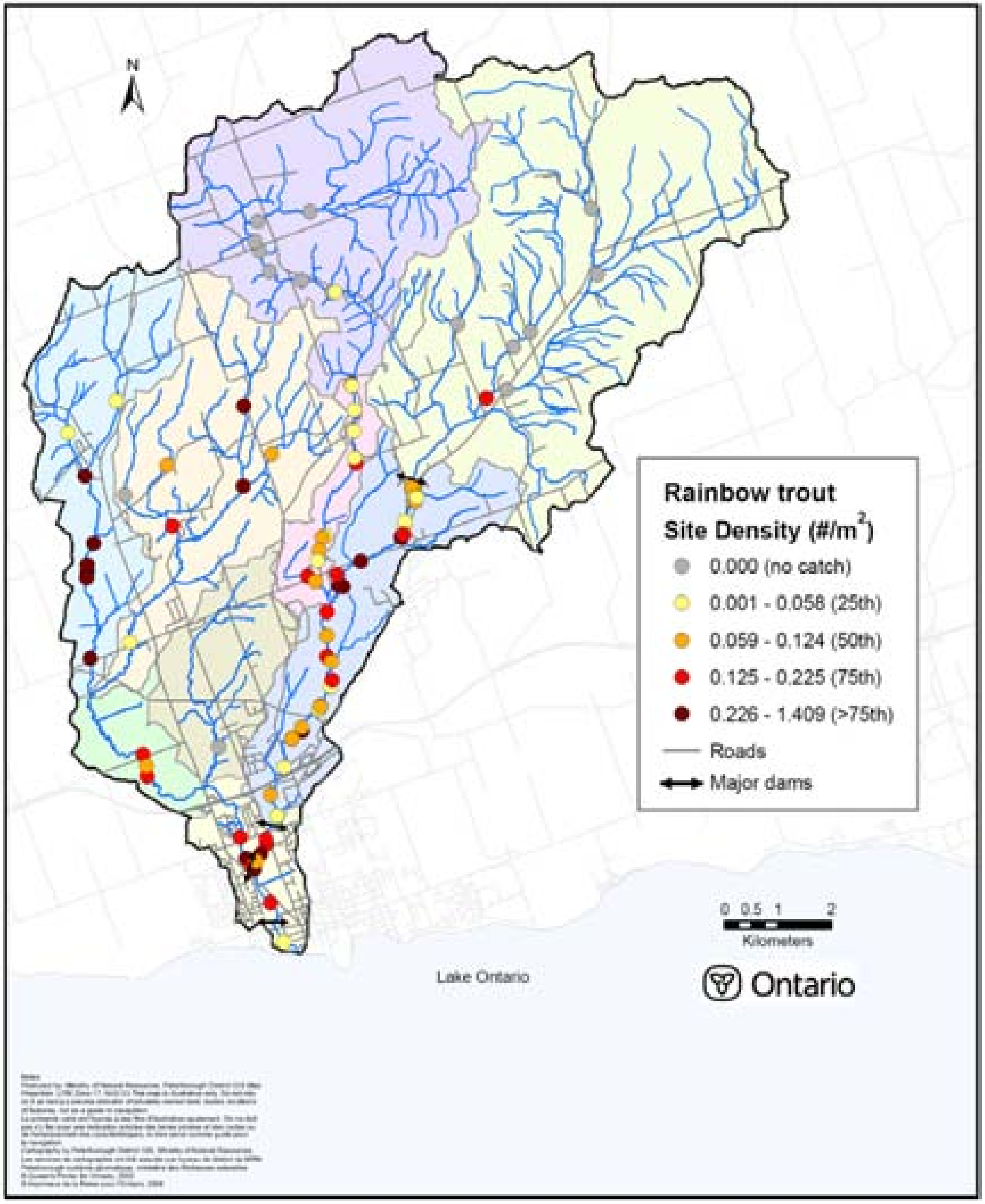


Figure 4.2: Rainbow trout July/August distribution

Rainbow trout are present in both the East and West Branches where densities ranged from 0.007 to 1.409 fish/m^2 and biomass from 0.075 to 15.394 g/m^2 (Figure 4.2). Rainbow trout are less common in the East Branch headwaters, but occupy the majority of the watershed and were present in 84% of the sampling sites. Rainbow trout are not transferred over the Ball's Mill Dam, however they were observed at one sample site above the dam. The mechanism of transfer is not known for certain, however recorded pond stockings of rainbow trout have occurred in the East Branch since 1974 and large storm events are known to facilitate escaping.

Brown Trout (Salmo trutta)

Brown trout are native to Europe and western Asia and were introduced into North America in 1883 to 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 Cobourg Creek, stream resident brown trout have been stocked from 1948 to 1988.

Brown trout densities ranged from 0.001 to 0.134 fish/m^2 and biomass ranged from 0.011 to 21.450 g/m^2 (Figure 4.3). Their large biomass is attributed to the life history traits of the resistant strain fishes. Brown trout have not been transferred over Pratt's Dam, fragmenting their distribution throughout the watershed. Despite unobstructed access to the West Branch, brown trout were only observed in one site on the West Branch (Figure 4.3). The driver for their modest presence in the West Branch is unknown and further research is required to understand why the adaptable species is not utilizing the West Branch.

Chinook Salmon (Oncorhynchus tshawytscha)

Chinook salmon are native to the Pacific Ocean and its freshwater tributaries from the Bering Sea southwest to northern Japan, and southeast to southern California. This large salmonid was first introduced into Lake Ontario from 1874 to 1881 (Scott and Crossman 1998), with intermittent stocking after 1916 and intensive stocking since 1969. Spawning occurs during the fall, generally September/October in riffles. Females create large redds (nests) 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.

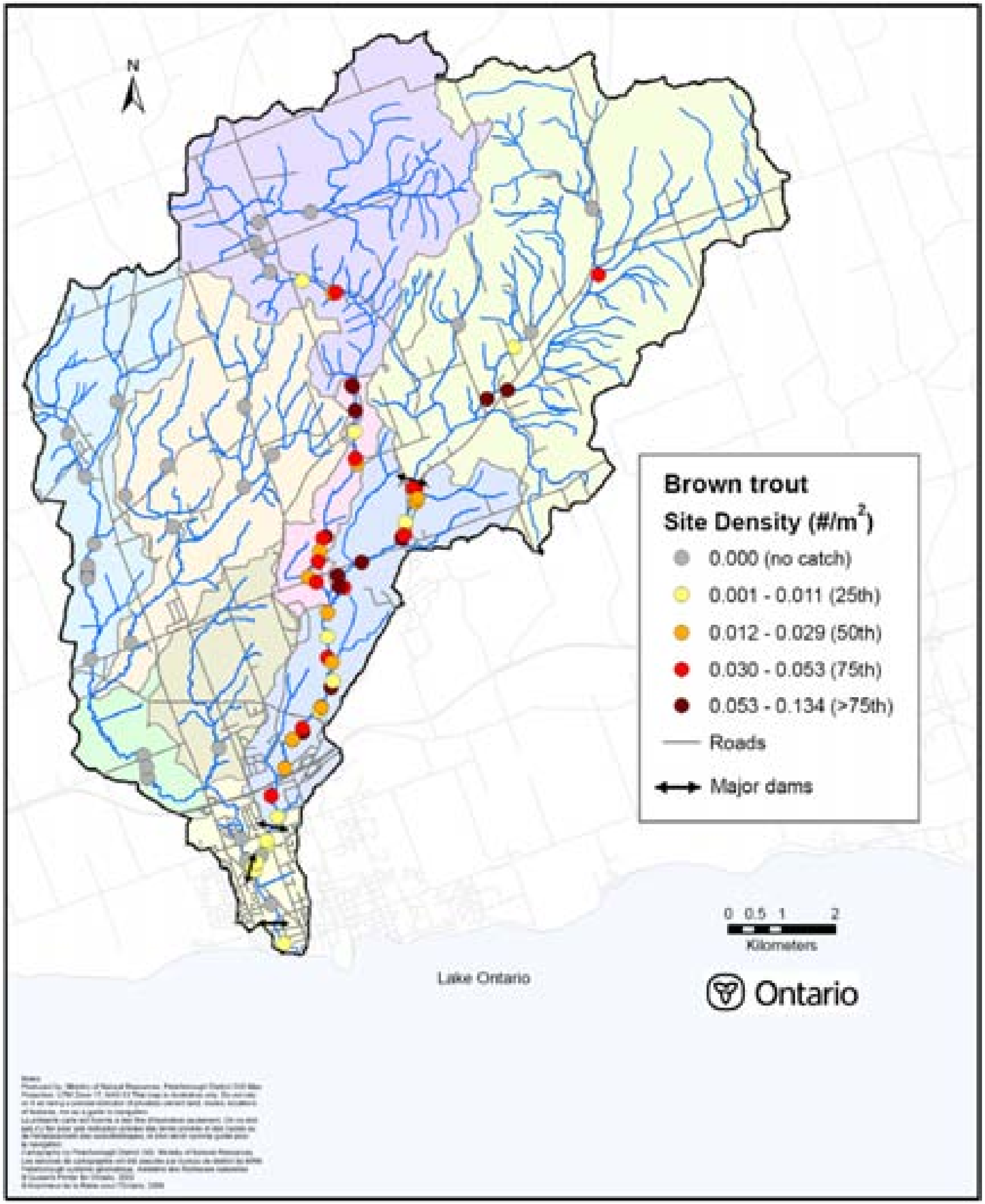


Figure 4.3: Brown trout July/August distribution

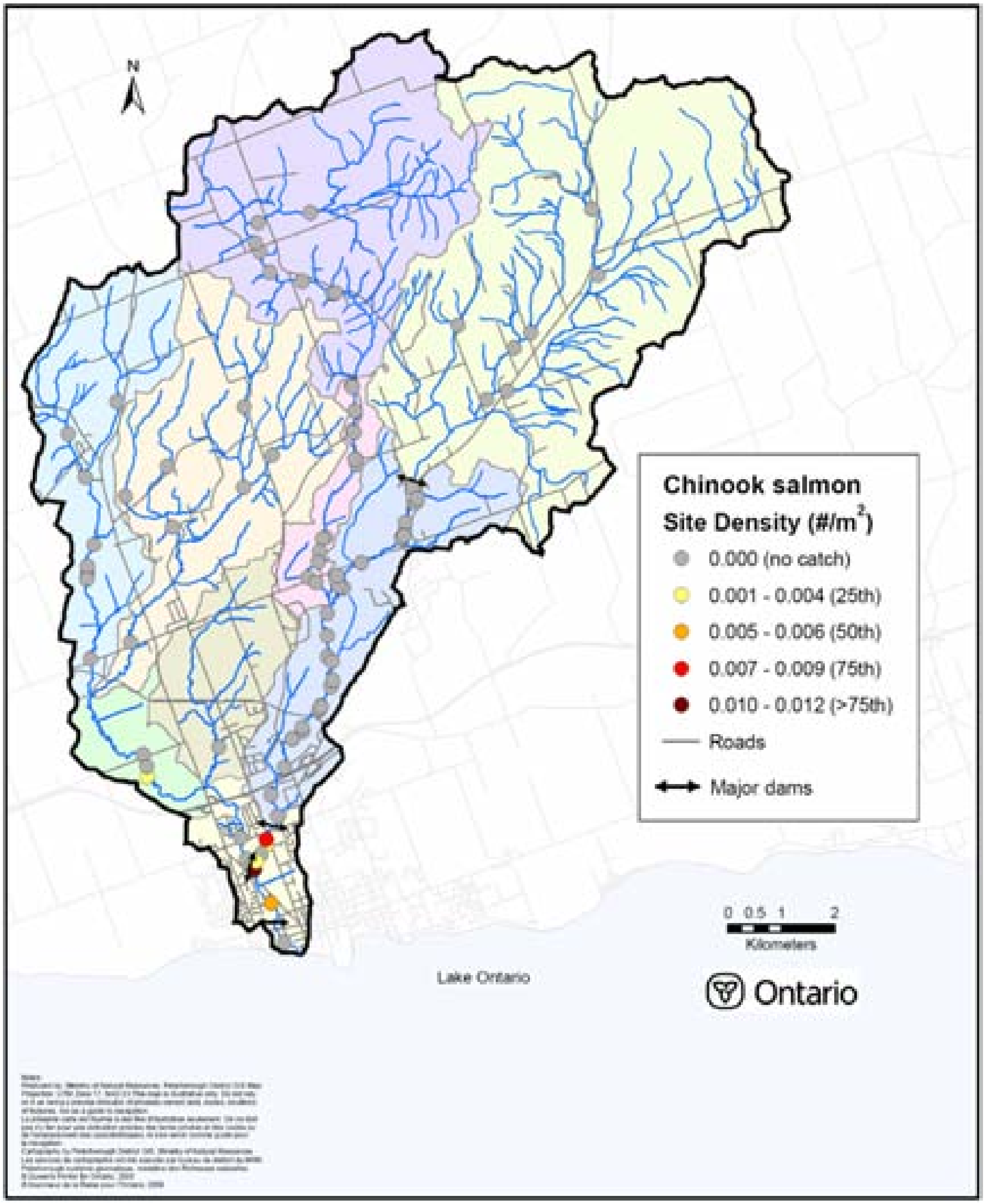


Figure 4.4: Juvenile Chinook salmon July/August distribution

Chinook salmon have not been transferred over Pratt's Dam, limiting their spawning distributions to the Main and West Branch of the watershed. Approximately 394,000 fingerlings (three to nine months of age) were stocked in Cobourg Creek from 1988 to 2000 in the lower reach of the Main Branch, south of King Street by the Ontario Ministry of Natural Resources.

Chinook salmon were observed south of the 401 in the lower Main Branch of the watershed with the exception of one site in the West Branch, north of 401 (Figure 4.4). Juvenile fish were observed in low densities ranging from 0.005 to 0.012 fish/m^2 and biomass ranging from 0.028 to 0.087 g/m^2. The distribution of Chinook salmon reflects their life history characteristics and agency management. The abundance of the spawning adult Chinook salmon in Cobourg Creek has not been assessed. However, their large body size and adfluvial spawning habits have made this Pacific salmon a popular sport fish in Cobourg Creek.

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

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

The longnose dace is native to North America and occurs 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 the longnose dace is not commonly used as a baitfish, but is a valuable prey item for salmonids. Longnose dace spawn in early spring on riffle bars over gravel substrate (Scott and Crossman 1998).

Blacknose dace densities ranged from 0.002 to 1.2 fish/m^2 and biomass ranged from 0.008 to 2.87 g/m^2 (Figure 4.5). They were observed throughout the entire watershed occurring in 87% of the sample sites, making this cyprinid the most common species observed in the watershed. Currently, one bait block exists in the Cobourg Creek watershed and approximately 35,000 minnows were harvested in 2006 and 2007. In both years blacknose dace were the dominant species harvested.

Longnose dace densities ranged from 0.002 to 0.651 fish/m^2 and biomass ranged from 0.002 to 2.786 g/m^2. They were observed in both the East and West Branch and above all major dams in the watershed (Figure 4.6). Longnose dace were only observed in two headwater sites, and both site densities were low.

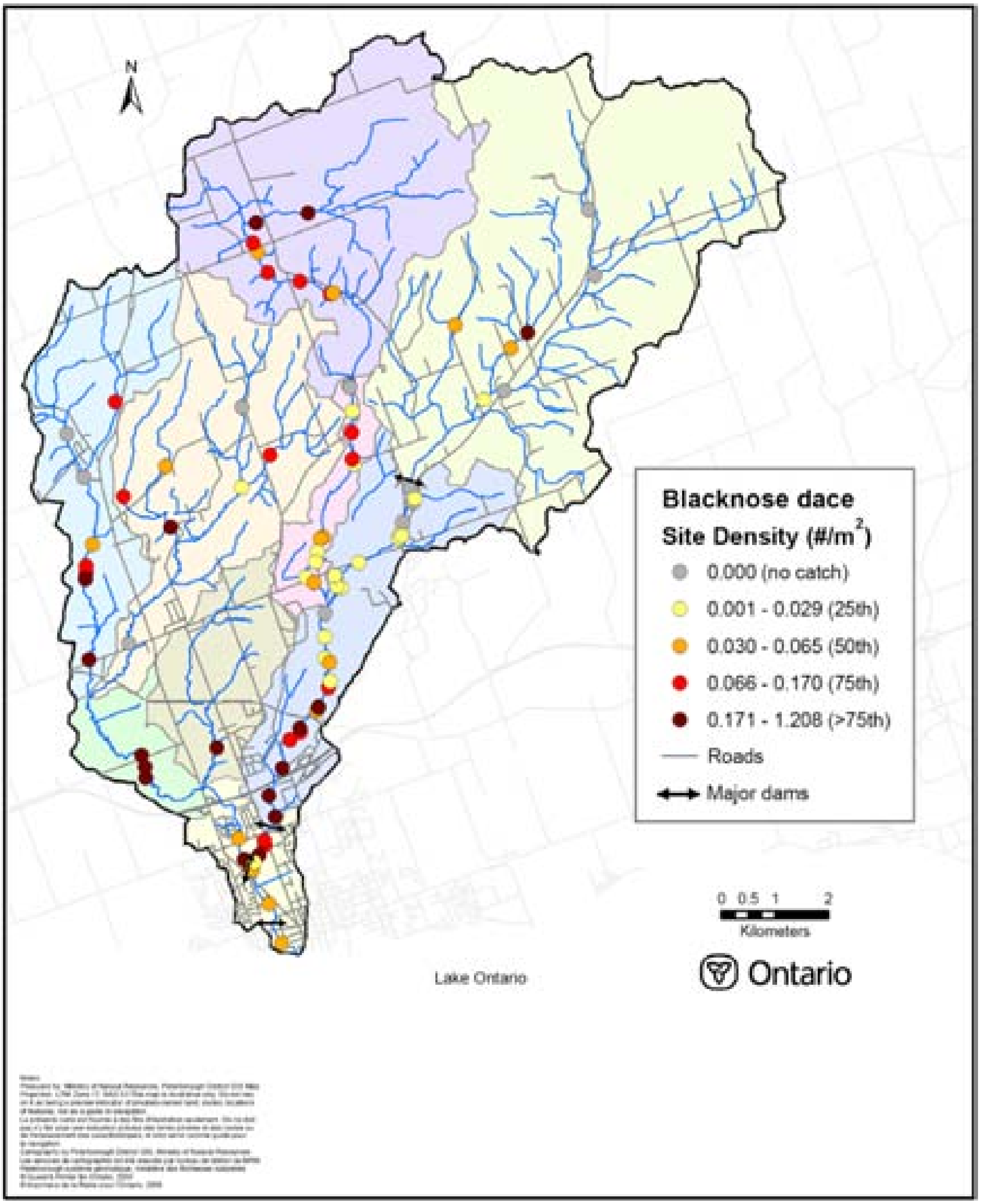


Figure 4.5: Blacknose dace July/August distribution

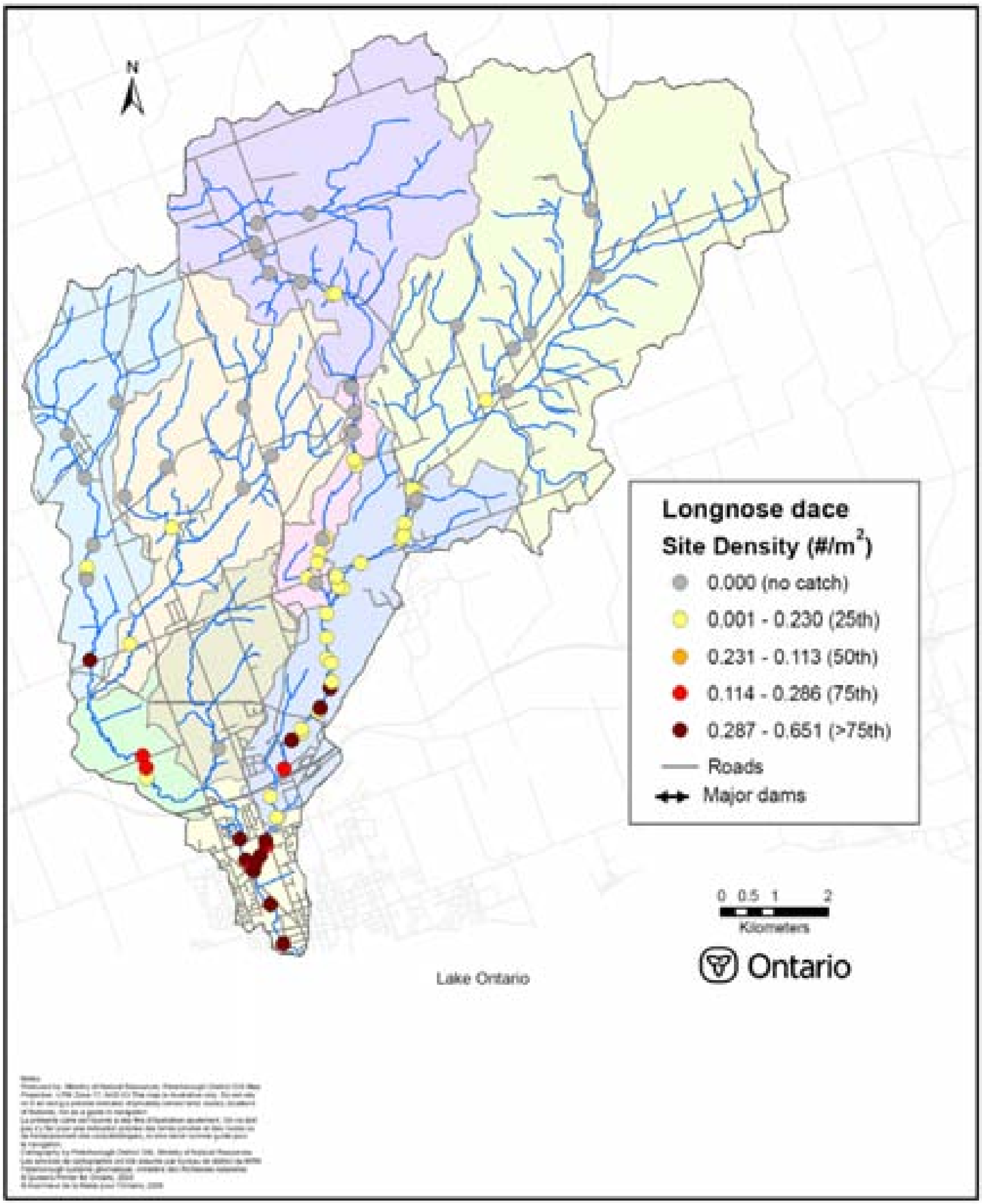


Figure 4.6: Longnose dace July/August distribution

White Sucker (Catostomus commersonii)

Native to 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 sucker eggs adhere to stream substrate. Atlantic salmon and brook trout are known to consume juvenile white suckers. Adults return to their native stream in two to four years to spawn (Scott and Crossman 1998). White suckers are tolerant of warmer water, however they are commonly found in coldwater systems.

The highest percentages of suckers were observed above Pratt's Dam (Figure 4.7), indicating a non-migratory population. White sucker densities ranged from 0.002 to 0.224 fish/m^2 and biomass ranged from 0.011 to 10.945 g/m^2. The adfluvial white sucker run had an average of 1118 individuals transferred upstream of the low-head lamprey barrier at King Street from 1997 to 2007. White suckers do not seem to use the West Branch to the same extent as the East Branch.

Sculpin Species (Cottidae)

Mottled sculpin (*Cottus bairdii*) and slimy sculpin (*Cottus cognatus*) were observed in Cobourg Creek, and were grouped together for analysis. 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). Sculpins were observed through the East and West Branch (Figure 4.8). Sculpin densities ranged from 0.011 to 0.778 fish/m^2 and biomass ranged from 0.047 to 3.934 g/ m^2. West Branch headwaters had higher densities than the East Branch headwaters.

Johnny Darter (Etheostoma nigrum) and Fantail Darter (Etheostoma flabellare)

Two darter species were observed in the Cobourg Creek watershed. Darters are native and are only found in North America, however the fantail darter's range is more restricted than that of the Johnny darter. Darters in southern Canada spawn around April/May under rocks where the male provides parental care. The Johnny and fantail darter were found in the southern end of the watershed. Fantail darters were only observed in sites where Johnny darters were present (Figure 4.9). Both darter species were observed in the East and West Branch of the watershed. Johnny darter densities ranged from 0.003 to 0.137 fish/m^2 and biomass ranged from 0.003 to 0.286 g/m^2. Fantail darter densities ranged from 0.004 to 0.09 fish/m^2 and biomass ranged from 0.005 to 0.0157 g/m^2 (Figure 4.10).

Uncommon Fish Species observed in Cobourg Creek

Fish species infrequently observed in sampling sites include common shiner, creek chub, bluntnose minnow, fathead minnow, northern redbelly dace/finescale dace, brook stickleback and pumpkinseed (Table 4.1). Hornyhead chub and brassy minnow were both observed in one location in the headwaters of the Crossen tributary (sub-catchment 8). All of the uncommon species observed in the watershed are common within the Great Lakes basin and tributaries.

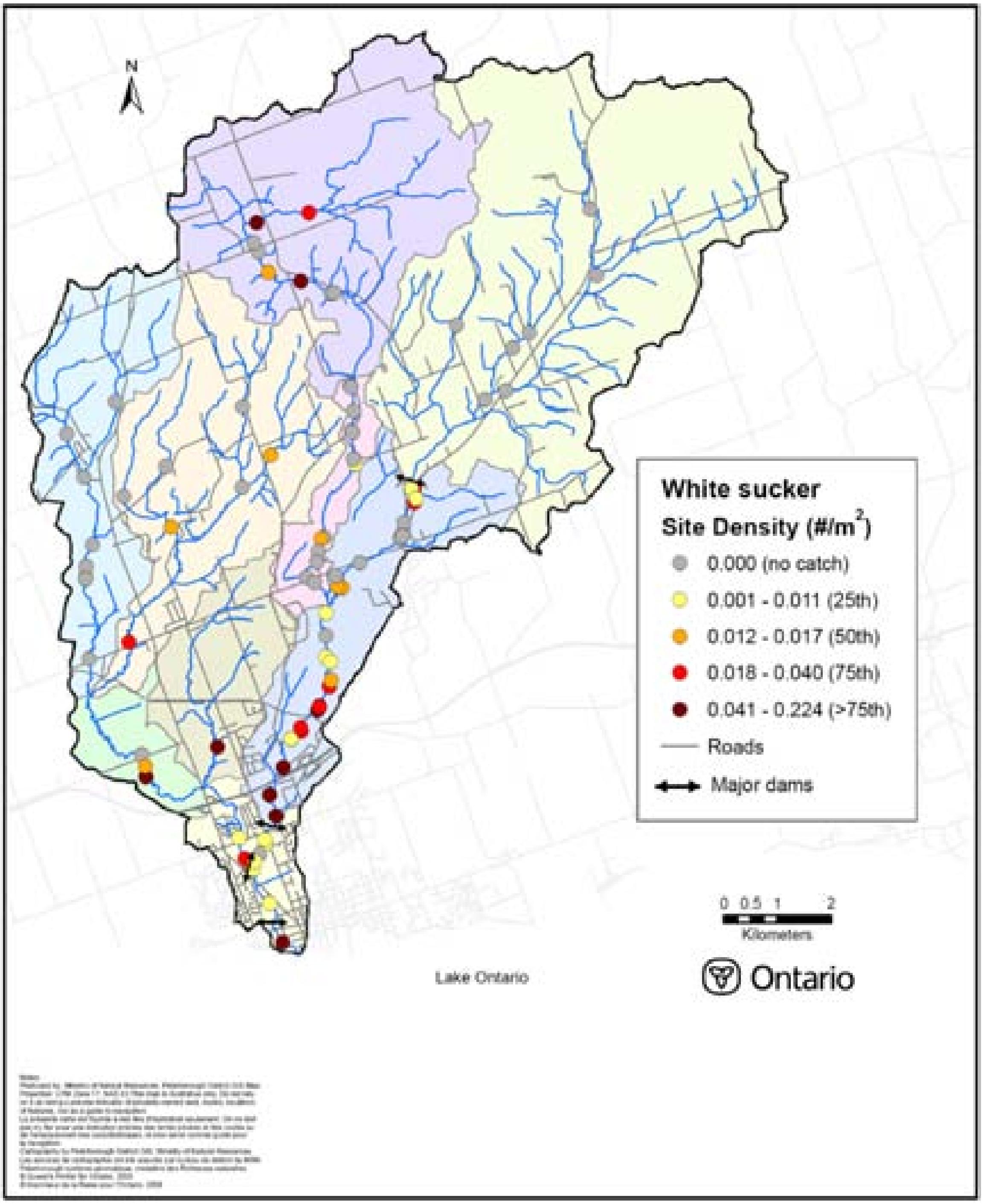


Figure 4.7: White sucker July/August distribution

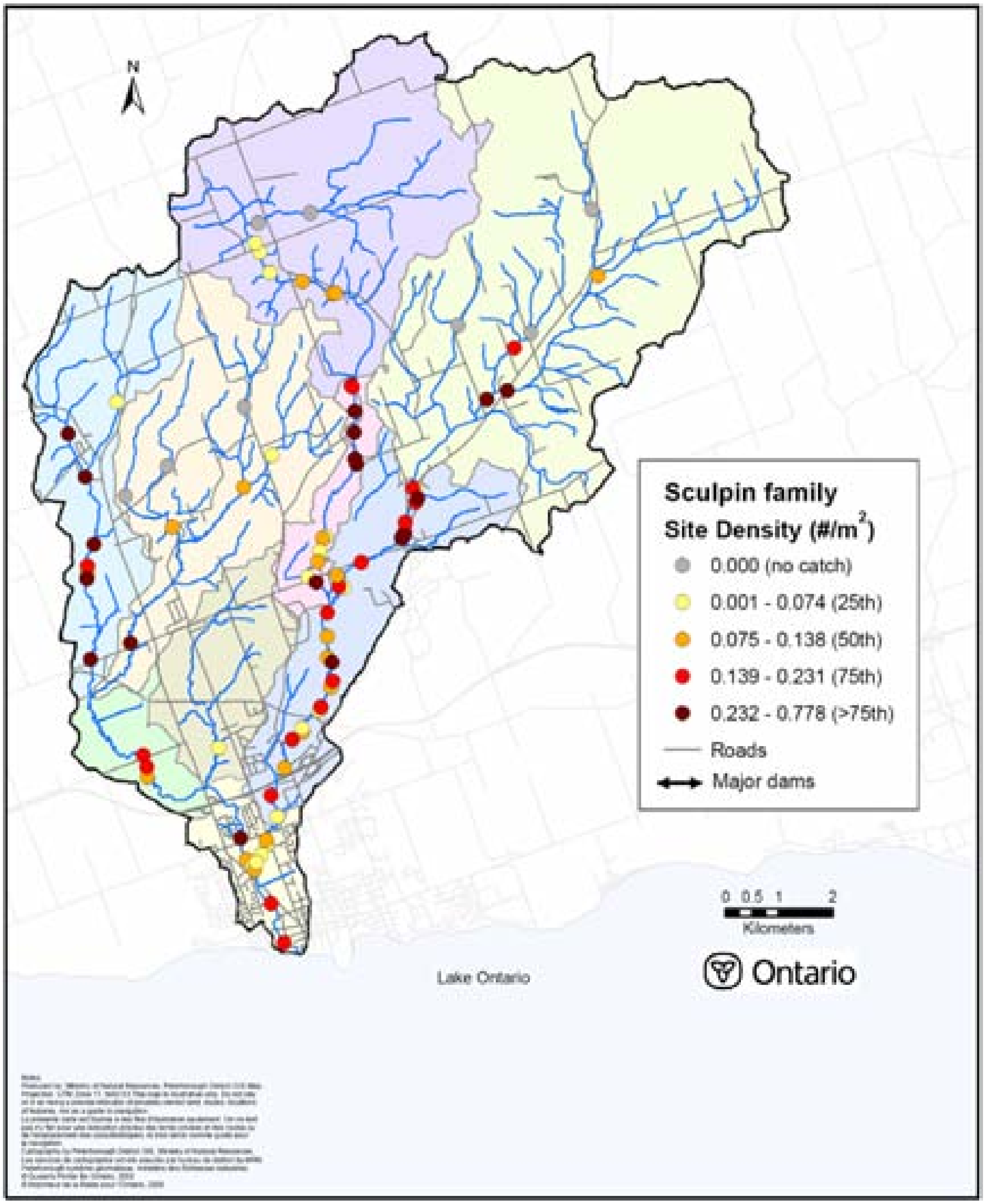


Figure 4.8: Sculpin July/August distribution

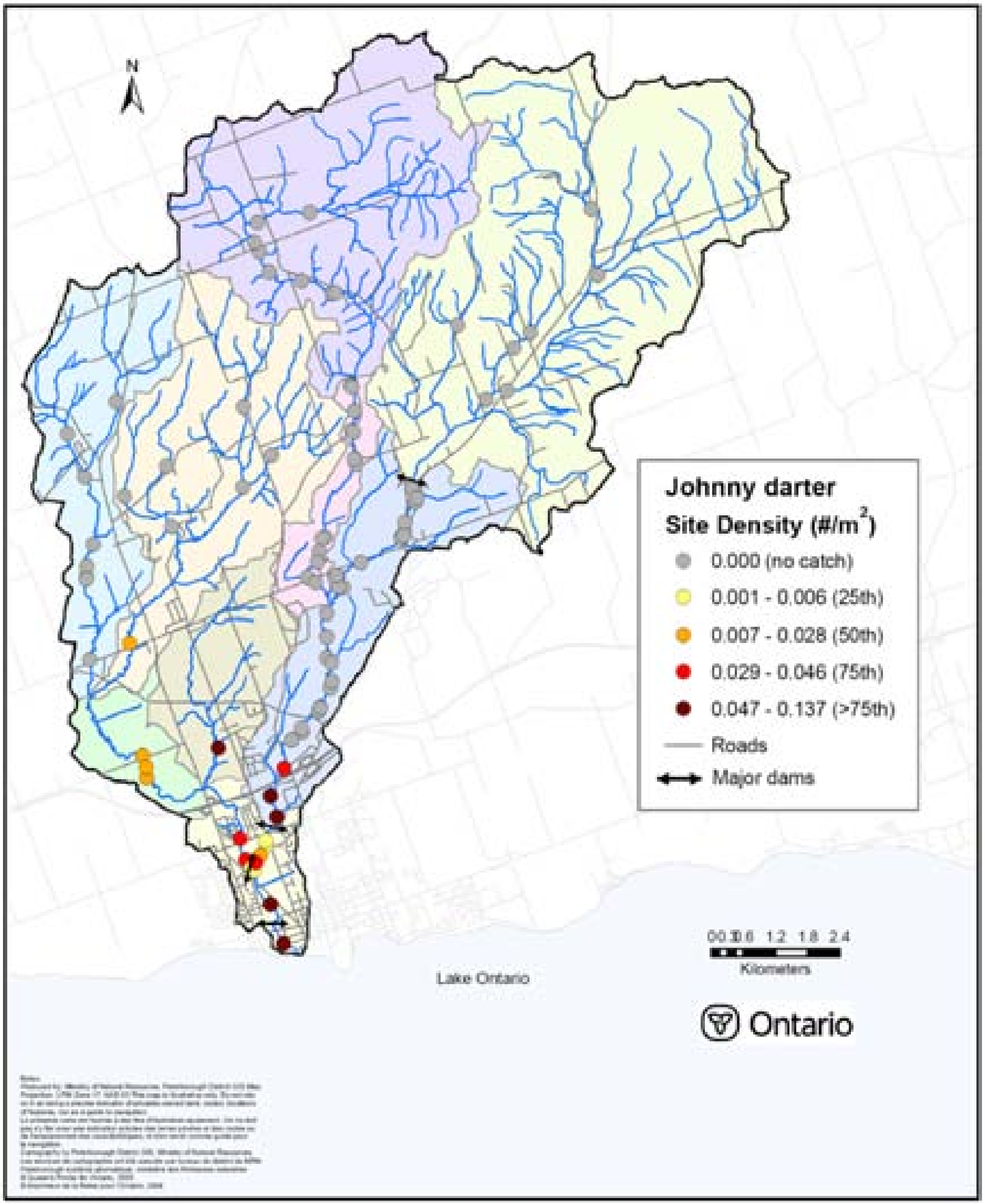


Figure 4.9: Johnny darter July/August distribution

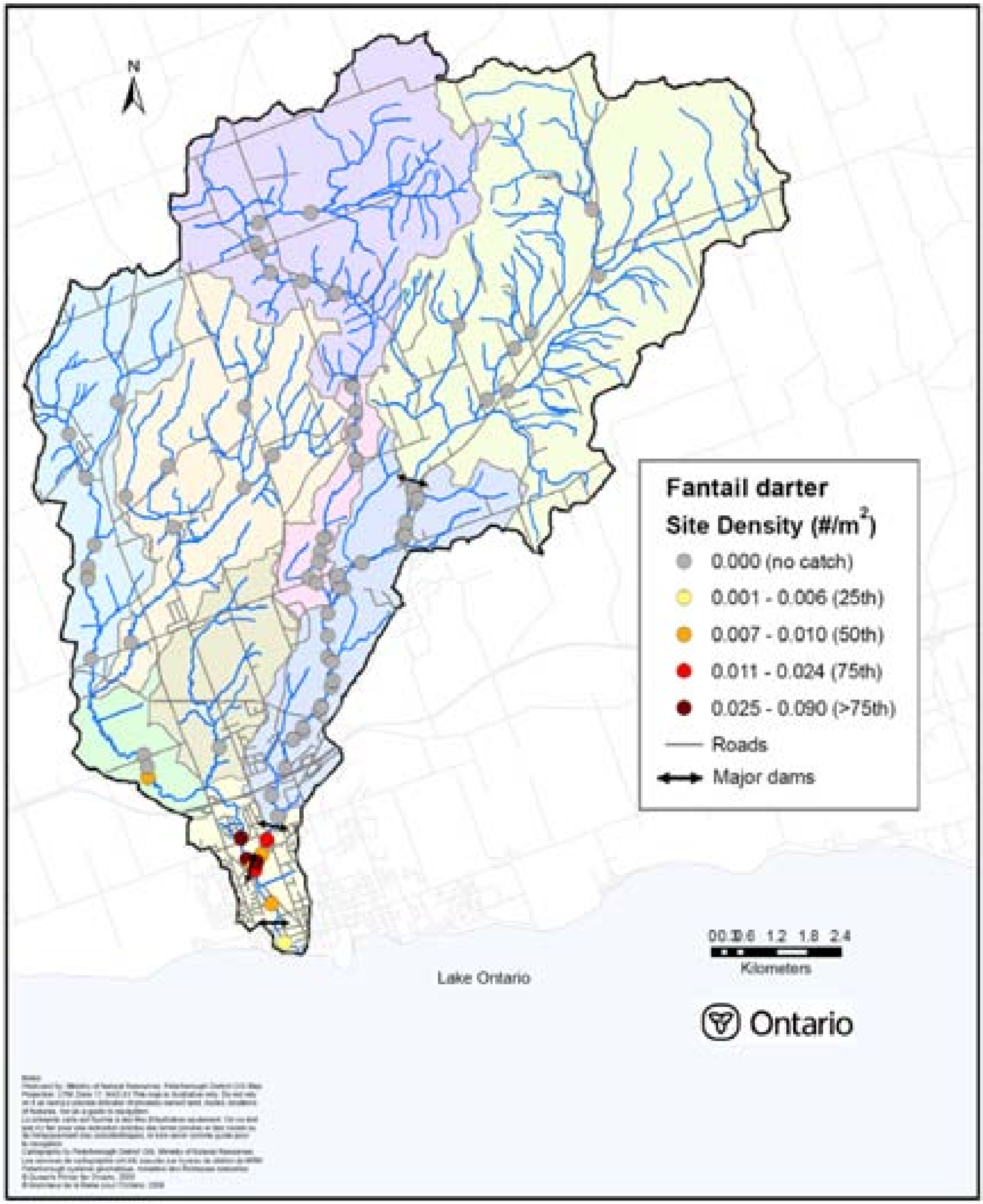


Figure 4.10: Fantail darter July/August distribution

Fish Communities
Four fish communities were identified within the Cobourg Creek watershed (Figure 4.11). Communities were identified at each sample site, in which abundance and densities of fish caught were used to classify that individual community. These communities will be used in the Fisheries Management Plan to aid in the formation of Management Zones.

Rainbow Trout, Cyprinids/Darters and Sculpin Community

This fish community is characterized by similar high abundance and densities of cyprinids, darters and rainbow trout. Sampling sites defining this fish community were located in the lower portion of the watershed, primarily south of Danforth Road in both the East and West Branch. Community sites located south of the 401 function as a migratory corridor for Lake Ontario fish species. The invasive round goby has been observed exclusively within this fish community assemblage south of the 401.

Rainbow Trout, Brown Trout and Sculpin Community

This community is dominated by rainbow trout, brown trout and sculpin species. The community is driven by the absence of darters and uncommon species (species found in less than 10% of the sampling sites). Sampling sites defining the fish community were located in the northern portion of sub-catchment 6 on the East Branch. This fish assemblage is almost exclusive to the East Branch, with the exception of one site in the West Branch headwaters.

Brook Trout Headwater Community

This headwater fish community was dominated by brook trout, rainbow trout and sculpin species. Sampling sites were distributed in the northern half of both the East and West Branch. The site groupings were driven by low abundance and density of non-salmonids.

Uncommon Cyprinids Community

This was the smallest fish community, defined by six sites located in the upper-central area of the watershed. These sites were grouped by high abundance of uncommon fish species and very low densities of salmonids.

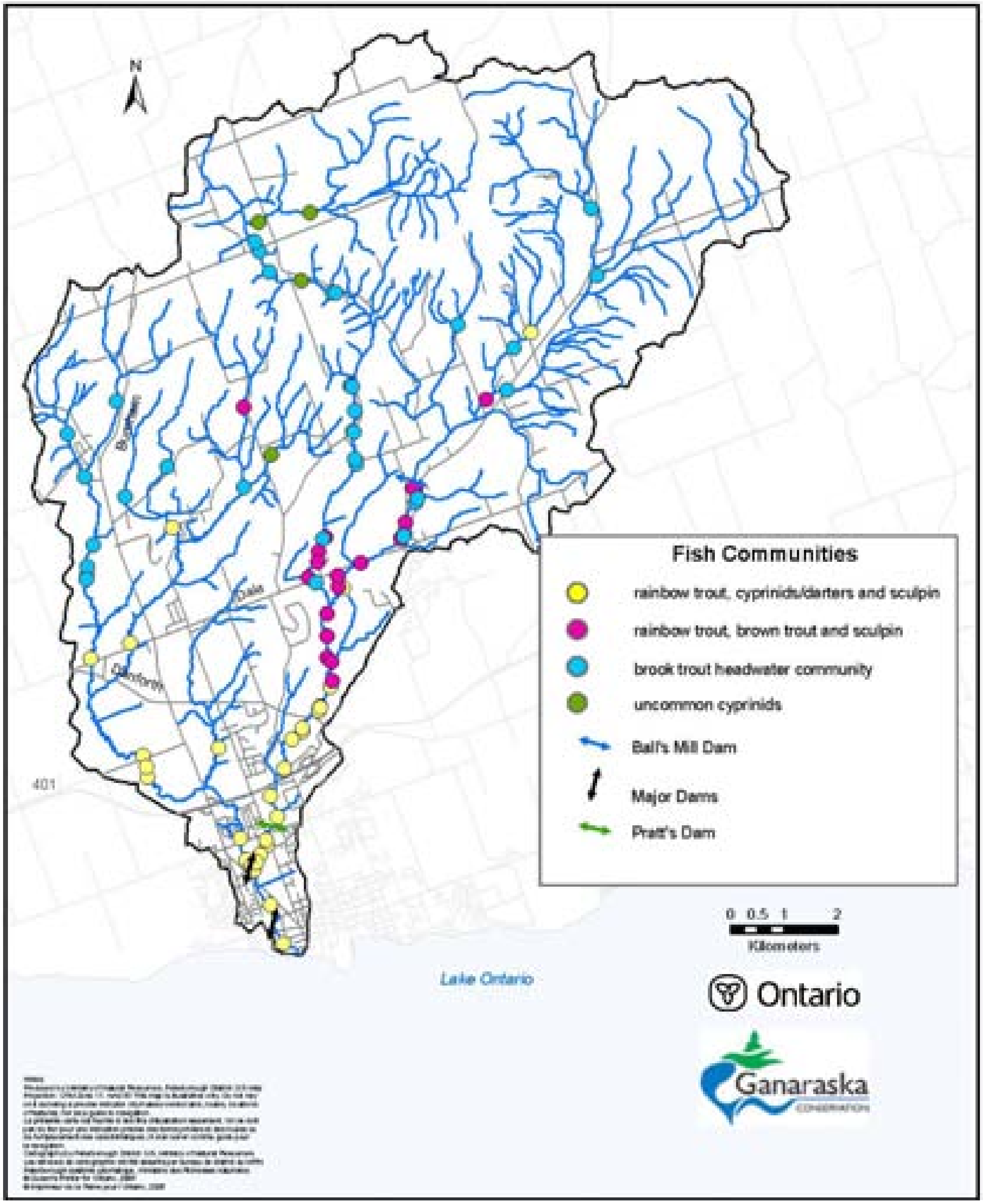


Figure 4.11: Fish communities within Cobourg Creek

Atlantic Salmon Restoration

The exploitation of the Lake Ontario Fishery in the early and mid-1800s, coupled with habitat loss and degradation, resulted in the rapid decline of natural fish stocks and extirpation of the top native salmonid predator, the Atlantic salmon (*Salmo salar*). Within the Lake Ontario basin the main causes of the extirpation of the Atlantic salmon were the construction of mill dams on tributaries (which denied access to spawning grounds), domestic pollution, deforestation and over-exploitation (Scott and Crossman 1998).

Today, reintroduction of wild Atlantic salmon to Lake Ontario is one of the largest freshwater conservation projects in North America. The current success of this program is attributed to the united relationships of over 30 partners and sponsors. Atlantic salmon are currently being reintroduced through support from Banrock Station Wetlands Foundation Canada, the Liquor Control Board of Ontario, the Ontario Federation of Angler and Hunters, the Ontario Ministry of Natural Resources and Conservation Authorities. The goal of this project is to restore self-sustaining populations of Atlantic salmon to Lake Ontario and its tributaries within 10 to 15 years.

The Atlantic salmon Restoration Program was launched in 2006 with restoration efforts focused on three Lake Ontario tributaries—Cobourg Creek (also referred to as Cobourg Brook), Duffins Creek and the Credit River. Partnership funding and in-kind support are going toward fish hatchery production and stocking, research and monitoring, stream habitat rehabilitation and stewardship, and education and outreach initiatives.

As of 2008, over one million Atlantic salmon juveniles have been stocked across the three tributaries. Three genetic strains of salmon are being introduced, each with different traits, in an attempt to increase the survivorship and success of achieving a self-sustaining population in Lake Ontario.

Research and monitoring of juvenile Atlantic salmon has occurred in the lower reaches of Cobourg Creek. Preliminary results indicate Atlantic salmon are surviving. They are exhibiting above-average growth rates within Cobourg Creek and are successfully smolting out into Lake Ontario. The Atlantic salmon smolts are expected to spend at least one year feeding and growing in Lake Ontario before returning to Cobourg Creek to spawn.

4.0.2 Instream Habitat

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

Cover within a stream is vital to aquatic organism survival. Cover consists of riparian vegetation, boulders, broken water (riffles), 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 (8.0 – 30.0% slope) to dune-ripple regime (<0.1% slope). Typically, streams with a step-pool (4.0 – 8.0% slope) or pool-riffle (0.1 – 2.0% 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 (i.e., 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, is necessary for spawning habitats.

Methods
The Ontario Stream Assessment Protocol (OSAP) Channel Morphology method was applied to 62 sample sites and a modified version of OSAP, the Rapid Assessment Method (RAM), was applied to 26 sites. In the modified RAM methods, particle data was physically measured instead of visually estimated.

Different parameters sampled included "particle size", that was divided into three categories—fines (<2 mm), gravel (2 mm-100 mm) and cobble (100-1000 mm). "Fish cover" was divided into two categories—wood and rock, and "velocity" was divided into four categories—pool (<5 mm hydraulic head), glide (10 mm hydraulic head), riffle (15 mm hydraulic head) and fast riffle (>15 mm hydraulic head) (Stanfield 2005). Hydraulic head is a surrogate for velocity and was measured to the nearest mm and was recorded for each transect point for all habitat sites (Stanfield 2005).

Data Analysis Methods
The percentage of each habitat variable (substrate particle size, instream fish cover and flow type [(# observed/ total # of observations)*100] were calculated for each site. Habitat types were identified using multivariate analysis (Principal

Component Analysis). Please refer to Ontario Ministry of Natural Resources and Ganaraska Region Conservation Authority 2008 for further details.

Instream Habitat Results

Substrate Size

The highest site percentages of fines are located along the West Branch. Within the East Branch, site percentages of fines substrate were low. Sub-catchment 1 and sub-catchment 6 had the lowest median percentage of fines and both were located directly downstream of Ball's Mill Dam and Pratt's Dam. This is likely due to the inability of sediment to be transported downstream because of these two dams.

Gravel and cobble have the highest site percentage in the Main Branch (sub-catchment 1) and the highest percentages of cobble were located within the East Branch in sub-catchment 7. The lowest site percentages of gravel and cobble were found in headwaters of the West Branch (sub-catchment 2).

Instream Fish Cover

The headwaters of the East Branch (sub-catchment 9) had the highest site percentages of wood cover, however, overall the West Branch has the highest percentage of wood cover. There was no wood cover observed in the Main Branch. The highest percentages of rock cover were observed in sites with the highest percentages of gravel and cobble substrate, sub-catchment 6 and sub-catchment 7. Similarly, the lowest percentages of rock cover were observed in sub-catchment 2.

Velocity (hydraulic head)

Sites dominated with pool habitat were found in the northern half of the watershed in areas characterized by low discharge. Overall, lower velocity habitats were present throughout the entire watershed. Sites composed of high percentages of glide habitat were located in the West Branch. The East Branch sites were composed of lower percentages of glide habitat and showed higher variation in glide habitat composition than the West Branch. Slower riffle habitats were found throughout the entire watershed and site percentages varied. Sites composed of the fastest velocities in the watershed were located in the East Branch mainstem, north of the creek mouth to Ball's Mills Dam and the Main Branch. Sites in sub-catchment 4 of the West Branch headwaters were also composed of fast riffle habitat.

Dominant Habitat Types

Based on Principal Component Analysis (PCA), five prominent habitat types were identified within the Cobourg Creek watershed (Figure 4.12).

1. Fines/gravel and glides: This habitat type was characterized by high percentages of both fines and gravel substrate, and glide habitat. Sites

defining this habitat group were located primarily throughout the West Branch.

2. Fines and Glides: Fines substrate and glides dominated this habitat group. This group was separated from the first habitat group through the absence of cobble substrate. Sites defining this habitat grouping were found in the West Branch north of the 401, with the exception of one site in the East Branch headwaters.
3. Gravel, rock cover and fast riffles: This group was dominated by gravel, rock cover substrate and fast riffle runs. Sites defining this habitat grouping were located throughout the East Branch and Main Branch of the watershed.
4. Gravel, rock cover and pools/riffles: This habitat was dominated by gravel, rock cover substrate and pool/riffle sequences. Sites categorized into this group were distributed throughout the entire watershed.
5. Fines/gravel, rock cover and pools/riffles: This group was characterized by fines/gravel substrate and pool/riffle sequences. Sites defining this habitat group were distributed throughout the entire watershed, except in the Main Branch.

Instream Habitat Discussion

The highest proportion of fine substrate is located in the West Branch. Gravel and cobble dominated the East and Main Branch. In addition, pool habitats dominated the headwaters of Cobourg where discharge and velocities are lower. Headwater areas of Cobourg Creek and the West Branch are dominated by wood cover, whereas the southern end of the East Branch and the Main Branch are dominated by rock cover. This is potentially due to the lower discharges and velocities coupled with large natural riparian areas dominated by forested habitat in headwater areas (Section 4.0.5).

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. For example, trout and salmon species require a range of gravel sizes for redd (nest) building, and cyprinids require a diverse array of habitat types (Scott and Crossman 1998) (Section 4.0.1). In addition, stewardship and restoration initiatives can focus on areas where certain instream characteristics are absent or minimal in order to increase instream cover or spawning area. 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.

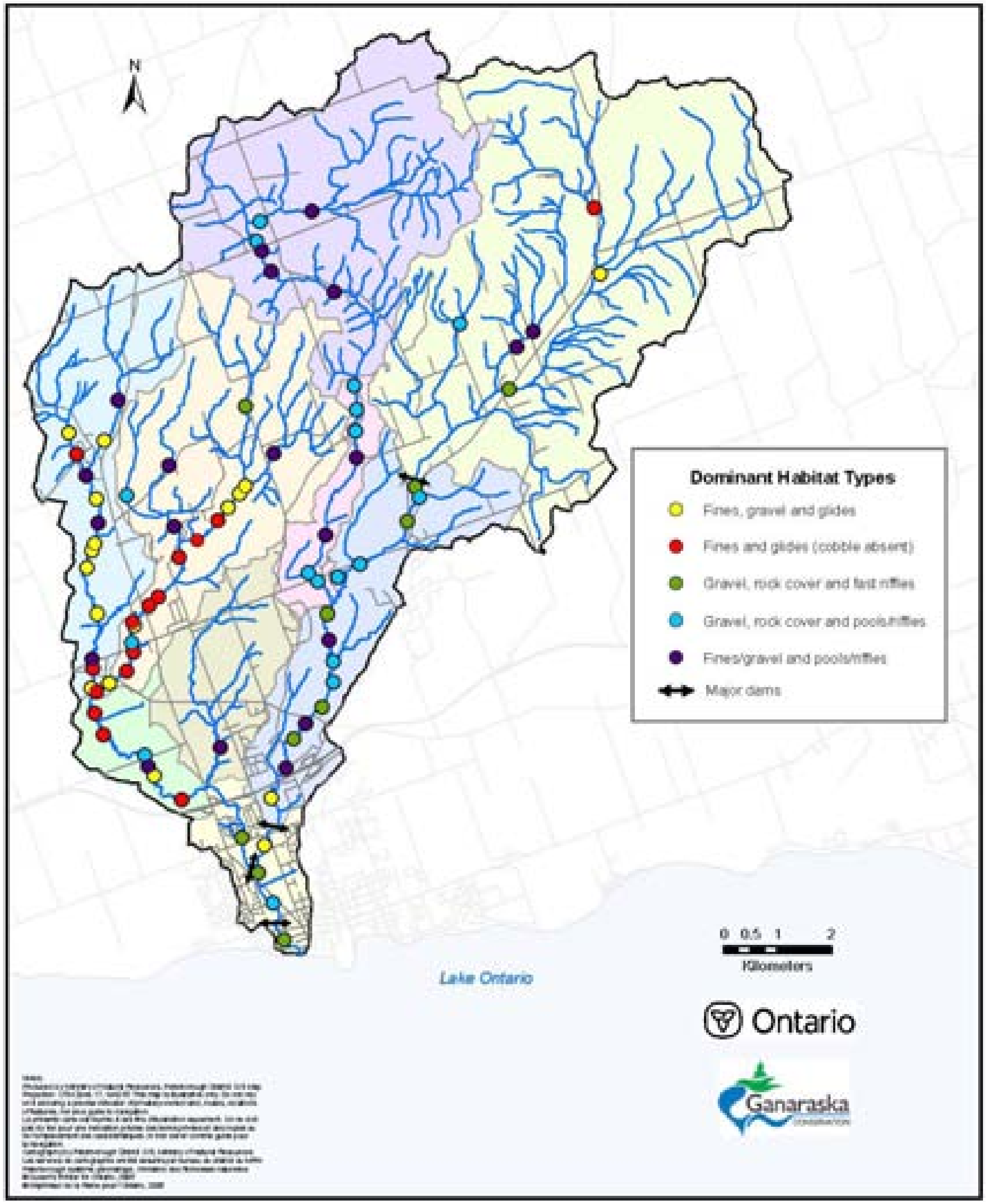


Figure 4.12: Dominate instream habitat types

4.0.3 Surface Water Temperature

Surface water temperature is spatially and temporally variable and reflects the instantaneous balance among inputs, storage and outputs (Wetzel 2001). In streams, water temperature (thermal habitat) is influenced by air temperature, precipitation, relative humidity, flow, geology, topography, land use, watershed vegetation, channel and floodplain morphology, and riparian vegetation (Poole and Berman 2001). Out of all of these controlling factors however, the temperature of a stream varies in relation to air temperature, and a strong linear relationship often exists between air and river water temperature (Wetzel 2001), with some time lag by the water temperature to reflect the air temperature (Stoneman and Jones 1996).

Stream temperature can indicate inputs of groundwater and the types of biota that are found within a particular reach or area of the stream. Coldwater fish species require stream temperature below 19^{o}C, coolwater fish species, between 19^{o}C and 25^{o}C and warmwater 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).

Methods

Data Collection and Analysis

Water temperature data was collected through two methods: digital temperature loggers and spot temperatures. Both methods were used to find the maximum summer surface water temperature. The Ganaraska Region Conservation Authority deployed temperature probes in 2004, 2006 and 2007 as part of their annual watershed monitoring program. Trent University Watershed Ecosystems Graduate studies in 2007 deployed temperature probes throughout the East Branch as part of an Atlantic salmon reintroduction research project.

Water temperatures were digitally recorded in 30-minute intervals from June to September, from 2000 to 2007 with Hobo Temp Pro loggers, Version 1 and 2, and Hobo Tidbits. Temperature probes were anchored to a cement block and secured to the bank or stream substrate in a shaded flowing reach of the stream. Spot temperature data were recorded manually with the YSI^{TM} 600QS model water quality probe and provided an instantaneous measure of water temperature reflecting the environmental condition during the time of the measurement. The spot temperature data set was standardized to Stoneman and Jones (1996), where temperature data is recorded between 15:30 and 17:00 hours, and when no precipitation has fallen in two consecutive days prior.

Stream Temperatures

Sixty-seven temperature sample locations provide a picture of the thermal regime within Cobourg Creek. Eighteen sites are defined as cold water (<19.0^{o}C), forty sites are defined as cool water (between 19.1^{o}C and 25^{o}C), and nine sites are defined as warmwater (>25.1^{o}C). Figure 4.13 shows the sample locations and thermal regimes within Cobourg Creek. Cold and cool water dominates the northern areas of the watershed within and below the Oak Ridges Moraine. Warmer water occurs within the Main Branch of the watershed, primarily below the 401.

Stream Temperature Summary

The temperature of surface water plays an important role in the use and availability of the water by humans and by the environment. Aquatic organisms are affected by changes in stream water temperature variations or prolonged warming of water (Wootton 1996). Aquatic organisms will either avoid or become acclimatized to the effects of temperature change on metabolic processes (Wootton 1996). Organisms that have prolonged exposure to temperatures outside of optimal ranges may experience slow growth, because the optimal ranges for physiological processes have been exceeded (Power et al. 1999), or if unable to escape the high temperatures, they may experience lethal effects (Wootton 1996).

Based on the surface water temperature data, sites below and immediately above the 401 are classified as warmwater sites. Sites above the confluence of the West Branch and Central Branch and above the 401 in the East Branch are cool or coldwater sites. However, given a point-in-time warm water temperature measurement, Cobourg Creek is considered a cold water system. This designation is confirmed by the presence of coldwater species such as salmonid and scuplin species present throughout Cobourg Creek, including the Main Branch.

Groundwater inputs into surface water are one of the dominant controlling factors of stream temperature (Power et al. 1999). Groundwater provides the majority of baseflow to a stream and therefore affects the quantity, quality and temperature of the surface water it is entering. Areas of groundwater discharge into a stream cause the stream's temperature to be cooler than areas that do not experience discharge (Section 3.2.2). Groundwater discharge areas provide places of refuge from warm stream temperature, and coldwater fish tend to take advantage of these locations (Power et al. 1999). Water temperature, and therefore the presence or absence of groundwater discharge into an area of a stream, is an important factor 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. They are often replaced by other species where water temperatures are warmer (Section 4.0.1).

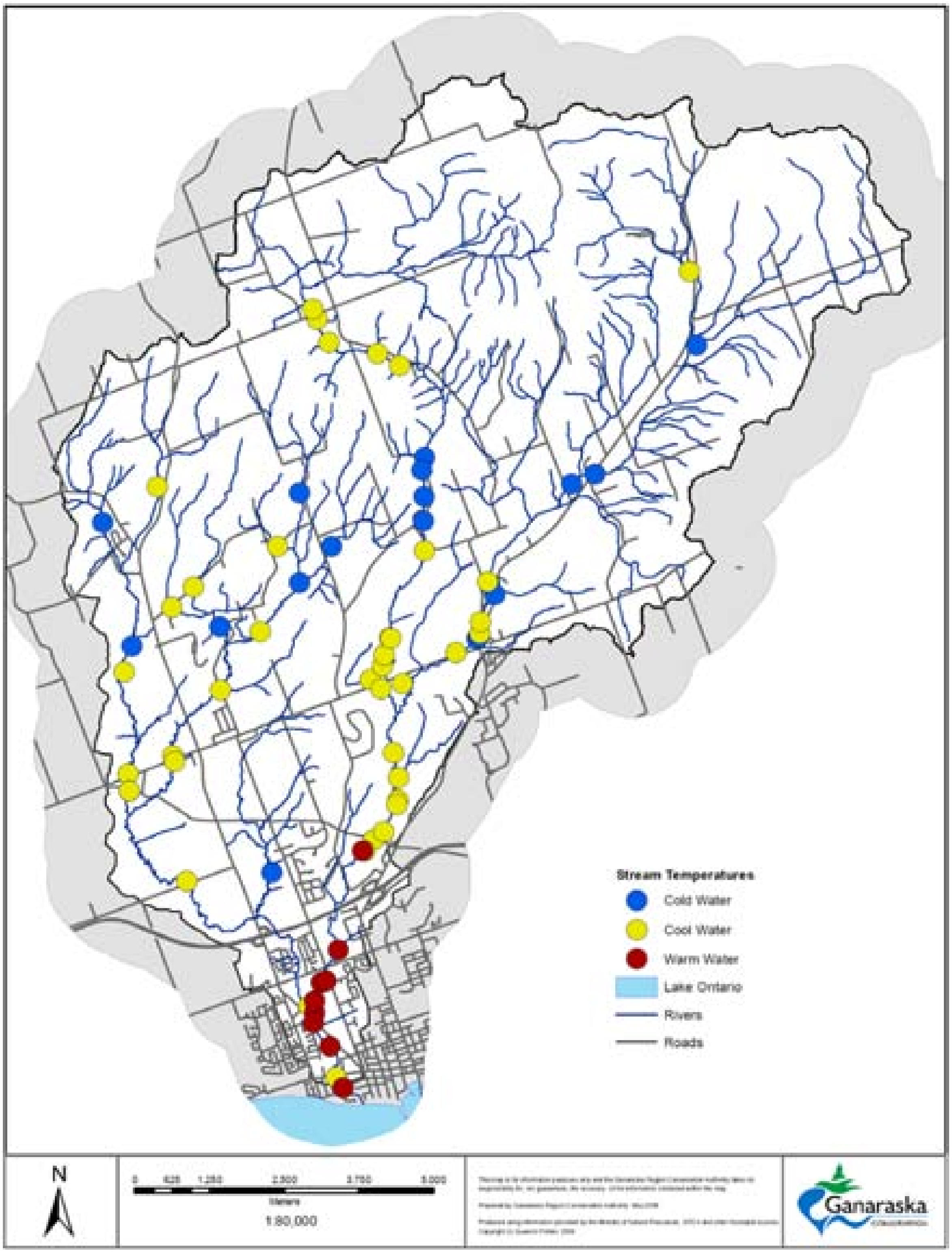


Figure 4.13: Summer stream thermal classification

Another explanation for sites experiencing differing water temperatures is the effect of shading from the riparian area (Section 4.0.5). 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.

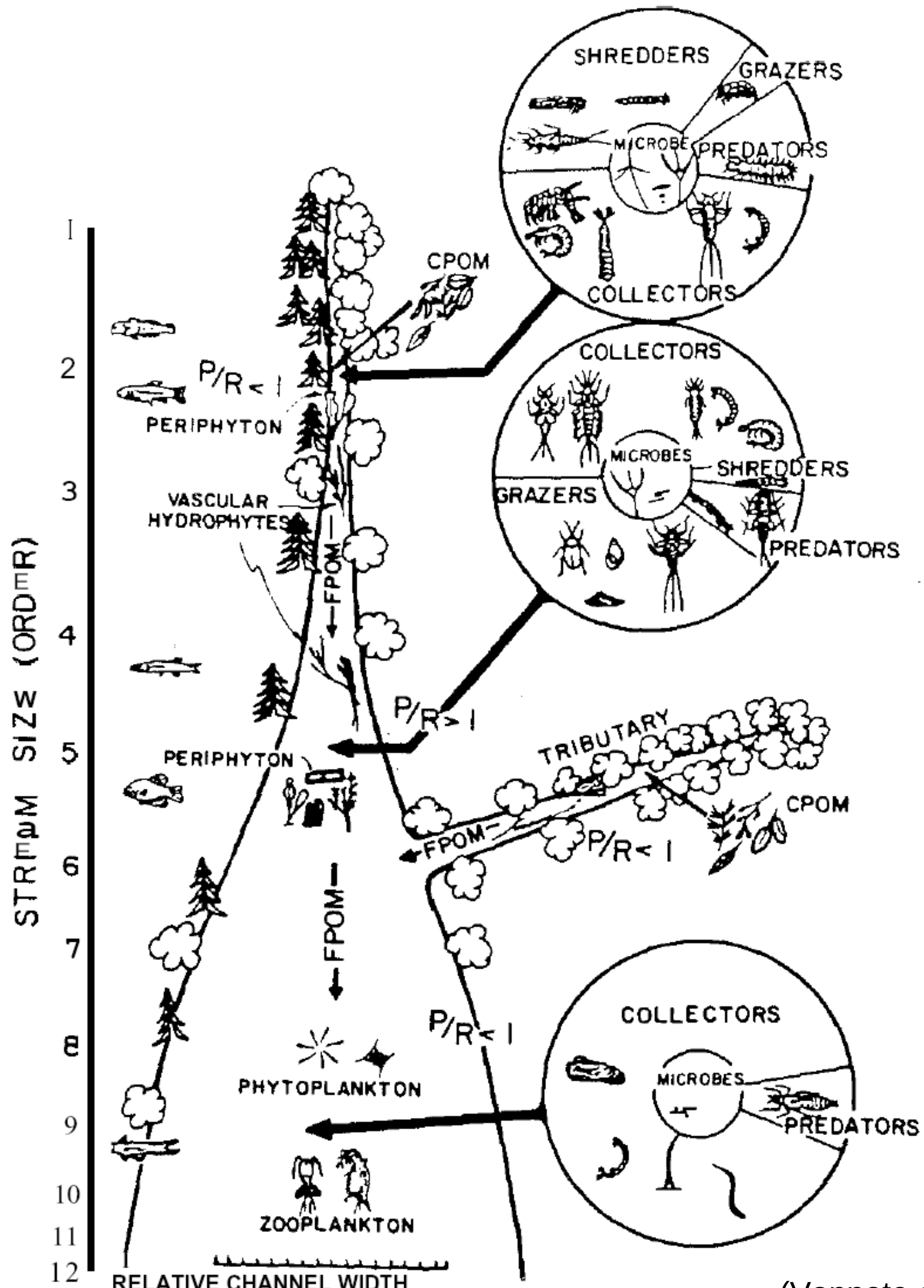
Channel structure and riparian areas can play a role in providing shade to stream. Narrow channels can be shaded more easily by stream banks (Moore et al. 2005) and tree shading can help minimize temperature variability in streams. Conversely, wide channels tend to be less shaded because they have a 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 receiving water. Stream bank armouring discourages this mixing, and in combination with other urban impacts in the lower reaches of Cobourg 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 within 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 (i.e., reproduction or 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 within a stream, which 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 4.14 depicts the generalized model of the River Continuum Concept.



(Vannote et al. 1980)

Figure 4.14: 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 macroinvertebrates were sampled at 34 sites from 2003, 2004 and 2006. Identification of 27 taxa groups was completed 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 organisms given the high water temperature and low oxygen levels. However, there is a low richness of species in relation to life history patterns (i.e., 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 0.14 to a high diversity of 0.46 within the Cobourg Creek watershed. However, this reflects the diversity at coarser taxonomic levels, other 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 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 13 to 76 % and percent Chironomidae ranged from 0 to 28%.

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 4.2). 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 summer-time sampling due to life stage cycles. 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, % of diatoms in *Eunotia* spp., 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 within Cobourg Creek is presented through water chemistry analysis, which is described in Section 3.7 of this document.

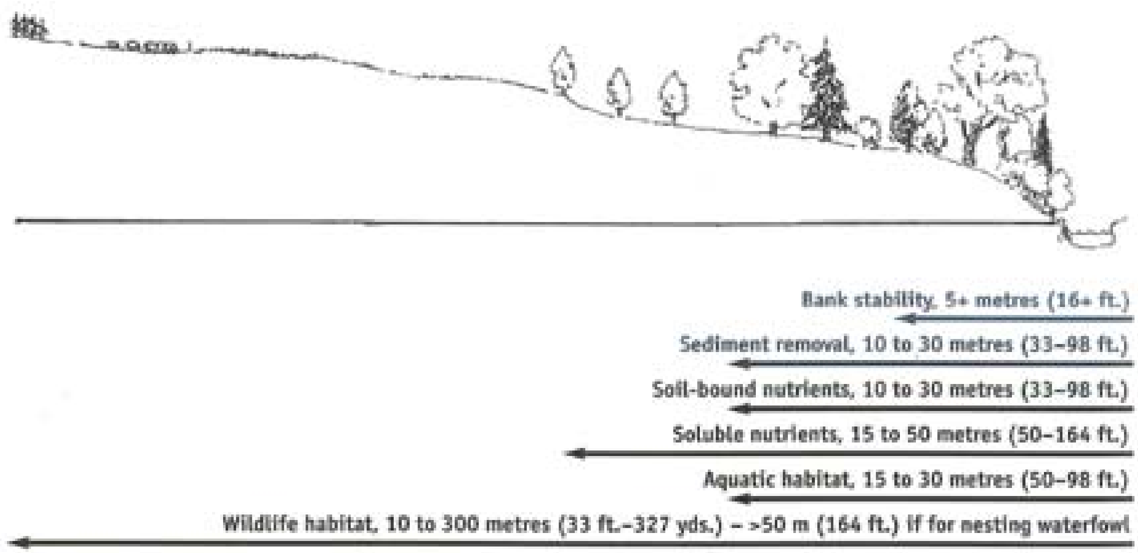
Table 4.2: Hilsenhoff index of benthic macroinvertebrates

Hilsenhoff Index	Water Quality	Degree of Organic Pollution	Number of Sample Sites
0.00 to 3.75	Excellent	Organic pollution unlikely	2
3.76 to 4.25	Very Good	Possible slight organic pollution	1
4.26 to 5.00	Good	Some organic pollution probable	16
5.01 to 5.75	Fair	Fairly substantial organic pollution likely	14
5.76 to 6.50	Fairly Poor	Substantial organic pollution likely	1
6.51 to 7.25	Poor	Very substantial organic pollution likely	0
7.26 to 10.00	Very Poor	Sever organic pollution likely	0

4.0.5 Riparian Areas

Riparian zones 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 strips 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 within the riparian area, nutrient removal before entry into the water body, 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 in terms of the benefit provided in relation to the width and functional contribution of the riparian area (Figure 4.15). The following describes the role and composition of a 50-metre riparian area along Cobourg Creek[4]. 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 4.14). The role of riparian areas and their effectiveness on benefiting the adjacent water body depends on soil type, slope, and 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 4.15: Riparian area functions

Riparian Area Composition

Classifying riparian area cover types using Ecological Land Classification data from 2002 indicates that natural cover (forest, meadows and wetlands) dominates the amount of land cover within 50 metres to Cobourg Creek (Figure 4.15). Agricultural land use occurs within 20% and developed land within 8% of the 50-metre riparian area (Table 4.3).

Table 4.3: Land cover within 50 metre buffers of Cobourg Creek

Land Cover	Percentage within 50 metre buffer
Forest	50
Agriculture	20
Meadows, savanna and thickets	12
Developed	8
Wetlands	8
Manicured open space	0.8
Aggregate	0.2

[4] A 50 meter buffer is being used for data analysis to understand land use within 50 meters to a stream. This does not necessarily reflect a recommended buffer width target. Please refer to the Cobourg Creek Watershed Plan for information on riparian area management.

Riparian Area Contributions and Benefits

Riparian areas of Cobourg Creek mitigate surface water quality by reducing surface runoff into Cobourg 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 within 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 is necessary in maintaining or improving water quality.

Riparian areas contribute to instream habitat through bank stabilization and cover creation through 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 within the Cobourg Creek watershed. The high amount of wood cover observed in the headwaters of the East Branch (Central Branch and Baltimore Creek tributary), as sampled through the Ontario Stream Assessment Protocol, and in the entire West Branch is also evident through the amount of forested riparian areas in those same tributaries (Figure 4.16). In addition, the lack of wood cover in the Main Branch is also seen through the lack of forested riparian areas within the Main Branch (Figure 4.16). In addition, the woody debris may not be allowed to enter the stream as a result of public and private land management within the urban areas of Cobourg Creek.

Stream temperature is maintained at a cold to cool water regime as a result of riparian areas providing shade to Cobourg Creek. Along with groundwater, 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 occur.

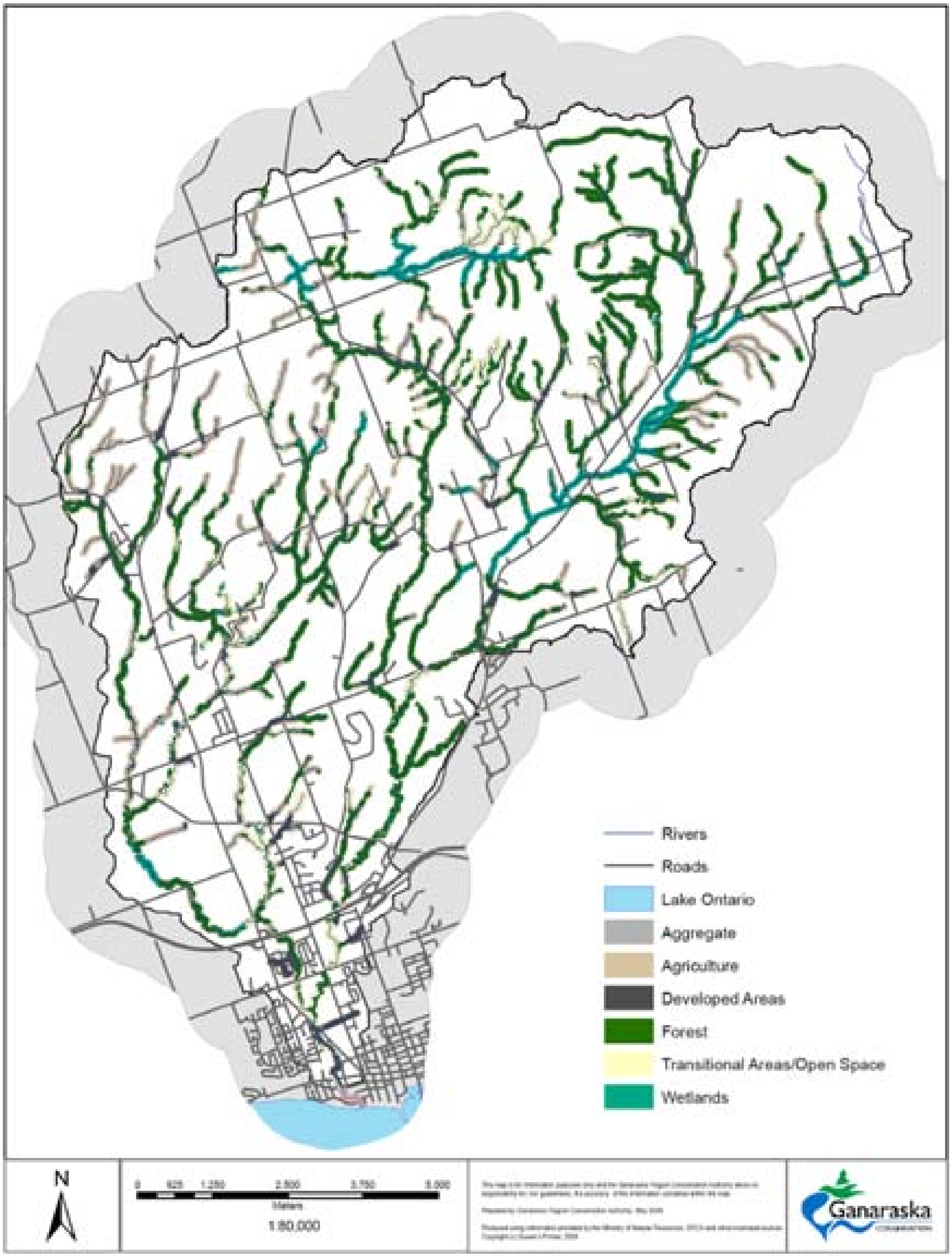


Figure 4.16: Fifty metre riparian area

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. The functions and features provided by natural heritage features contribute to healthy watersheds by means of 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 within the Cobourg Creek watershed is presented in Figure 4.17, and natural areas found within the Cobourg Creek watershed are presented in Table 4.4.

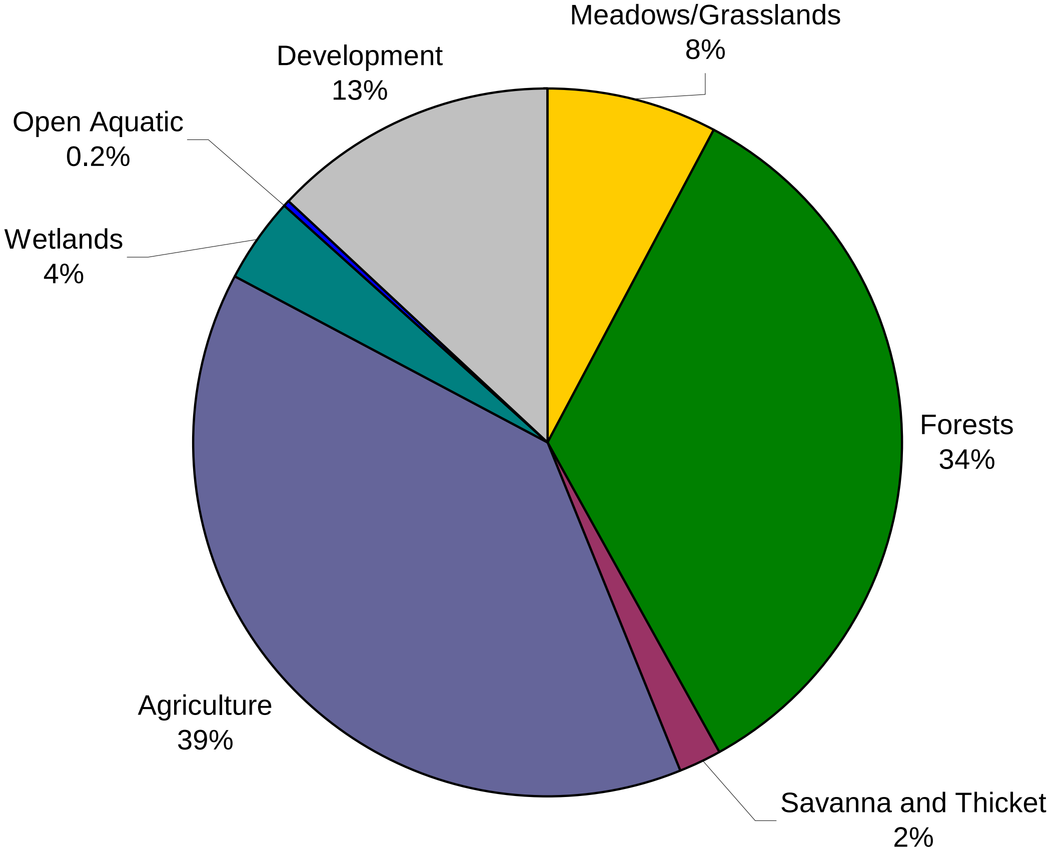


Figure 4.17: Land cover based on ecological land classification

Table 4.4: Natural areas within the Cobourg Creek watershed

Natural Feature	Area (km^2)*	Percentage of Cobourg Creek watershed*
Forests	41.8	34.2
Meadows/Grasslands	9.5	7.7
Savanna and Thickets	2.6	2.1
Wetlands	4.5	3.7

* 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 1995). In the heavily-settled landscape of southern Ontario, including the Cobourg Creek watershed, the original dominant landscape cover, forests and other associated natural areas, have become fragmented and are represented by patches. In the surrounding landscape the matrix, or 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 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 Ontario 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 forms (Hunter 1990). Forest ecosystems are dynamic, changing structure and composition as a result of evolution and disturbances such as fire, wind, climatic change and human influences.

Forests, for the purpose of this study and as defined through Ecological Land Classification (Lee et al. 1998), include coniferous, deciduous and mixed forests, and cultural plantations and woodlands. 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, deciduous and mixed forests are classified as areas of land that contain more that 60% tree cover, with a canopy cover of more than 75%. (Lee et al. 1998). Cultural plantations and woodlands are defined as an ecological communities resulting from or maintained by cultural or anthropogenic disturbances. A cultural plantation has more than 60% tree cover, whereas cultural woodland contains 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 4.5 describes the proportion of forest types within the Cobourg Creek watershed and Figure 4.18 shows the locations.

Table 4.5: Forest types within the Cobourg Creek watershed

ELC Defined Forest Type	Area (km^2)	Percentage of Cobourg Creek watershed
Coniferous Forest	5.2	4.2
Deciduous Forest	3.95	3.2
Mixed Forest	24.4	19.9
Cultural Plantation	7.4	6.0
Cultural Woodland	1.3	1.1
Thicket Swamp	0.07	0.05
Coniferous Swamp	1.3	1.1
Deciduous Swamp	0.06	0.05
Mixed Swamp	2.7	2.2

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 containing 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.

Ecological 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). Different plant and animal species are associated with different stages of succession. Therefore, maintaining various successional stages within the forests and woodlots of the Cobourg Creek watershed will help ensure the presence of a high diversity of flora and fauna.

Not only is the successional stage of forest important for diverse habitats, so is forest patch size. Small isolated patches have limited capacity to sustain populations of 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 4.6 and 4.7 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 2001-2005 Atlas of the Breeding Birds of Ontario (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, and based on 2002 ELC, only 4.9% of the total forest cover in Cobourg Creek watershed is forest interior.

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

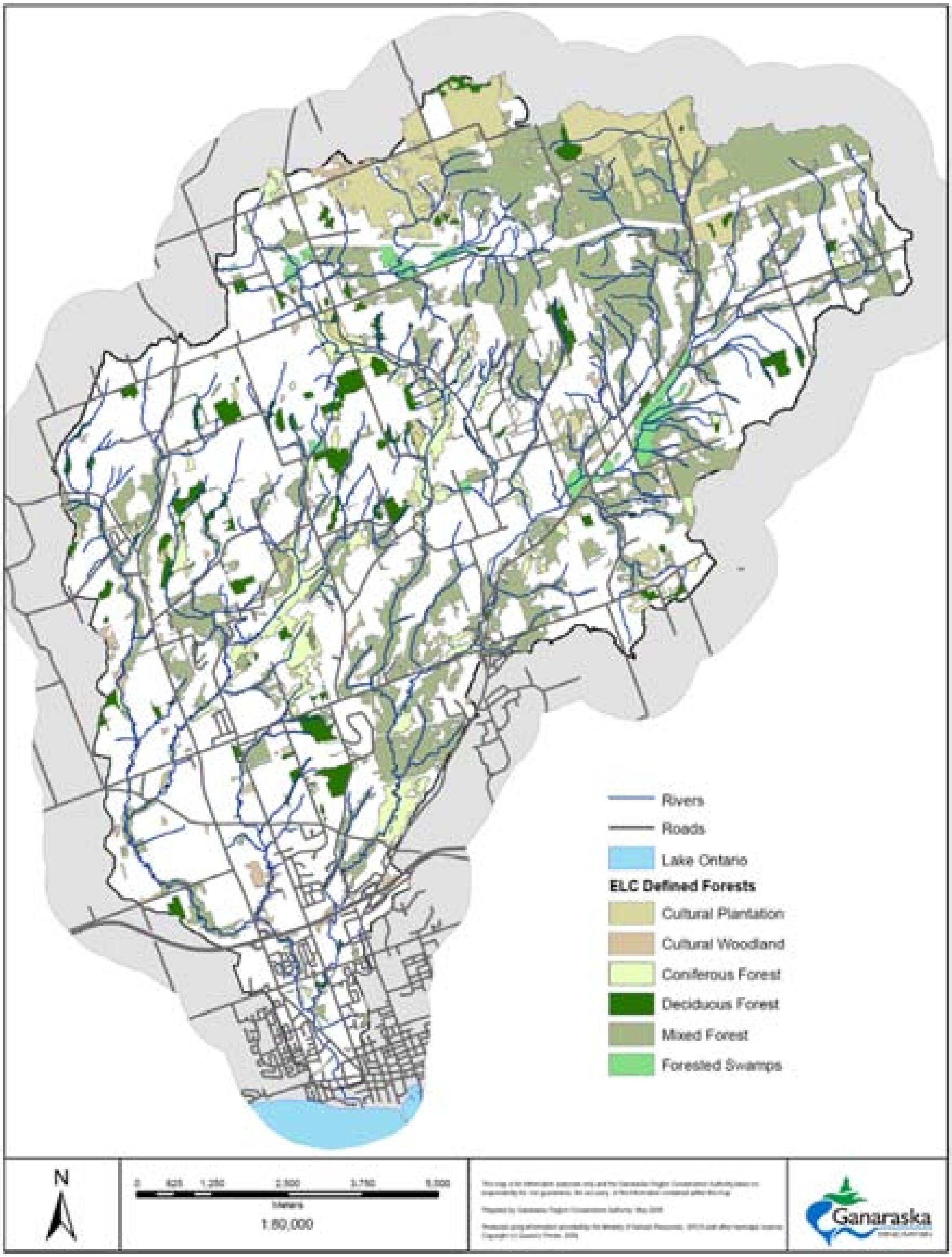


Figure 4.18: Forests

Table 4.6: 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 4.7: 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)

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. Species such as American Crows (*Corvus brachyrhynchos*) are habitat generalists and have unlimited mobility. In contrast, habitat specialists with limited mobility require contiguous specific habitats for food and cover. It is the latter which tend to be conservation concerns. 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 structural connectivity with Geographic Information Services (GIS), such as the proximity of forest or other habitat patches (using GIS polygons or pixels). However, measuring functional connectivity would require modelling the potential movements of species or groups of species of conservation concern. This approach can be combined with a measure of road density, as roads are barriers to wildlife movement through the natural heritage system. More data on the specific habitat requirements of species and more detailed vegetation type mapping will be required in order to undertake this analysis of functional connectivity.

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 that demonstrated that landscapes with 20 to 30% forest cover tended to support the majority of bird species known in a given area. However, we must use precaution 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? At 34% forest cover based on 2002 data, the Cobourg Creek watershed is a case in point.

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 Cobourg 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 Cobourg 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 *2001-2005 Atlas of the Breeding Birds of Ontario* (Cadman et al. 2007). There are also declines within the Lake Simcoe-Rideau atlas study region, which includes the Cobourg Creek watershed (Cadman et al. 2007). This is part of a disturbing trend across eastern North America. Bird species include Bobolink (*Dolichonyx oryzivorus*), Eastern Meadowlark (*Sturnella magna*) 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 19th and early 20th 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 (i.e., improved pastures and increased cropping), and urban development.

Tallgrass prairie and savanna are globally rare ecosystems and there are many rare plants and animals associated with them. Prior to European settlement, tallgrass prairie occurred on sand plains in Ontario from Walpole Island on Lake St. Clair to the Rice Lake Plains. However, due to conversion to agriculture and other land uses, less than 1/10 of one percent of the original tallgrass prairie and savanna habitat remains (Clarke 2005), making it a high conservation priority. The Alderville Black Oak Savanna, located northeast of the Cobourg Creek watershed is the largest single remaining tallgrass prairie and savanna in east central Ontario. In addition, smaller remnant tallgrass prairie habitats are scattered across this part of the Oak Ridges Moraine in the vicinity of the Northumberland Forest, including some in the upper part of the Cobourg Creek watershed. Given the sandy soils of the area, there was probably considerably more tallgrass than at present, and there may be opportunities to restore tallgrass prairie or savanna ecosystems where suitable conditions exist.

Meadow/grassland and tallgrass prairie may look similar, however a prairie is maintained primarily by fire, whereas a meadow is maintained by other disturbances such as flooding, drought or human influences. Furthermore, some flora and fauna are found in one habitat or the other (Delaney et al. 2000). Cultural meadows/grasslands make up 7.7% of the landscape within the Cobourg 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 that occurred from retired agricultural lands and other land that has been left fallow.

Cultural savanna and thickets make up 2.1% (0.6% and 1.5% respectively) of the watershed area. 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 overrepresented in southern Ontario relative to the historical amount of forest cover. Second, because there 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 some 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. Perhaps a concerted effort to expand the area of tallgrass prairie would be an ideal approach to maintaining grasslands and their associated species.

4.1.4 Wetlands

Wetlands make up 3.7% of the Cobourg Creek watershed. Based on the ELC wetlands include meadow marsh, shallow marsh, deciduous swamps, coniferous swamps, mixed swamps, thicket swamps, fens and bogs. There are no known fens or bogs in the Cobourg 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 are calculated. Two large wetland complexes exist within the Cobourg Creek watershed and are 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 2m 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 4.8 describes the proportion of wetland types within the Cobourg Creek watershed, and locations are shown in Figure 4.19.

Table 4.8: Wetland types within the Cobourg Creek watershed

ELC Defined Wetland Type	Area (km^2)	Percentage of Cobourg Creek watershed
Meadow Marsh	0.3	0.2
Shallow Marsh	0.07	0.06
Coniferous Swamp	1.3	1.1
Deciduous Swamp	0.06	0.05
Mixed Swamp	2.66	2.2
Thicket Swamp	0.07	0.05

Swamps are the most abundant wetland type in southern Ontario, and within the Cobourg 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 4.9).

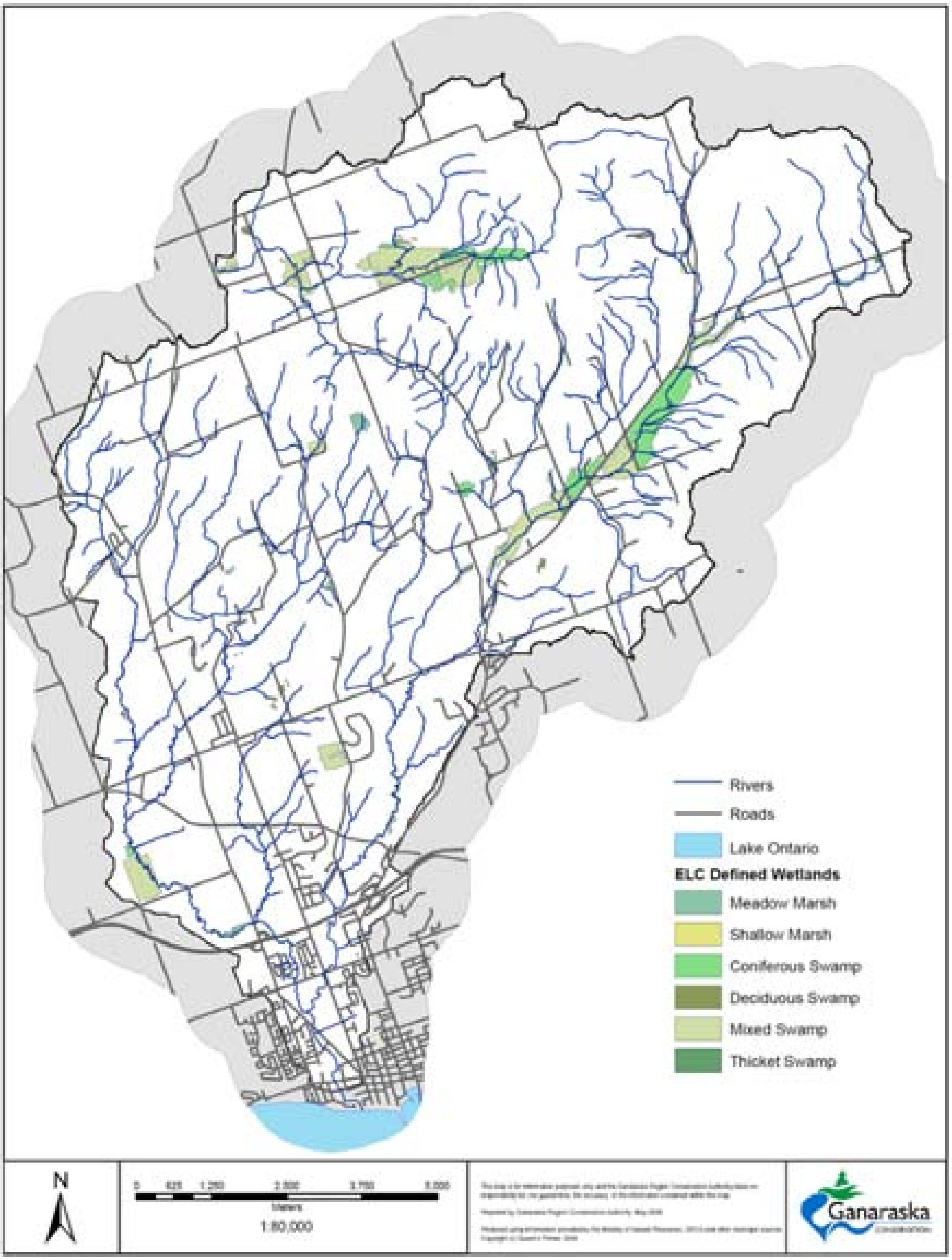


Figure 4.19: Wetlands

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 cold water fish species. Swamps also contribute nutrients, food and habitat to aquatic organisms within 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 and speckled alder. 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 rapid population declines throughout its range. In many cases thicket swamps are too small to pick up when interpreting aerial photographs, therefore the total cover figures for this wetland type may be deceiving. Even tiny thicket swamps can support an entire local breeding population of chorus frogs, therefore the value of these areas should be recognized.

Roadside surveys suggest that chorus frogs have a limited distribution in the Ganaraska Region Conservation Authority, and they were only found in one high quality wetland in the Cobourg Creek watershed. However, this may reflect broader trends and limited distribution of suitable habitat for the species more than watershed health. In contrast, full choruses of wood frogs (*Rana sylvatica*), spring peepers (*Pseudacris crucifer*) and gray treefrogs (*Hyla versicolor*) were heard in numerous locations suggesting good connectivity between forest and wetland areas.

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 and wood frog 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).

Environment Canada's framework for guiding habitat rehabilitation (Environment Canada 2005c) recommends that watersheds should contain more than 10% wetland cover, however not all watersheds had this much historically. The capacity for natural wetlands is based largely on topography and soils. Much of the soil in the headwater area of Cobourg 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 6.3%, 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 Cobourg Creek watershed.

Table 4.9: 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 Bitterns 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)

4.1.5 Species of Concern

There are a number of species at risk in the Ganaraska Region Conservation Authority area, including the Cobourg Creek watershed. These species have been designated as such by both the federal Committee on the Status of Endangered Wildlife in Canada (COSEWIC) and the Committee on the Status of

Species at Risk in Ontario (COSSARO) coordinated by the Ministry of Natural Resources. Table 4.10 lists the identified species at risk by both COSEWIC and COSSARO. This list has recently been expanded dramatically. Many species have not officially been listed by the federal or provincial governments, yet are recognized as rare by the Natural Heritage Information Centre (NHIC), which tracks the status and distribution of species and communities. The NHIC provides rarity ranks for both species and vegetation communities. Within the Ganaraska Region Conservation Authority area two provincially rare vegetation community types are recognized, dry tallgrass prairie and dry black oak-pine tallgrass savanna.

Table 4.10: Species at risk potentially within the Ganaraska Region Conservation Authority

Scientific Name	Common Name	COSEWIC Status	COSSARO Status
Glaucomys volans	Southern Flying Squirrel	NAR	SC
Colinus virginianus	Northern Bobwhite	END	END
Lxobrychus exilis	Least Bittern	THR	THR
Chlidonias niger	Black Tern	NAR	SC
Buteo lineatus	Red-shouldered Hawk	SC	SC
Haliaeetus leucocephalus	Bald Eagle	NAR	SC
Rallus elegans	King Rail	END	END
Coturnicops noveboracensis	Yellow Rail	SC	SC
Lanius ludovicianus	Loggerhead Shrike	END	END
Chordeiles minor	Common Nighthawk	THR	
Chaetura pelagica	Chimney Swift	THR	
Melanerpes erythrocephalus	Red-headed Woodpecker	THR	SC
Dendroica cerulea	Cerulean Warbler	SC	SC
Vermivora chrysoptera	Golden-winged Warbler	THR	
Icteria virens	Yellow-breasted Chat	SC	SC
Ammodramus henslowii	Henslow's Sparrow	END	END
Emydoidea blandingii	Blanding's Turtle	THR	THR
Sternotherus odoratus	Stinkpot Turtle	THR	THR
Graptemys geographica	Northern Map Turtle	SC	SC
Heterodon platyrhinos	Eastern hog-nosedSnake	THR	THR
Lampropeltis triangulum	Eastern Milk Snake	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, NAR = Not At Risk

4.1.6 Invasive Species

In terrestrial habitats the invasive species that are currently of greatest concern are plants, especially dog-strangling vine (*Cynanchum rossicum)*, European buckthorn (*Rhamnus cathartica)* and garlic mustard (*Alliaria petiolata)*. 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 understorey 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 are 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.

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 would 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 Provincially Significant Wetlands

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

Millvalley Hills Forest

The Millvalley Hills Forest is located within the Township of Alnwick/Haldimand (Figure 4.20). Located in the headwaters of the Baltimore Creek tributary, this ANSI is 297 hectares in size, and protects an important recharge area of Cobourg Creek. The majority of the vegetative species are associated with the dry-mesic and dry sandy soils. The dominant tree species are red and white pine, and red and white oak, however red oak dominates an area of land 64 hectares in size and red maple dominates another 31 hectares (Natural Heritage Information Centre 2008). Closer to the stream banks the area is characterized by white cedar thickets, and bottomland tree species such as yellow birch, black ash and basswood, with an understorey of sedges, ferns and jewelweed in the areas of mineral soils (Natural Heritage Information Centre 2008). Human impacts are limited to selective logging and a hydro corridor that bisects the forest.

Northumberland County Forest

The Northumberland County Forest is 2,111 hectares in size, however 593 hectares are located within the Cobourg Creek watershed (Figure 4.20). In the early 1800s forests on the Oak Ridges Moraine and surround areas were exploited for timber resources and to access land for agricultural production. However, because of environmental degradation caused by the sandy fragile soils, the areas were abandoned and subsequently reforested to restore the landscape. As a result, over four million trees were planted in less than 40 years and land was secured to create the Northumberland County Forest (County of Northumberland 2007). Today the management of the forest's natural resources and recreational opportunities is under the jurisdiction of Northumberland County.

Harwood Road Wetland

The Harwood Road Wetland is a class 2 provincially significant wetland located in the Township of Hamilton and the Township of Alnwick/Haldimand (Figure 4.20. 95.9 hectares in size, the wetland is comprised of 95% swamp and 0.5% marsh (Natural Heritage Information Centre 2008).

Baltimore Creek Swamp

The Baltimore Creek Swamp is located within the Township of Hamilton and the Township of Alnwick/Haldimand (Figure 4.20). It is a provincially significant single contiguous wetland of 156 hectares (Reid and Rhonda 1987). The Baltimore Creek Swamp is part of the larger 220 hectare Baltimore Creek Area of Natural or Scientific Interest (ANSI) designation (Natural Heritage Information Centre 2008). This riverine valley is classified as a wet-mesic cedar-white birch-black ash floodplain forest, a very wet black ash-alder-cattail scrub marsh, and an open tamarack-balsam fir-white birch swamp (Natural Heritage Information Centre 2008). This area does experience human impacts such as County Road 45 bisecting the swamp, as well as concession roads and the occurrence of residential areas.

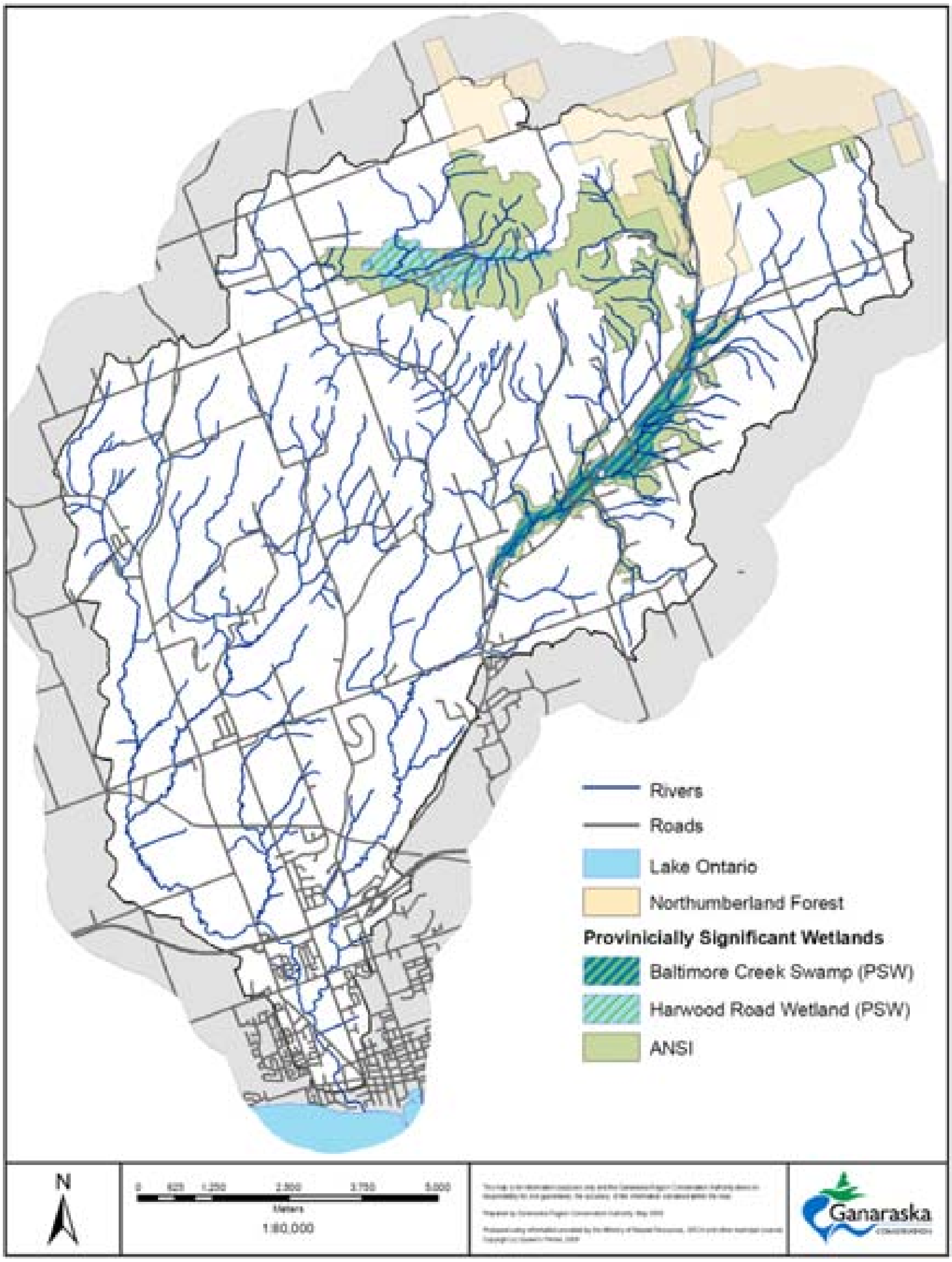


Figure 4.20: Provincially Significant Wetlands and ANSI

Chapter 5 – CULTURE CHARACTERISTICS OF COBOURG 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 within the watershed in a localized manner.

5.1.1 Municipal Populations and Growth

Cobourg Creek flows through the Township of Alnwick/Haldimand, the Township of Hamilton and the Town of Cobourg, all of which are located in Northumberland County (Figure 5.0). The headwaters of Cobourg Creek are found within the Township of Alnwick/Haldimand and the Township of Hamilton, whereas the Main Branch flows through the Town of Cobourg, and empties in to Lake Ontario within the town boundaries. Within the Cobourg Creek watershed, 14.8 km^2 or 12% of the watershed area has a land use associated with settlement and growth areas (i.e., roads, railways, urban and rural development), as defined by Ecological Land Classification mapping (Ganaraska Region Conservation Authority 2002). According to the 2006 Statistics Canada Census, there are 9,427 people living within the Cobourg Creek watershed.

Both provincial legislation and municipal official plans have defined areas within 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. The provincial *Places to Grow Act, 2005* has identified no urban growth centres in the Ganaraska Region Conservation Authority or within the Cobourg Creek watershed. In addition, the *Oak Ridges Moraine Conservation Act, 2001* has provided further development directions within the Oak Ridges Moraine portions of the Cobourg Creek watershed (Figure 5.1).

Nevertheless, given its proximity to the Greater Toronto Area, the Ganaraska Region Conservation Authority watersheds, including the Cobourg Creek watershed, are expected to experience a significant increase in population. As a result, population projections are necessary to ensure development and infrastructure occurs at a sustainable rate for municipalities and the environment. Planning documents such as growth management strategies consider 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 (County of Northumberland 2008). In 2008-2009, the County of Northumberland is carrying out a growth management strategy guided by the *"Places to Grow: Growth Plan for the Greater Golden Horseshoe"* provincial document. Official plans also direct growth within a given municipality. The Township of Alnwick/Haldimand, Township of Hamilton and Town of Cobourg all have official plans.

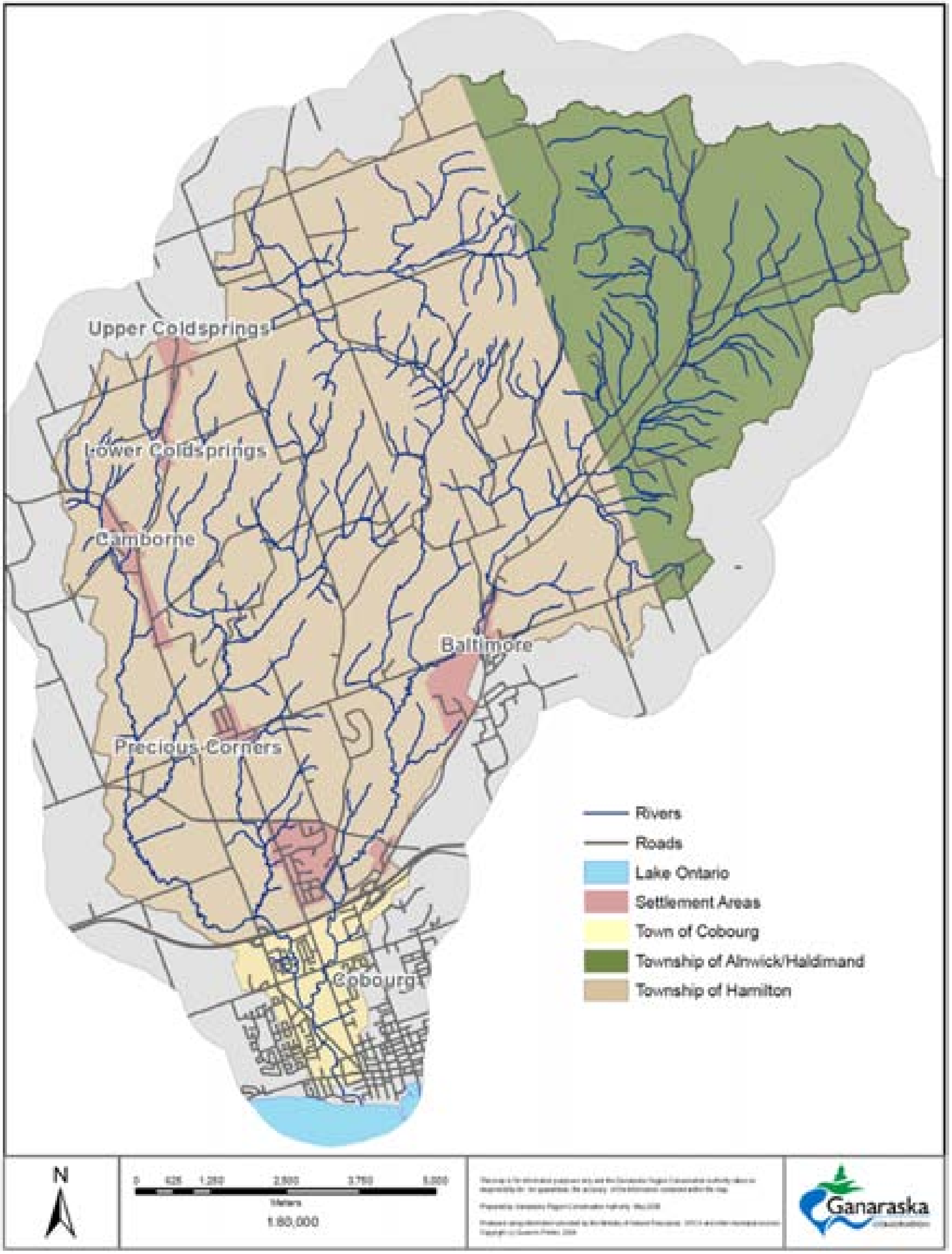


Figure 5.0: Settlement areas

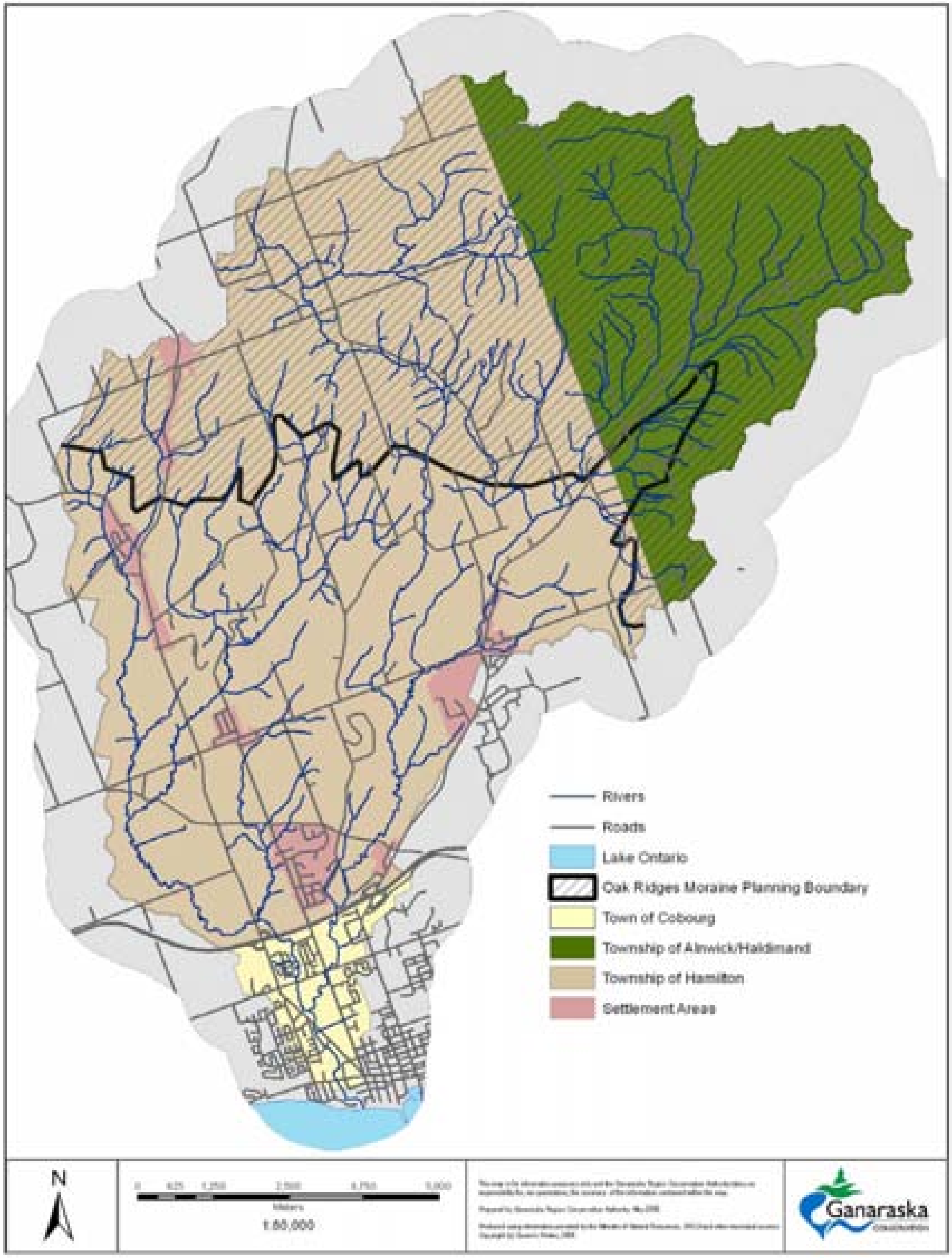


Figure 5.1: Oak Ridges Moraine planning boundary

Township of Alnwick/Haldimand

The Township of Alnwick/Haldimand encompasses 398.08 km^2, is predominately rural, and is located in the east end of the Cobourg Creek watershed. The population of the Township as a whole was 5,846 in 2001 and grew by 10.1% to 6,435 by 2006 (Statistics Canada 2007) (Table 5.0), with a 2% average population growth rate in the intervening five years. Over the next 20 years, there is a projected increase in population of 1,500 people from the existing population (Peter A. Joseph and Associates 2007). In addition, each year there is a seasonal cottage population influx of 1,500 individuals, which is expected to continue into the future (Peter A. Joseph and Associates 2007).

The 2006 census information also indicates that the population density is 16.28 people/km^2, and the population of the Township of Alnwick/Haldimand in the Cobourg Creek watershed is 433 people. The Township of Alnwick/Haldimand is situated on 31.3 km^2 of the Cobourg Creek watershed, or 25.4% of the watershed area. There are no designated hamlets within the Cobourg Creek watershed within the Township of Alnwick/Haldimand (Figure 5.2). In fact, the majority of the area of the Cobourg Creek watershed within the Township of Alnwick/Haldimand is located primarily in the Oak Ridges Moraine Conservation Plan boundary and physiographic region.

Township of Hamilton

The Township of Hamilton is 256 km^2 in area, is predominately rural, and surrounds the Town of Cobourg. Settlement areas identified in the *Township of Hamilton Official Plan* (Ainley Group 2003) that are within the Cobourg Creek watershed include Cold Springs, Camborne, Baltimore, Precious Corners, Camborne, and areas adjacent to Highway 401 (Figure 5.3). Residential estates also occur around Cornish Hollow Road and Sky Valley Drive within the Township of Hamilton (Figure 5.3). Limited growth will take place in Cold Springs and will be restricted to infilling and minor rounding out of development in accordance with the Oak Ridges Moraine Conservation Plan.

The population of the Township of Hamilton as a whole was 10,785 in 2001 and grew by 1.7% to 10,972 by 2006 (Statistics Canada 2007) (Table 5.0), with 0.3% average population growth rate in the intervening five years. The 2006 census information also indicated that the population density is 42.8 people/km^2. At this rate it is anticipated that the Township will have a total permanent population of 14,712 by 2021 (Table 5.1). Currently, about 42% of the population is concentrated in settlement areas within the Township, where as the remaining 58% reside on farms, rural residential lots, estate residential subdivisions, and waterfront residential properties on the shores of Rice Lake. The Township of Hamilton is situated within 83.8 km^2 of the Cobourg Creek watershed, or 68.1% of the watershed area, and contains a population of 4,695 people.

Town of Cobourg

The Town of Cobourg is classified as an urban centre with a population density in 2006 of 814 people/km^2 on a land base of 22.37 km^2. The population in the Town of Cobourg grew as a whole by 6.0% from 17,172 in 2001 to 18,210 in 2006 (Statistics Canada 2007). In 2005 the population of the Town of Cobourg was estimated to be 18,201, an increase of 1.98% from 2001 (Town of Cobourg 2005) (Table 5.0). The Town of Cobourg is noted as one of the fastest-growing communities in Eastern Ontario and its projected population growth is found in Table 5.21.

A portion of the Town of Cobourg is situated within 8 km^2 of the Cobourg Creek watershed, or 6.5% of the watershed area. 4,779 people live within the Town of Cobourg and the Cobourg Creek watershed. The Town of Cobourg is the largest urban area within the Cobourg Creek watershed. Designated development areas within the Town of Cobourg limits are shown in Figure 5.4. The Town of Cobourg has built out its development areas and now is infilling development where it can occur.

Figure 5.5 shows the future development areas, as specified in municipal official plans, within Cobourg Creek. These areas are to occur within the Township of Hamilton and the Town of Cobourg, around and within current settlement areas.

Table 5.0: Municipal populations

	2001 Population	2006 Population	2001 to 2006 Population Change	Annual Population Change from 2001 to 2006
Township of Alnwick/Haldimand	5,846	6,435	10.1%	2.0%
Township of Hamilton	10,785	10,972	1.7%	0.3%
Town of Cobourg	17,172	18,210	6.0%	1.2%

Source: (Statistics Canada 2007)

Please Note: The Township of Alnwick/Haldimand populations include those areas outside of the Ganaraska Region Conservation Authority.

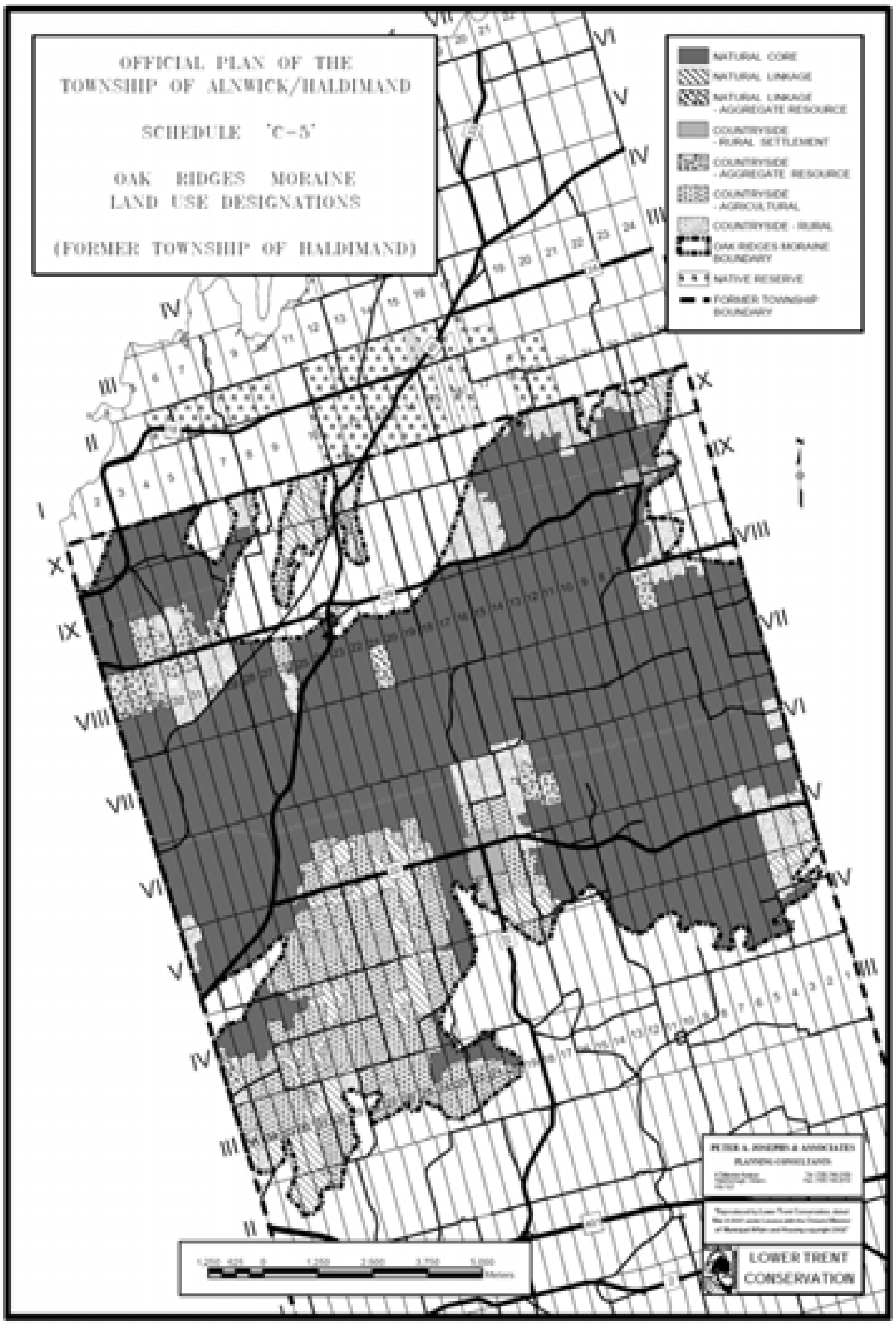
Table 5.1: Municipal population projection

Region	Census Population	Population Projections			
	2006	2011	2016	2021	2025
Township of Alnwick/Haldimand [A]	6,435				7,935
Town of Cobourg [B]	18,377	20,312	22,350	24,532	
Township of Hamilton [C]	11,878	12,639	13,390	14,712	

[A] Peter A. Joseph and Associates 2007

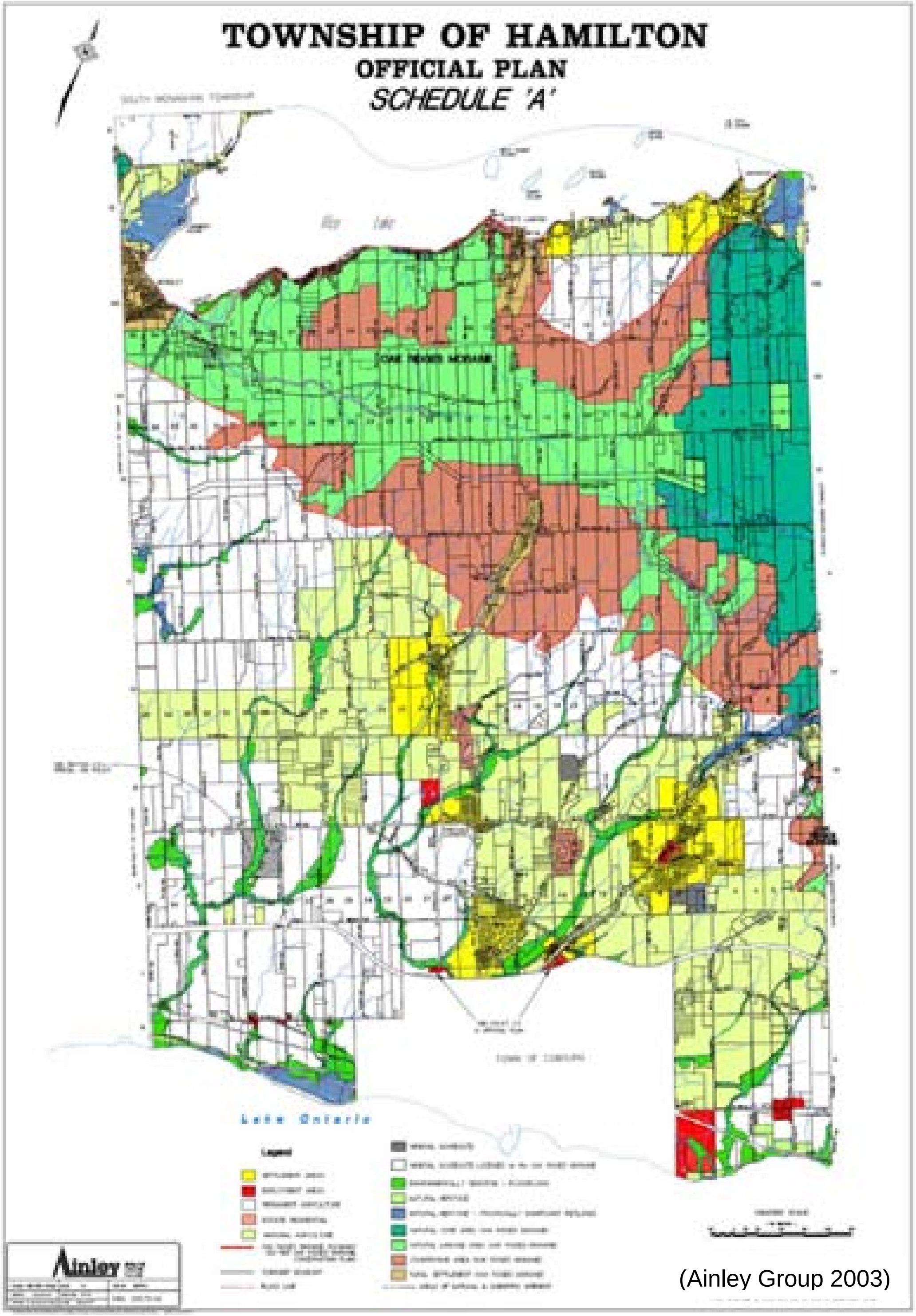
[B] Town of Cobourg Personal Communications 2007

[C] Township of Hamilton Personal Communications 2007



(Peter A. Joseph and Associates 2007)

Figure 5.2: Land use within Township of Alnwick/Haldimand and within the designated area of the Oak Ridges Moraine



(Ainley Group 2003)

Figure 5.3: Settlement areas and land use within the Township of Hamilton

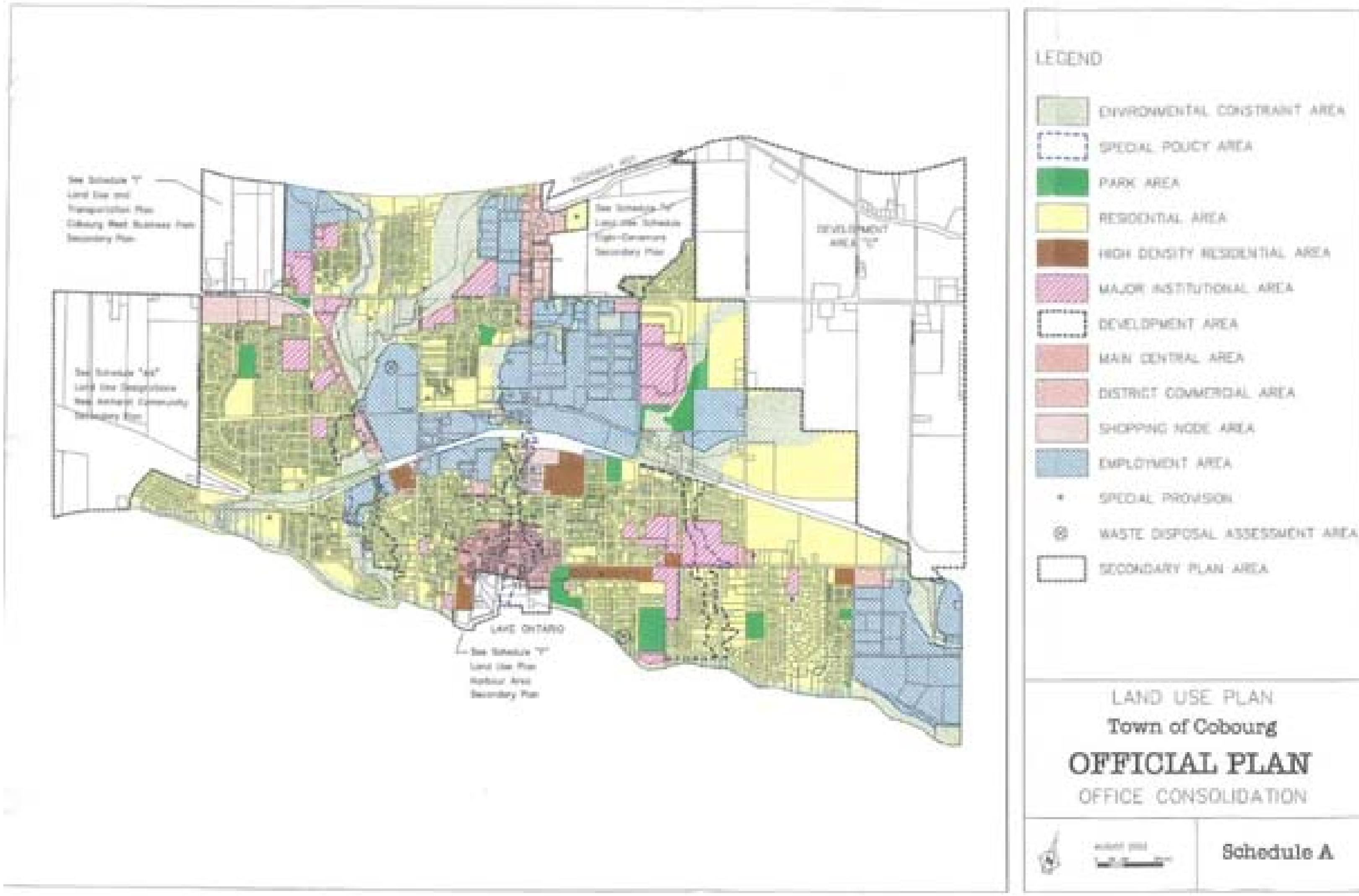


Figure 5.4: Settlement areas and land use within the Town of Cobourg (Town of Cobourg 2002)

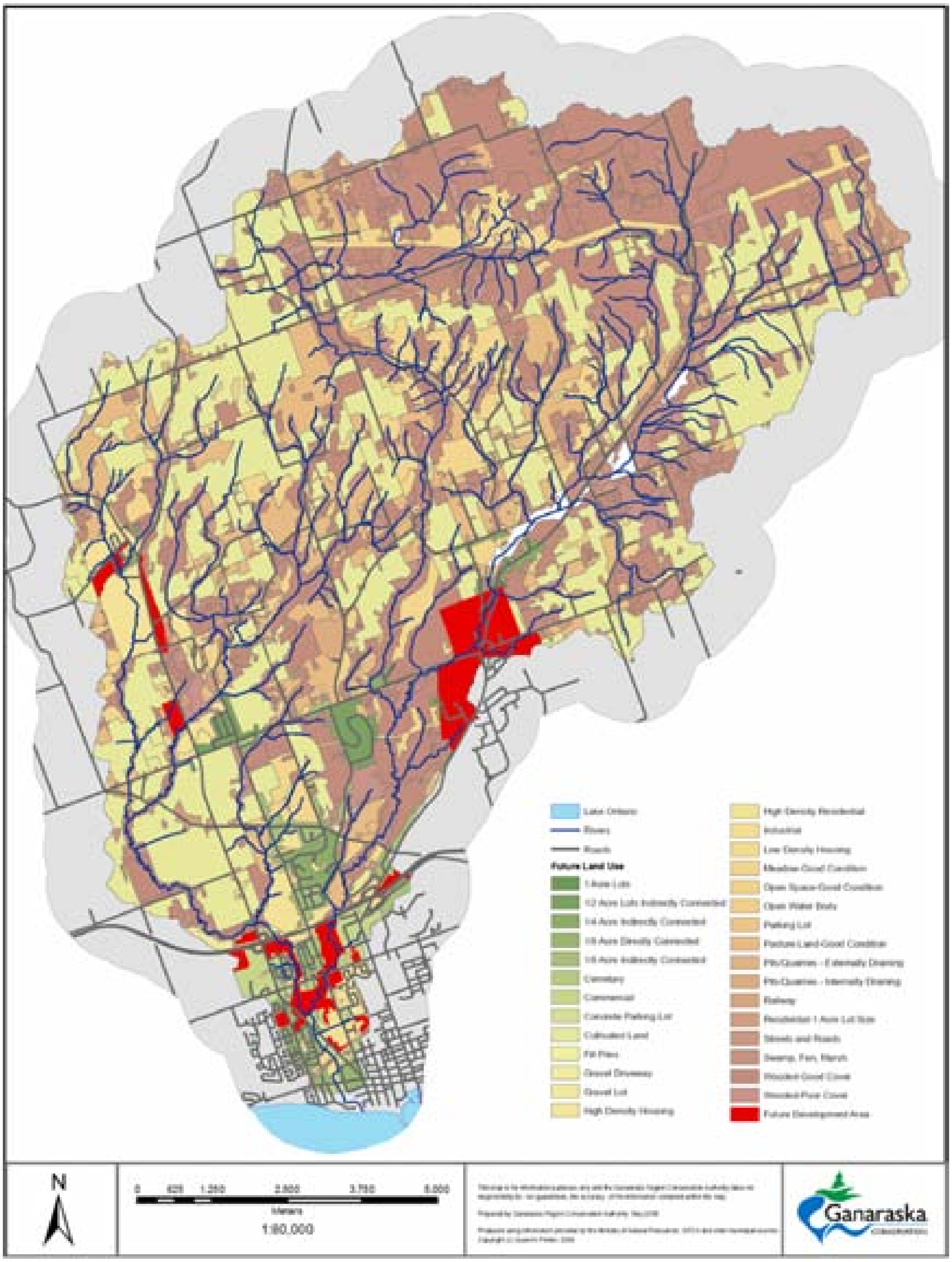


Figure 5.5: Future development areas

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 review under other plans providing necessary background information. In rural areas, tourism and agriculture remain the main industries, along with aggregate extraction. Figures 5.2 to 5.4 portray the locations of employment, commercial and institutional designated areas, identified tourism sites such as parks, agricultural lands, and aggregate licensed areas. Although not all of the noted industries are within the Cobourg Creek watershed, their presence influences the local community within and around the watershed. These influences can influence the Cobourg Creek watershed.

The Township of Hamilton has identified eight employment areas, and all are located south of the Oak Ridges Moraine and Concession 4 (Ainley Group 2003). Four of these employment areas are within the Cobourg Creek watershed. There are no designated industrial or commercial lands within the Township of Alnwick/Haldimand jurisdiction of the Cobourg Creek watershed.

The Town of Cobourg has a diverse industrial base, manufacturing a wide variety of products from airport communication towers to foil laminated paper products. The food industry presently represents a large portion of manufacturing employment. Some of these industries include Weetabix of Canada Limited and Weston Bakeries Limited. These companies manufacture products such as cereal, fruit cake, and coffee. In 2007 an announcement was made that one of the largest employers, Kraft Canada Incorporated, was closing in October 2008. This shift in employment within the Town of Cobourg will be felt by local residents. Work is underway to bring in a new industry to this site. The importance of knowing what industries are within and around the Cobourg Creek watershed is in relation to waste discharge to the sewage Treatment Plant 1, which outlets into Cobourg Creek (Section 5.1.4).

Other major employment industries include plastic and rubber product manufacturing, paper manufacturing, electrical equipment, appliance and component manufacturing, fabricated metal product industries and machinery manufacturing (Town of Cobourg, Community Development Office 2007). There are 57 manufacturers in the Town of Cobourg employing close to 3,000 people (Town of Cobourg, Community Development Office 2007).

Commercial use of groundwater and surface water exists within the Cobourg 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 Section 3.5.4 of this document.

5.1.3 Agriculture

Agricultural practices are the dominant land use within the Cobourg Creek watershed. Based on Ecological Land Classification mapping (Ganaraska Region Conservation Authority 2002), agricultural land covers an area of ~4,797 ha or 39% of the Cobourg Creek watershed (Figure 5.6). Intensive agriculture, as shown in Figure 5.6, is defined as row crops and orchards, while non-intensive agriculture is defined as pasture fields. Depending on the interpretation of the aerial photo, hay fields and fallow fields may be defined as non-intensive agriculture or cultural meadows. As indicated by Statistics Canada's 2006 census, agricultural production types and intensities vary throughout Northumberland County, however crop production prevails over livestock production (Statistics Canada 2008). Table 5.2 contains a breakdown of agricultural land use in the various municipalities and counties within the Cobourg Creek watershed.

Please note that only portions of the Township of Alnwick/Haldimand and Northumberland County are within the Ganaraska Region Conservation Authority. Statistics related to agriculture will be reported at the county level, as many statistical reports are unavailable at a smaller scale. Similarly, statistics are not available on a scale smaller than that of an entire municipality. However, activities will be assumed to be generally constant across the county or municipality.

Table 5.2: Agricultural land use in 2006 within municipalities of Cobourg Creek

Region	Number of Farms	Land Farmed (Hectare)
Northumberland County [A]	1,031	97,594
Township of Alnwick/Haldimand [A]	173	17,992
Township of Hamilton	147	10,975
Town of Cobourg	0	0

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

Agricultural Land

Northumberland County farm acreage greatly ranges in size. Out of a total of 1,031 farms reported in 2006, 517 farms are less than 53 hectares, 359 farms are between 53 and 161 hectares, and 155 farms are greater than 162 hectares (Statistics Canada 2008). Of the total land farmed (97,594 hectares) in Northumberland County, 32,098 hectares of farmland are rented or leased.

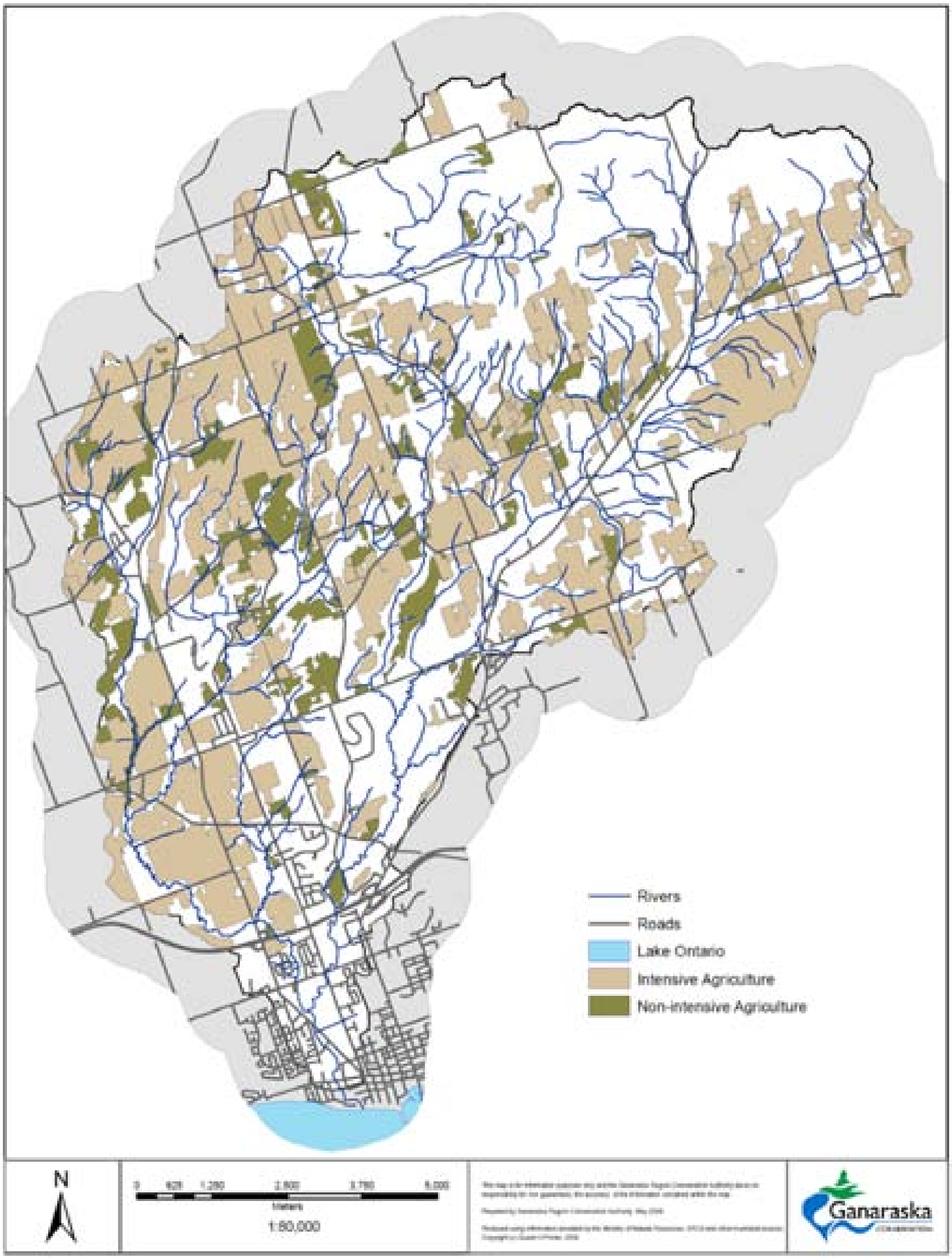


Figure 5.6: Agricultural land use

Crops and Livestock

61,357 hectares within Northumberland County are dedicated to crop production, including fruits and vegetables (Statistics Canada 2008). The five most predominant field crops grown within Northumberland County 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). Many other field crops are produced throughout the Cobourg Creek watershed.

Produce is also grown in Northumberland County. A total of 502 hectares of fruit are grown consisting predominantly of apples, raspberries, strawberries and grapes (Statistics Canada 2008). In 2006, major vegetable crops grown within Northumberland County included sweet corn, tomatoes, pumpkins, and green or waxed beans on 278 hectares of land (Statistics Canada 2008). Many other vegetable and fruit varieties are grown throughout Northumberland County, including floriculture (flowering plants), nursery, and sod production operations.

Livestock production in 2006 included dairy and beef cattle, pigs, sheep, and poultry (chickens and turkeys) (Statistics Canada 2008), however other livestock are raised within Northumberland County including goats, horses, buffalo, elk, llamas, rabbits and bees (Statistics Canada 2008). Dairy and beef cattle are the predominant livestock raised in the Cobourg Creek watershed.

Agricultural Conservation Measures

In 2006, 12 farms within Northumberland County were reported as certified organic producers (Statistics Canada 2008) and an additional 55 were reported as uncertified organic producers. Soil conservation is widely practiced throughout the area, helping to mitigate soil erosion and surface runoff and to increase soil and crop productivity (Table 5.3). Many farmers within the Cobourg 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. The Ontario Soil and Crop Improvement Association reported from April 2005 to March 2008 that 81 stewardship projects were completed within the Ganaraska Region Conservation Authority and claimed under cost share funding programs through the Environmental Farm Plan program.

Table 5.3: Soil conservation practices in Northumberland County in 2006

Activity	Number of Farms Reporting
Total Number of Farms Reporting	1,031
Crop Rotation	674
Winter Cover Crops	167
Rotational Grazing	342
Buffer zones around riparian areas	292
Windbreaks or Shelter Belts	350
Green Manure Crops for Plough-down	170

Agricultural production within the Ganaraska Region Conservation Authority and the Cobourg 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 within 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 are all necessary in communities. Each utilizes natural resources or affects the natural environment in different ways. Infrastructure requires proper planning, management and development in order to sustain the local community and the natural environment.

Transportation and Transmission Line Corridors

Provincial highways and county roads, as well as local roads within the Cobourg Creek watershed, are shown in Figure 5.7. Highway 401 and County Roads 2, 22 and 74 are the east-west transportation roads. Major north-south transportation corridors include County Roads 45, 15 and 18. The CPR and CNR railroad runs east to west along the south half of the Cobourg Creek watershed (Figure 5.7). Many hydro corridors and stations exist within the Cobourg Creek watershed mainly running in an east to west direction and along transportation routes (Figure 5.7). The Enbridge Gas Line runs east-west and north of Dale Road (County Road 74) through the Cobourg Creek watershed.

Roads are managed for the safe passage of people and goods. Provincial and municipal road standards direct the construction of roads, maintenance of existing roads and access to roads by private driveways. Roads can cause negative impacts on local streams in regards to stream crossings. Culverts are used to allow for surface water to drain under a road in such a way that running water does not causing road flooding or damage. Many culverts, however, are aging and, as a result of improper construction or erosion, have become perched. Perched culverts create a barrier to fish movement, since there is a vertical distance between the stream bottom and the bottom of the culvert at its downstream end. Roads also restrict the movement of stream channels. Naturally, a stream channel meanders through the creek valley and over time changes its position. With the placement of a culvert, the stream can not move naturally. Within the Cobourg Creek watershed, 13 perched culverts have so far been identified. Some culverts, due to their size, do not allow for the passage of woody debris, a necessary component of a healthy aquatic ecosystem. In addition, stream road crossings and side roads are easy access points for illegal garbage dumping. This negative social action contaminates the local watershed with household garbage and hazardous waste such as electronics, tires and appliances.

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) within the Cobourg Creek watershed. Northumberland County is responsible for county roads, and lower tier municipalities are 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.

Northumberland County is responsible for County Roads 2, 22, 45, 74, 18 and 15, and follow a salt management plan to ensure that environmental regulations are followed when applying winter material and disposing of snow. Northumberland County applies a mixture of sodium chloride and sand on roads that they manage, at a rate of 130 kg/km of salt to 600 kg/km of sand (County of Northumberland 2005). Of the eight storage sites that the County operates, two exist in the Cobourg Creek watershed; both are located on Veronica Street in the Town of Cobourg. A dome storage facility holds 3,400 tonnes of sand and a covered shed holds 140 tonnes of salt (County of Northumberland 2005). No snow disposal sites for Northumberland County exist within the Cobourg Creek watershed.

Municipalities manage the remaining roads within the Cobourg Creek watershed. Salt management plans exist for the Township of Hamilton and the Town of Cobourg. The Township of Alnwick/Haldimand does not require a salt management plan as less than 500 tonnes of salt are used for road operations.

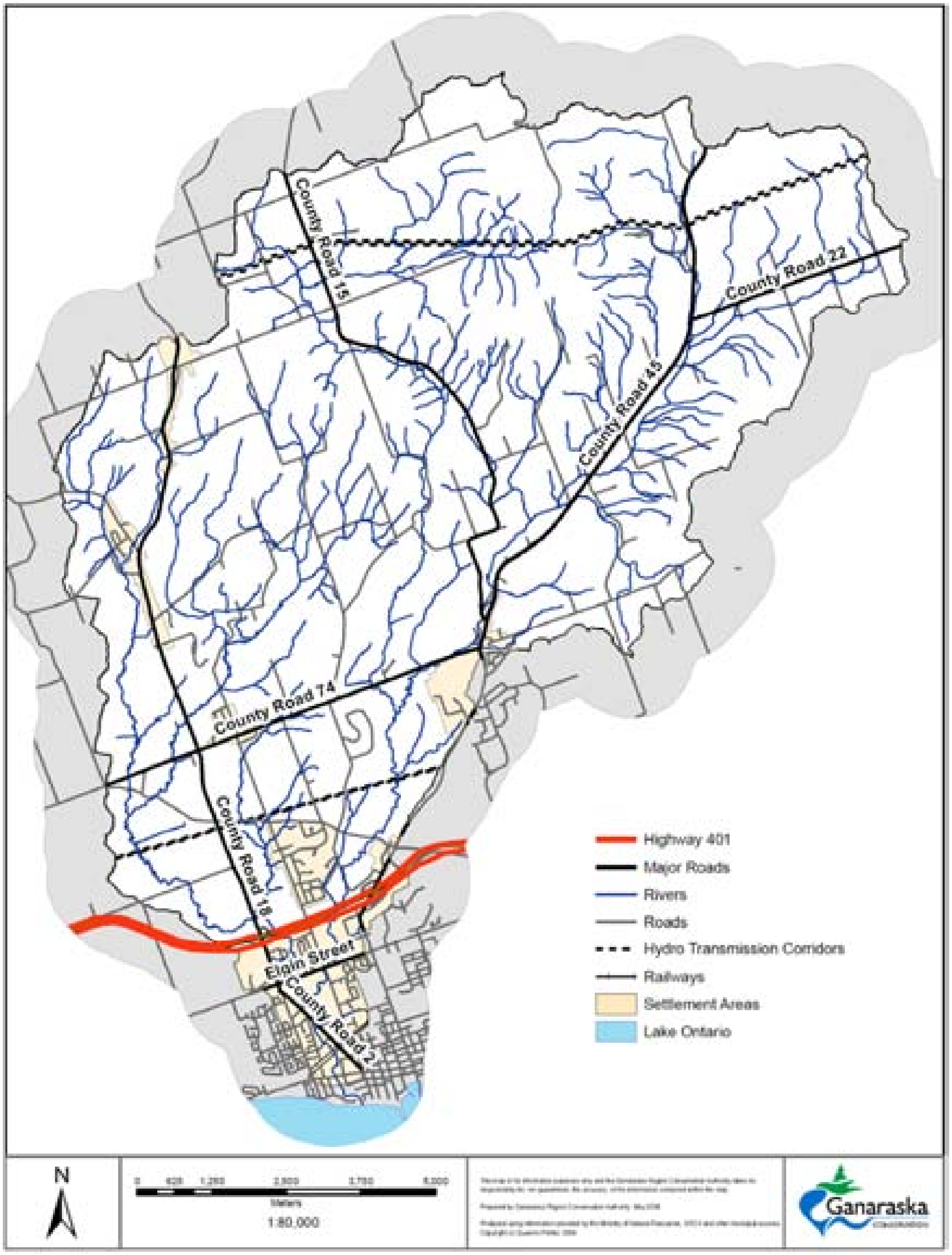


Figure 5.7: Transportation and utility corridors

The Township of Hamilton uses a mixture of rock salt and sand, with about 5% of the mixture comprised of salt (Township of Hamilton 2005). All winter maintenance equipment and materials are located at the Township of Hamilton yard on Majestic Hills Drive within the Cobourg Creek watershed. The equipment and material are managed in a responsible and environmentally sensitive manner. No snow disposal sites operated by the Township of Hamilton exist within the Cobourg Creek watershed.

The Town of Cobourg manages winter maintenance on town roads within the Cobourg Creek watershed. The level of service varies according to the class of roads (Town of Cobourg 2005b). Arterial streets are managed to achieve bare pavement, and over-application of salt is avoided. Collector streets are managed to produce a centre-bare pavement condition using salt application. Local streets are managed once priority roads are addressed. The amount of salt applied is aimed at preventing the formation of ice at intersections, and is only applied during daylight hours when temperatures and traffic volumes are high enough to make the application of salt practical (Town of Cobourg 2005b).

Salt is stored and handled at a covered building located on King Street within the Cobourg Creek watershed. The storage building is 800 m^3 with a sloped floor to contain brine runoff (Town of Cobourg 2005b). Proper management occurs at this facility to ensure environmental degradation does not occur. The Town of Cobourg does not have any snow dumps within the Cobourg Creek watershed.

Landfills

Waste management within the Ganaraska Region Conservation Authority is primarily under the jurisdiction of the upper tier municipalities. There are no active landfills within the Cobourg Creek watershed. Residents can take waste to the Bewdley Transfer Station in the Rice Lake watershed, or partake in curbside pickup. In addition, hazardous household waste depots are available throughout Northumberland County. There are no plans for future landfills within Northumberland County (Pam Russell, Director of Transportation and Waste, Northumberland County, Personal Communication). There are many closed landfills throughout the Ganaraska Region Conservation Authority, however there are no known historic landfills with the Cobourg Creek watershed.

Water Treatment Plants and Private Wells

Figure 5.8 shows the municipal water serviced areas within the Cobourg Creek watershed. The Town of Cobourg draws water from Lake Ontario to be treated for drinking water. The Township of Hamilton operates two municipal drinking water systems that provide water to residents in Camborne and Creighton Heights/Baltimore communities. The Township of Hamilton municipal drinking water systems draw water from groundwater wells. The Creighton Heights municipal system serves some residential areas that are located outside of the Cobourg Creek watershed. Information on these wells from a water use perspective is found in the water budget section of this document (Section 3.5.4). Details on these water treatment systems are found in Table 5.4. Within the Township of Hamilton, 85 residences near the boundary of the Town of Cobourg are serviced by drinking water systems by Lakefront Utilities Services Incorporated. The rest of the population in the Cobourg Creek watershed relies on private water supply wells for drinking water (Figure 5.9). These wells draw water from either overburden or bedrock aquifers.

Table 5.4: Municipal Water Treatment System Information

	Camborne Municipal Well	Creighton Heights Municipal Well	Town of Cobourg Water Treatment Plant
Location	Camborne	Creighton Heights	Cobourg
Population Served	200	1,100	18,500
Water Source	Groundwater	Groundwater	Lake Ontario
Number of Wells	2	3	--
Number of Intake Cribs	--	--	1
Maximum Daily Permitted water taking(m^3/d)	412	979.2	31,822

Wastewater Treatment

There is one wastewater treatment plant in the Cobourg Creek watershed, the Cobourg Water Pollution Control Plant #1, that outlet into Cobourg Creek approximately 1.2 km upstream from the creek mouth at Lake Ontario (Figure 5.10). Within the Township of Hamilton there are no municipal sanitary systems (Ainley Group 2003). Areas without municipal waste treatment services within the Cobourg Creek watershed rely on private septic systems. Currently, there is no specific data available regarding the number, concentrations, or other information about private septic systems within the Cobourg Creek watershed.

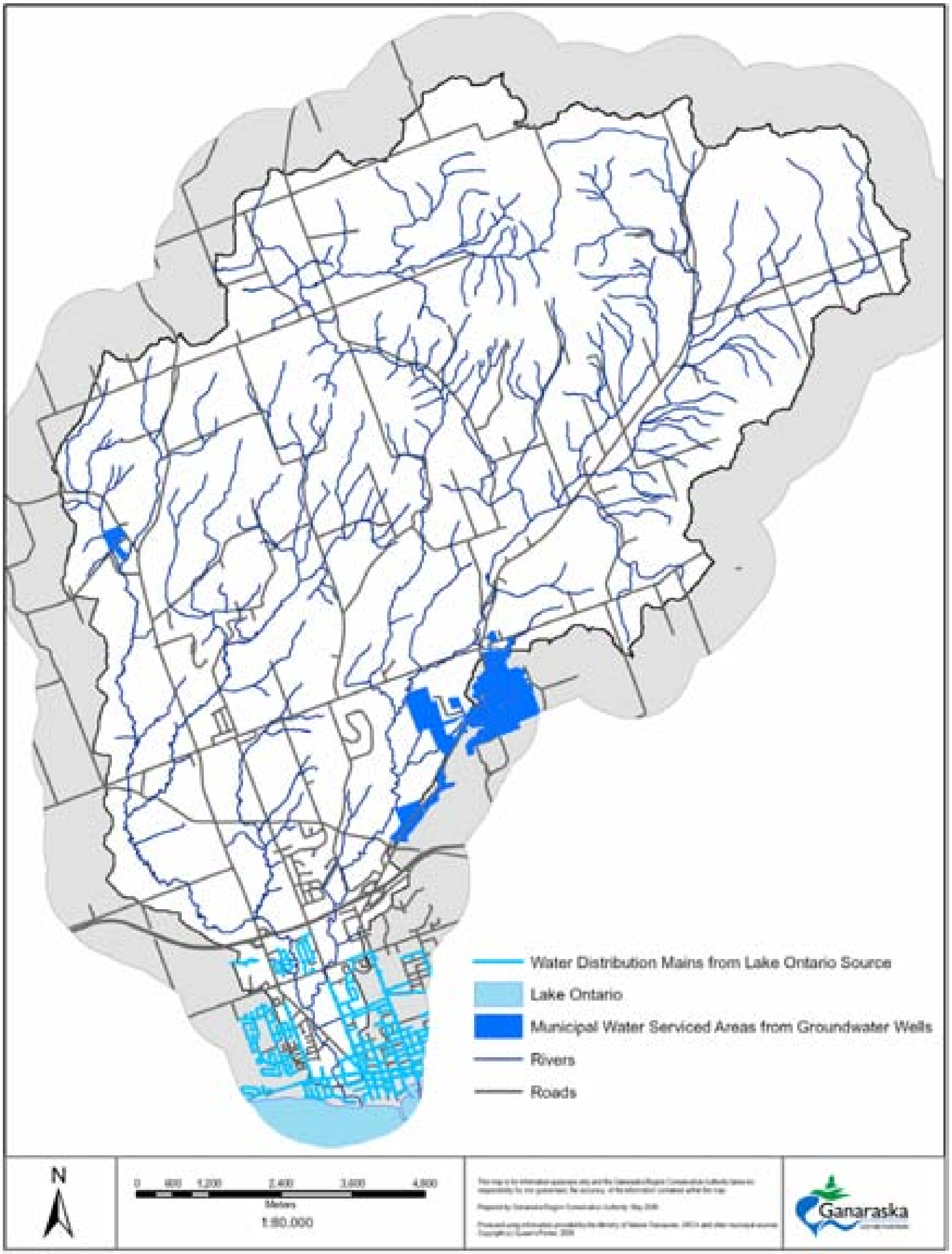


Figure 5.8: Municipal water serviced areas

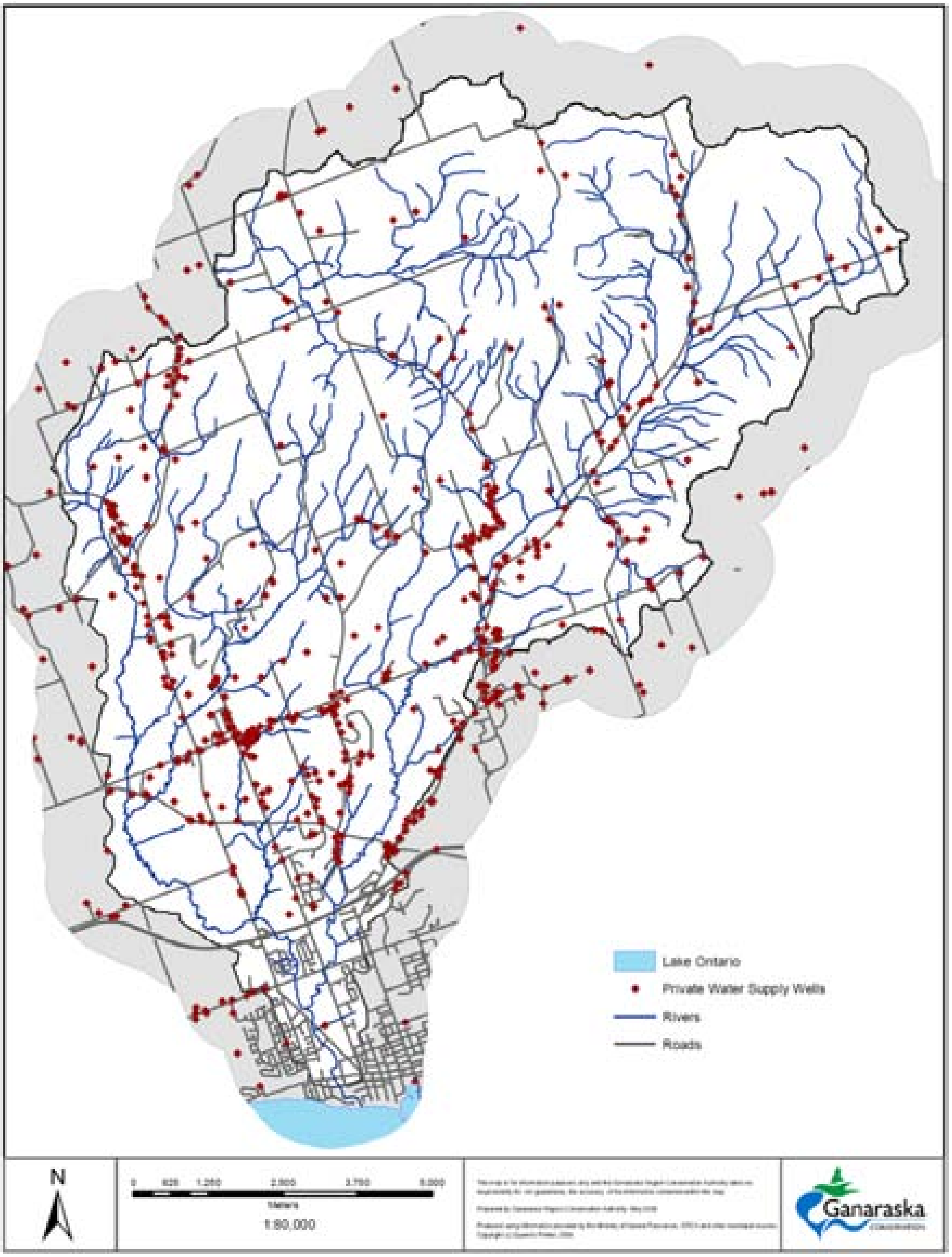


Figure 5.9: Private water supply wells

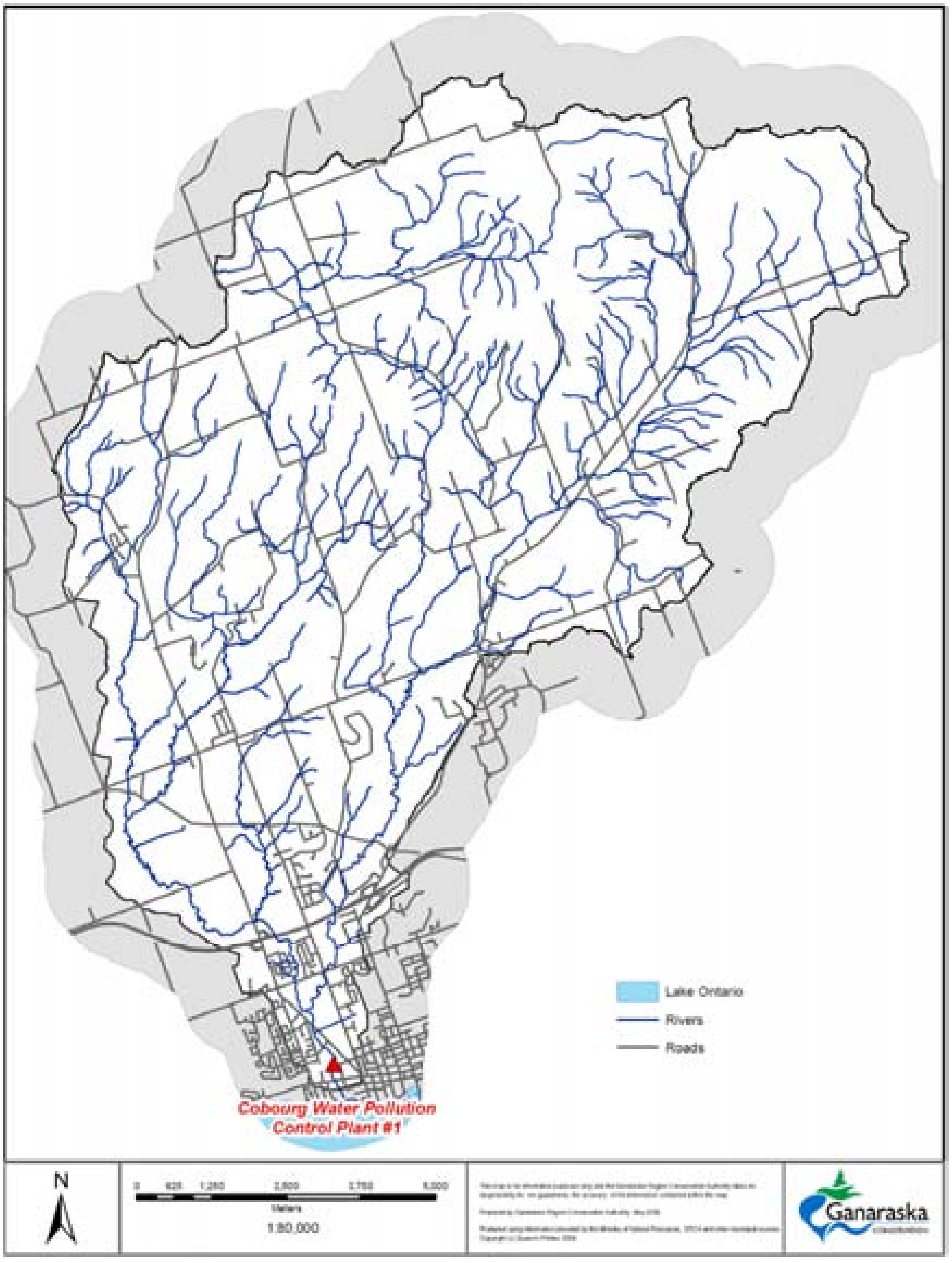


Figure 5.10: Wastewater treatment plant

Stormwater Management

Stormwater management (SWM) facilities are normally associated with urban areas of the Cobourg Creek watershed where runoff is directed toward detention ponds, constructed wetlands and infiltration trenches. In rural areas, most of the runoff from roads and residential areas is directed toward ditches and depression areas where higher infiltration rates are anticipated due to high permeability of surficial soils.

Staff at the Ganaraska Region Conservation Authority review all development proposals to ensure they comply with stormwater requirements defined locally (Ganaraska Region Conservation Authority 2004b) and within 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 Environment and are defined as:

> *"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)

Three Stormwater Management Ponds exist within the Town of Cobourg and within the Cobourg Creek watershed (Ganaraska Region Conservation Authority 2007b).

- Burnham Street North SWM Pond – services the commercial lands west of Burnham Street and north of Elgin Street with a drainage area of 41 hectares
- Terry Fox Subdivision Pond – located east of Burnham Street and north of Elgin Street – services the Terry Fox Subdivision
- Densmore Road SWM Pond – east of Division Street and Highway 401 with a drainage area of 28.4 hectares

To meet urban development requirements, several Master Drainage Plans have been developed for the Cobourg Creek watershed. R. V. Anderson (1992) provides the hydrologic analyses of the 2- to 100-year storm and Hurricane Hazel with Visual OTTHYMO models for Cobourg Creek based on both existing land use and future land use. These scenarios are used to set discharge targets. In 2007 updates were made to the hydrology and hydraulic analyses using calibrated Visual OTTHYMO Modeling (Ganaraska Region Conservation Authority 2007b). Please refer to the Surface Water Analysis section for more detail (Section 3.5).

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 (i.e., timber or water) or non-renewable (i.e., aggregates, oil and gas).

Aggregate Extraction, Oil and Gas

Within the Cobourg Creek watershed, the Oak Ridges Moraine and the Lake Iroquois Shoreline provide many aggregate resource opportunities. A total of 0.51 km^2 or 0.4% of Cobourg Creek watershed is defined as an aggregate land use by 2002 Ecological Land Classification Mapping. 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 Lake Iroquois Shoreline region grades from fine sand to crushable oversized gravels. The lateral extent and depths of beach deposits are variable. There are no bedrock quarries within the Cobourg 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 Cobourg Creek watershed. According to the Ontario Geological Survey (1994) records, much of the aggregate resources in this area have been depleted. Other aggregate resource areas have been sterilized by the construction of Highway 401 and by the housing development north of Cobourg. Areas of high aggregate potential and areas under aggregate extraction within the Township of Hamilton are presented in the Official Plan (Figure 5.11 and Figure 5.3). Areas of aggregate licences within the Township of Alnwick/Haldimand are shown in Figure 5.2.

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 pubic health and safety. In addition, the Oak Ridges Moraine Plan contains requirements as to which Oak Ridges Moraine land use designation can be developed for aggregate resources (i.e., natural linkage area and countryside area). Municipalities also have requirements on how a licensed aggregate operation is to close. The Ministry of Natural Resources regulates how an aggregate area is to be rehabilitated.

Due to the nature and the depositional history of the local geological formations, there is no oil and gas production in the Cobourg Creek watershed. However, data from the Ontario Geological Survey shows that there has been exploration wells drilled in the area south of Rice Lake in the Township of Hamilton.

Forestry
Along with private forests, the Northumberland County Forest is located partially (593 ha) within the Cobourg Creek watershed (Figure 5.12). With a total size of 2,111 ha, the Northumberland County Forest provides for the production of wood products through the implementation of ecologically based resource management practices that will continue to be an important component of the multiple-use nature of the forest.

The Northumberland County Forest, located on the Oak Ridges Moraine, provides a protected headwater and groundwater recharge area for Cobourg Creek, and protects the dry sandy soils on the Oak Ridges Moraine from erosion. The majority of the Northumberland County Forest has been established through past restoration efforts. Conifer plantations make up a large portion of the Northumberland County Forest, however deciduous species exist throughout the forest including oak, maple and ash. Historically, the Northumberland County Forest was managed by the Ministry of Natural Resources; after the expiration of the management agreement in 2002, the County of Northumberland assumed responsibility for the management of the forest. A Forest Management Plan is currently being developed for the Northumberland Forest.

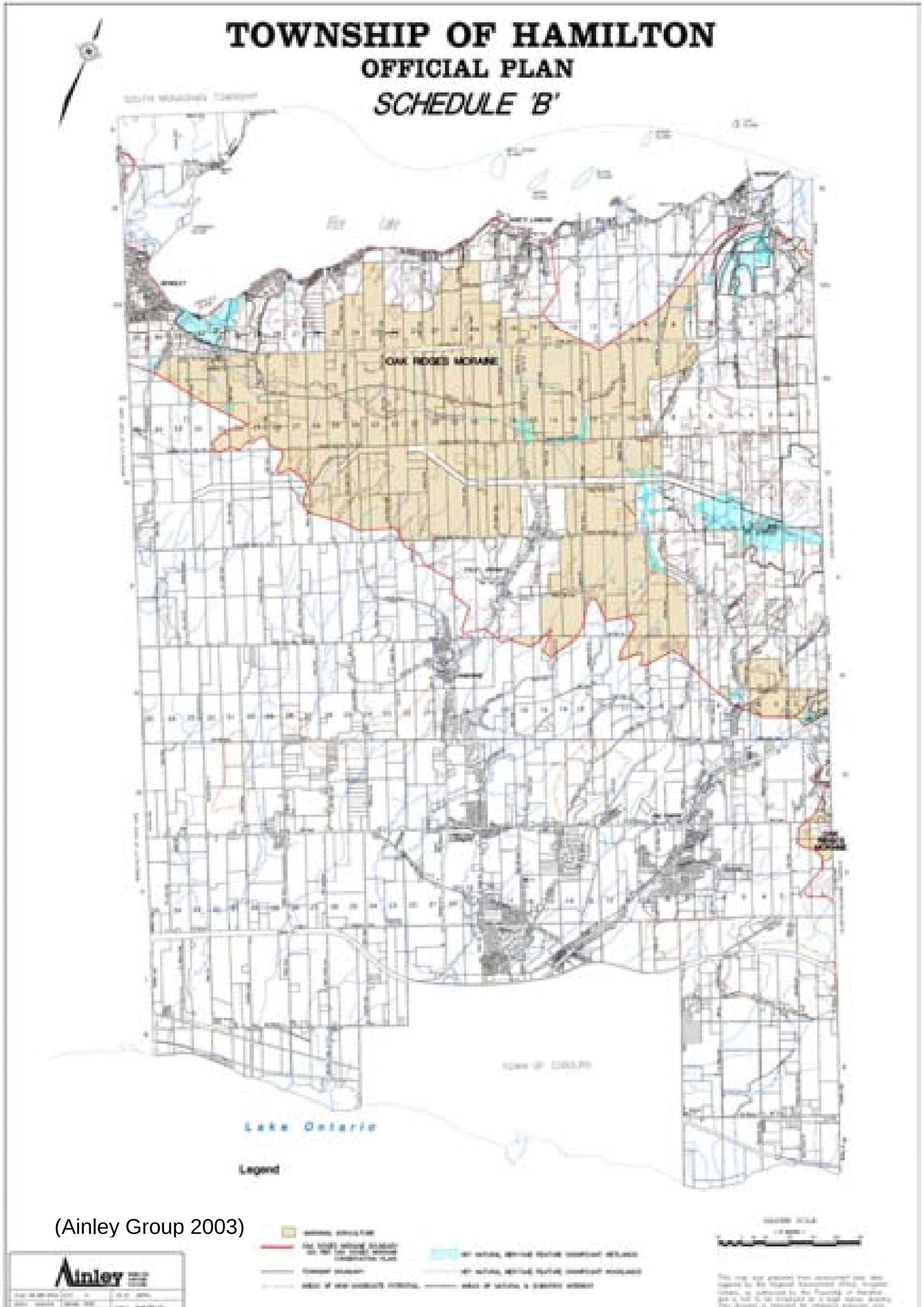


Figure 5.11: Areas of high aggregate potential within the Township of Hamilton

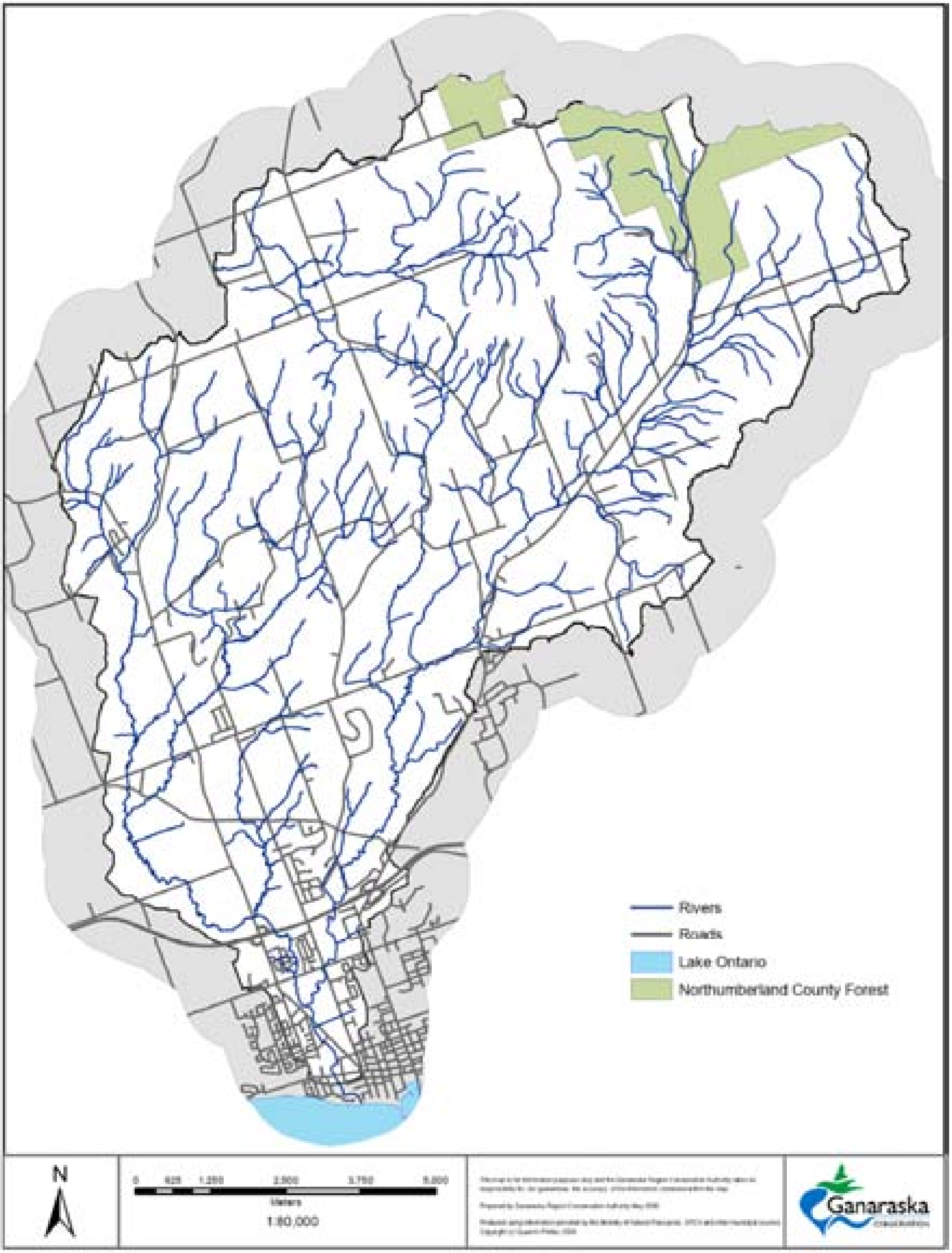


Figure 5.12: Northumberland County Forest

5.1.6 Conservation Areas

Certain lands within the Ganaraska Region Conservation Authority are designated as conservation areas. These properties are owned by the Ganaraska Region Conservation Authority and managed in cooperation with local municipalities. These lands are open to the public and have been created to satisfy many objectives. Objectives may include flood protection, mitigation, habitat creation, public education and recreation.

Cobourg Conservation Area

Purchased in 1971, the Cobourg Conservation Area is a 12.5 hectare (30.9 acre) property located in the northwest area of the Town of Cobourg (Figure 5.13). The property is bounded by William Street/County Road 2 on the west and Elgin Street to the north. A major feature of the area is the presence of the west and central branches of Cobourg Creek that confluence near the south end of the property. The area is generally flat and as a result, most of the site is prone to flooding (Franklin and Peacock 2002). A small weir located above the confluence forms a small elongated wetland along the west branch of Cobourg Creek. This area was formerly a pond but has since been drained as a management technique to allow regeneration of the site (Franklin and Peacock 2002).

As described by Franklin and Peacock (2002), the presence of the county roads along both main access points and the close proximity of the Highway 401 interchange bring many tourists and commuters into the area. Likewise, the nearby Northumberland County building, hotel and restaurants attract people into the area. Adjacent residential lands provide a steady input of visitors as well. Although the Conservation Area is not designated within the *Town of Cobourg Official Plan*, it acts as a gateway to the community for anyone entering the municipality from the west.

Cobourg Conservation Area has a long historical existence. Prior to its acquisition in 1971, the United Counties of Durham and Northumberland owned the area. From 1965 until 1971, the Conservation Area had been operated by the Rotary Club of Cobourg and the area still holds the name “Rotary Park” for many local people. Considerable alterations were carried out under the Rotary Club management that gave the area its general characteristics of a large, open grassed area and channelized riverbed.

Since its official opening on June 27, 1973 by Her Majesty Queen Elizabeth II, the Conservation Area has undergone interim development including the construction of a parking lot and footbridge, tree planting and the reconstruction of a small dam. A stone cairn in the middle of the Conservation Area commemorates the Queen’s visit. A number of erosion control and other projects have also been undertaken over the last 30 years. The site also holds the name James Cockburn Park. It was named The Honourable James Cockburn

Centennial Gardens on September 17, 1967 by the Archaeological and Historic Sites Board of Ontario as part of Canada's Centennial Year dedications in conjunction with the Cobourg Rotary Club. James Cockburn, a resident of Cobourg, was a Father of Confederation and the first speaker of the House of Commons from 1867 to 1874 (Franklin and Peacock 2002).

Today, Cobourg Conservation Area is owned by the Ganaraska Region Conservation Authority and operated by the Town of Cobourg. The master plan for the Cobourg Conservation Area was updated in 2002 to address current conditions and user request of the area. This document outlines activities and upgrades that could be applied to the conservation area to guide sustainable management into the future.

Ball's Mill Conservation Area

The Ball's Mill Conservation Area was purchased in 1971 by the Ganaraska Region Conservation Authority. The property located in Baltimore (Figure 5.12) is 21 hectares in size and is bounded by the Ball's Mill Pond to the north, Harwood Road to the west, County Road 45 to the east, and the junction of County Road 45 and Harwood Road to the south. The conservation area is used for passive recreation including hiking, nature appreciation, picnicking, dog-walking and fishing.

The major natural feature of Ball's Mill Conservation Area is the pond that is fed by Cobourg Creek and was created from an earthen fill dam with concrete abutments and stop logs. The pond and the associated unused raceways acknowledge the past when the pond was used in the operation of a grist mill and a small sawmill. Although the mill was owned and operated by many (West et al. 1999), five men played vital roles in the development of Ball's Mill; they were William McDougal, William Ball, John Ball, Fred Ball and Jon R. Ball (Gladstone 1979). The mill was in operation until it was sold to the Ganaraska Region Conservation Authority. On July 2, 1974 as a result of silt build-up in the pond and the occurrence of a peak flow event, the concrete dam failed causing damage to the pond (Gladstone 1979) and downstream areas. In 1988 the Ganaraska Region Conservation Authority sold the mill portion of the property to private interests. Ball's Mill dam is currently operated for the purpose of regulating upstream and downstream water levels for fish and wildlife management (Macpherson 2004).

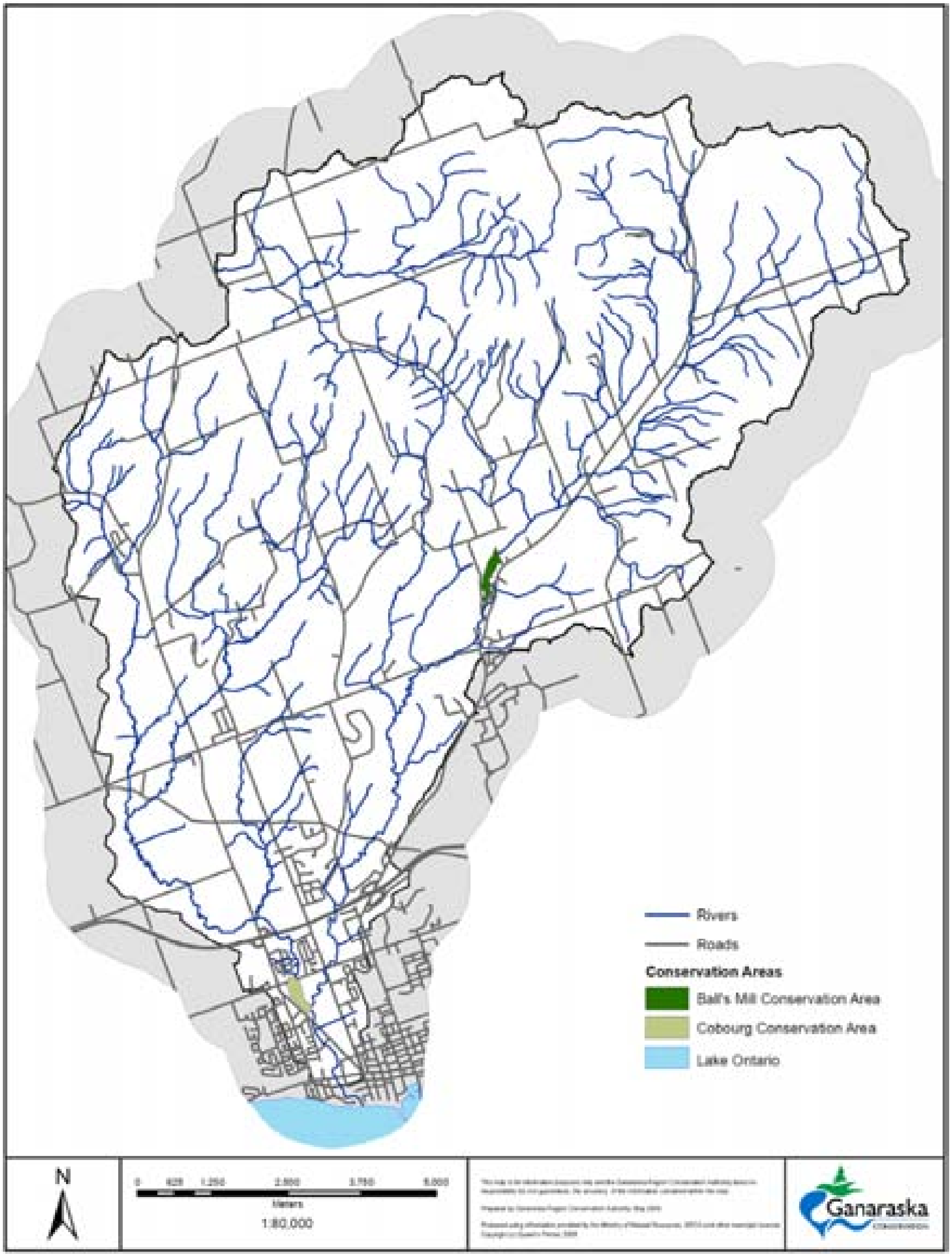


Figure 5.13: Conservation areas

5.1.7 Green Spaces

For the purposes of this study, green space is defined as parkland. 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. 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.

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

The quantity and quality of green space available also has a positive relationship to 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.

In the Town of Cobourg five municipal parks exist within the Cobourg Creek watershed (Table 5.5). Within the Township of Hamilton many community parks and green spaces exist, including the Cold Springs Memorial Hall, which also houses a ball park and playground area. In the Township of Alnwick/Haldimand, a small park is located within the Cobourg Creek watershed, off County Road 45.

Table 5.5: Parks within Cobourg Creek watershed and the Town of Cobourg

Park Name	Location	Size (acres)	Activities
Arboretum	Elgin Street	0.5	passive recreation and tree displays
Jubilee Park	William Street/Elgin Street	0.5	passive recreation
Sinclair Park	Sinclair Street	7.0	2 Softball Diamonds; Washrooms; Playground; 3 Tennis Courts; Lights
Burnham Manor Park	Burnham Manor Court	2.0	Passive recreation
Peace Park	Fourth Street	5.0	Passive recreation and playground, fishing

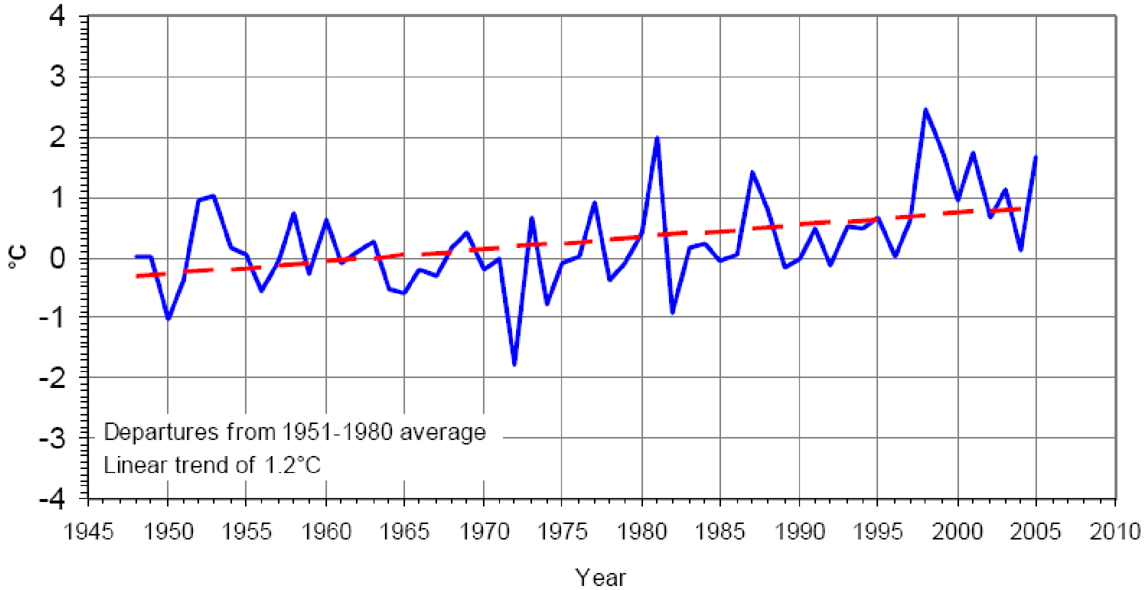
Chapter 6 - COBOURG CREEK IN A PROVINCIAL CONTEXT

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^{o}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 20cm during the 20th century, and an additional increase of 18 to 59cm 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 daily temperature average of a year, the 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 within the Cobourg 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.

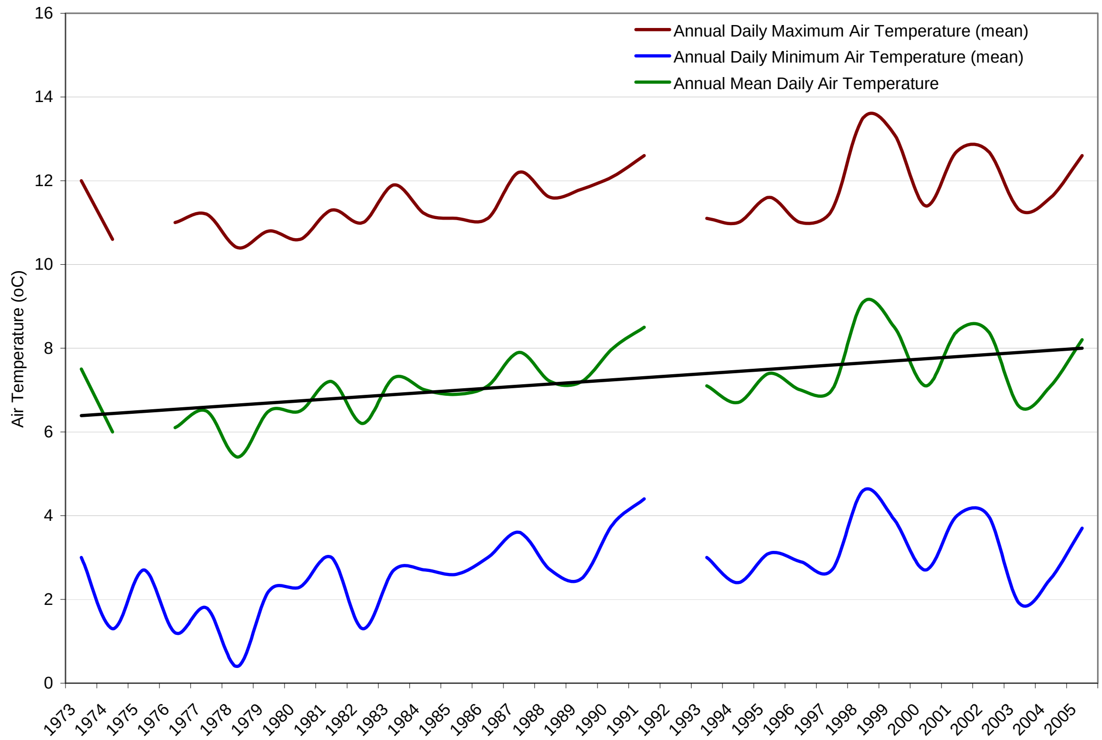


Figure 6.1: Annual average air temperature at the Cobourg STP Environment Canada Station 1973 to 2005

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

- The ice cover season on the Great Lakes has been shortened by about one to two 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. Warmwater 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 impair their functions under increased climate change.

Changes are also expected to water resources within the Great Lakes basin, and will affect both groundwater and all surface water sources (the 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, waterborne diseases and Ultraviolet Radiation. Agriculture may see increases in pest 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 affected 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 the magnitude they occur at 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 Cobourg 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,* 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 are found within 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, the 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).

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

For the purpose of drinking water source protection planning, the TCC Source Protection Region 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 4,171 km^2 outside of conservation authority jurisdiction is included in the Trent Conservation Coalition Source Protection Region.

Although source protection plans will be created for a source protection region, the planning area of interest is municipal surface water intake zones and wellhead protection areas. These areas have been defined using defensible science-based methods and represent the area of source water for municipal water systems. The Camborne and Creighton Heights municipal well supplies have been studied as part of drinking water source protection and have had wellhead protection zones delineated for the purpose of protecting the sources of the municipal water supply. See Section 3.3.2 for more detail on this study.

While the Cobourg 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 business representatives and a range of other stakeholders within 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 will set out who is responsible for carrying out different activities. The terms of reference will include strategies to consult with potentially affected property owners, to involve the public and to resolve disputes. While the committee creates an assessment report, the committee will identify threats, issues and concerns within 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 Cobourg 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 within the Great Lake drainage basin, before water flows through the St. Lawrence River to the Atlantic Ocean (Figure 6.2). Lake Ontario is bound 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 consisting of the upper Genesee River).

Lake Ontario is the smallest of the Great Lakes, with a surface area of 18,960 km2 (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 metres and a maximum depth of 244 metres (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, 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).

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 that will benefit and enhance Lake Ontario. In addition, many projects are occurring in Cobourg Creek that will benefit the health and sustainability of Lake Ontario.

(Great Lakes Information Network 2008)

Figure 6.2: Great Lakes drainage basin

(Environment Canada 2008)

Figure 6.3: Lake Ontario drainage basin

Water quality within Cobourg Creek is being studied in relation to storm events. The results of this study will be used to understand land uses in relation to water quality, and implement stewardship to improve water quality during storm runoff. In 2008, the Ministry of the Environment will be conducting a nearshore survey in Lake Ontario along and near the Cobourg Creek outlet. This will aid the Ganaraska Region Conservation Authority in understanding the effects of Cobourg Creek on the nearshore area of Lake Ontario.

The Lake Ontario fishery is dependent on its tributaries for spawning and rearing habitat. A native Lake Ontario salmonid, the Atlantic salmon (*Salmo salar*), is being reintroduced via Cobourg Creek. The exploitation of the Lake Ontario fishery in the early and mid-1800s, coupled with habitat loss and degradation, resulted in the rapid decline of natural fish stocks and extirpation of the top native salmonid predator, the Atlantic salmon (Ontario Ministry of Natural Resources and Ganaraska Region Conservation Authority 2008). Despite the trend of resource exploitation in the 1800s, there was a shift in resource management in the mid-1900s 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 1989). By the mid-1900s, few sportfishing opportunities existed and non-native salmonids were introduced in an 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). To aid in the reduction of sea lamprey, a lamprey weir was installed and is operated near the outlet of Cobourg Creek.

In order to address the absence of Atlantic salmon, a large scale restoration effort was launched in 2006, focused on three Lake Ontario tributaries - Cobourg Creek, Duffins Creek and the Credit River. In 2006, over 700,000 Atlantic salmon juveniles were stocked across the three tributaries. Three genetic strains of salmon are being introduced, each with different traits, in an attempt to increase the survival and success of achieving a self-sustaining population in Lake Ontario (Ontario Ministry of Natural Resources and Ganaraska Region Conservation Authority 2008).

It is envisioned that the Cobourg Creek watershed background document and management plan, as well as the Cobourg Creek Fisheries Management Background Document and Management Plan (Ontario Ministry of Natural Resources and Ganaraska Region Conservation Authority 2008) 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, UNITS AND GLOSSARY

AES	Atmospheric Environment’s
AMC	Antecedent moisture content
ANSI	Area of Natural or Scientific Interest
AVI	Aquifer Vulnerability Index
CEQG	Canadian Environmental Quality Guidelines
CGCM	Canadian Global Climate Model
CN	Curve Number
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
DNAPL	Dense Nonaqueous Phase Liquid
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
LiDAR	Light detecting and Ranging
ISI	Intrinsic Susceptibility Index
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
PCA	Principal Component Analysis
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
SOLRIS	Southern Ontario Land Resource Information System
STANDHYD	Standard Unit Hydrograph
SWM	Storm Water Management
TCC SPR	Trent Conservation Coalition Source Protection Region
TSS	Total Suspended Solids
WHPA	Well head Protection Area
WWRD	Water Well Record Database
YPDT-CAMC	York, Peel, Durham, Toronto, Conservation Authorities Moraine Coalition

Units

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

Glossary

A, B, C, D

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]
Cold Water Species/Habitat: Species with narrow thermal tolerance levels that is 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 water, 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]

E, F, G

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]
Flooplain: 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 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 diametre. [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]

H

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 water table 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]

I, J, K, L, M
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]

N, O, P, Q, R
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]
Piezometre: 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 Ontario 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 Ontario 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, fast flow, usually with gravel, cobble or boulder bed material. Riffle sections are found between pools. [6]
Riparian Area: the land adjacent to a watercourse that is normally not submerged, and provides for a vegetated 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]

S, T
Sand: Sedimentary particles ranging from 0.074 mm to 4 mm in diametre. [4]
Saturated zone: A subsurface zone in which openings in a soil or rock formation are filled with water. [4]
Settlement Areas: Urban and rural settlement areas within municipalities 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 surfaces. [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 glacial ice. Tills usually have a fine fraction 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 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]

U, V, W, X, Y, Z
Unconfined aquifer: An aquifer whose upper boundary is the water table. [4]

Unsaturated zone: A soil or rock zone above the water table, 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]
Water table: 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]
Well head 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 water table in which the pore spaces are filled with water. [4]

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Ganaraska

CONSERVATION