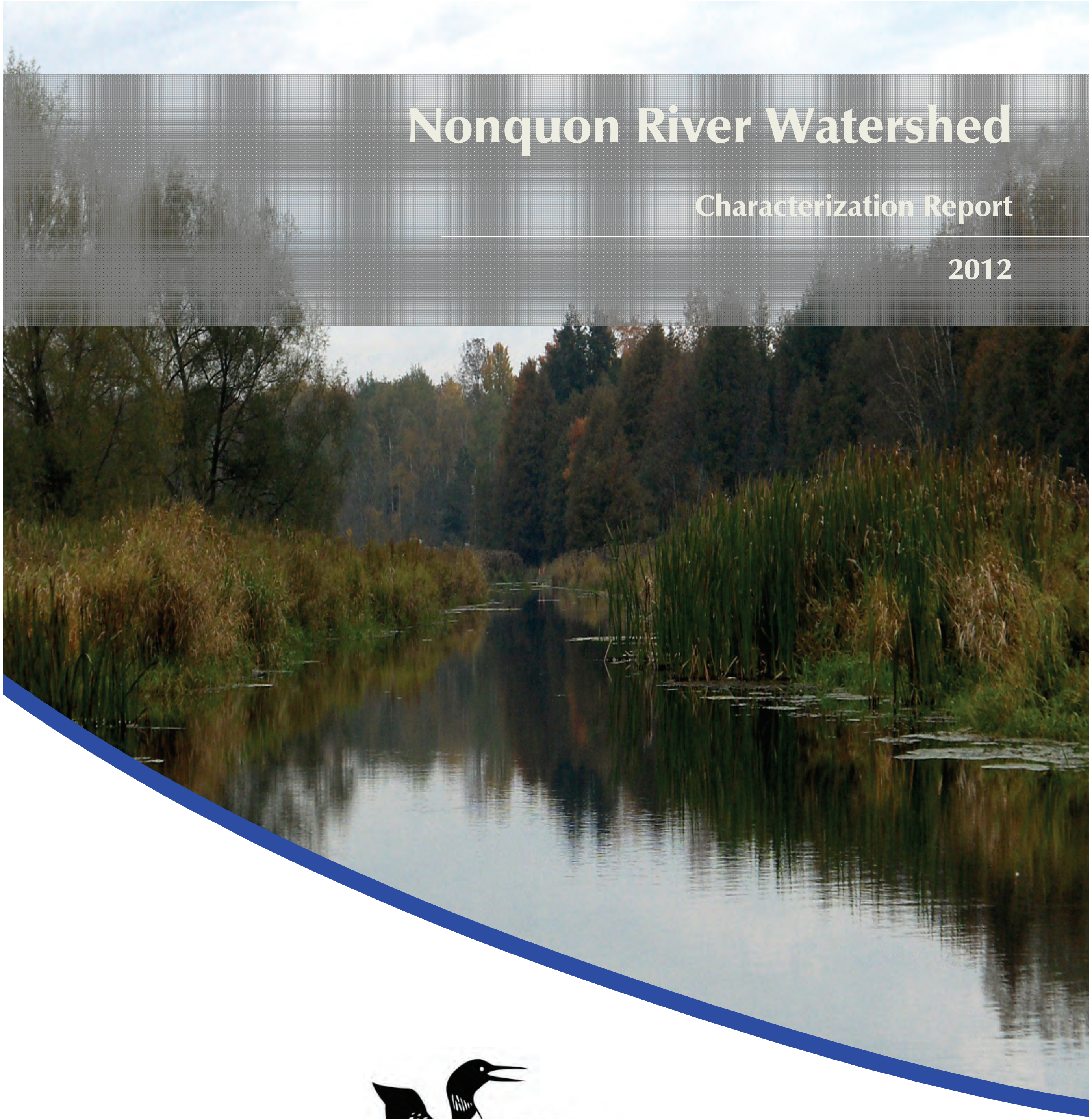

Nonquon River Watershed

Characterization Report

2012

KAWARTHA
CONSERVATION

About Kawartha Conservation

A plentiful supply of dean water is a key component of our natural infrastructure. Our surface and groundwater resources supply our drinking water, maintain property values, sustain an agricultural industry and support tourism.

Kawartha Conservation is the local environmental agency through which we can protect our water and other natural resources. Our mandate is to ensure the conservation, restoration and responsible management of water, land and natural habitats through programs and services that balance human, environmental and economic needs.

We are a non-profit environmental organization, established in 1979 under the Ontario *Conservation Authorities Act* (1946). We are governed by the six municipalities that overlap the natural boundaries of our watershed and voted to form the Kawartha Region Conservation Authority. These municipalities include the City of Kawartha Lakes, Township of Scugog (Region of Durham), Township of Brock (Region of Durham), the Municipality of Clarington (Region of Durham), Cavan Monaghan, and Galway-Cavendish & Harvey.

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Table of Contents

1.0 Introduction

Nonquon River main channel, west of Hwy12/7

1.1 Project Background

In 2007, Kawartha Conservation and the Regional Municipality of Durham initiated a watershed planning process for watersheds located within the Oak Ridges Moraine and within the jurisdictions of both agencies. These watersheds include: Nonquon River, Southern Lake Scugog Tributaries, Blackstock Creek and East Cross Creek. The watershed (i.e., the surface water drainage boundaries of a specific stream, river or lake) is widely recognized as an appropriate unit for managing human activities and water-related resources. This is because the health of rivers and streams is both influenced by, and illustrative of, the health of the lands through which they flow.

The need for a watershed management plan is usually brought upon by some type of trigger, such as public concern about environmental conditions. In this instance, it was the introduction of the *Oak Ridges Moraine Conservation Act* by the province of Ontario in 2001.

The Nonquon River Watershed Characterization Report is intended to be a complementary document to the Nonquon River Watershed Plan, providing much of the background information with respect to existing watershed resources, functions and linkages and information gaps. Summarizing this information into one comprehensive document will ultimately help inform management decisions throughout the development of the Nonquon River Watershed Plan, and provide detailed supporting background information.

1.2 Oak Ridges Moraine Conservation Plan

The Oak Ridges Moraine has a unique concentration of environmental, geological and hydrological features that make its ecosystem vital to south-central Ontario, including: clean and abundant water resources; healthy and diverse plant and animal habitat; an attractive and distinct landscape; prime agricultural areas; and, sand and gravel resources. In response to the increasing development pressures facing this significant landform, the province of Ontario introduced the *Oak Ridges Moraine Conservation Act* in 2001 which provided the legal basis for establishing the Oak Ridges Moraine Conservation Plan in 2002. The purpose of the Oak Ridges Moraine Conservation Plan is to provide land use and resource management direction on how to protect the Moraine's ecological and hydrological features and functions.

A key requirement of this plan is the integration of watershed management planning with municipal land use planning. It also provides direction on the content within these plans.

Section **24** of the Oak Ridges Moraine Conservation Plan (OMMAH 2002) states:

> **24.** (1) Every upper-tier municipality and single-tier municipality shall, on or before April 22, 2003, begin preparing a watershed plan, in accordance with subsection (3), for every watershed whose streams originate within the municipality's area of jurisdiction.
>
> (2) The objectives and requirements of each watershed plan shall be incorporated into the municipality's official plan.
>
> (3) A watershed plan shall include, as a minimum,
>
> (a) a water budget and conservation plan as set out in section **25**;
>
> (b) land and water use and management strategies;

(c) a framework for implementation, which may include more detailed implementation plans for smaller geographic areas, such as subwatershed plans, or for specific subject matter, such as environmental management plans;

(d) an environmental monitoring plan;

(e) provisions requiring the use of environmental management practices and programs, such as programs to prevent pollution, reduce the use of pesticides and manage the use of road salt; and,

(f) criteria for evaluating the protection and water quality and quantity, hydrological features and hydrological functions.

Since the Oak Ridges Moraine Conservation Plan planning boundary exists within the Nonquon River watershed, the legislative requirements listed above need to be addressed within the Nonquon River Watershed Plan. Technically, these provisions only apply to the portions of the Nonquon River watershed that exist within the Oak Ridges Moraine Conservation Plan boundaries. However, in taking a watershed management approach, the entire Nonquon River watershed has been included in the planning area.

1.3 Nonquon River Watershed Plan

The scope of watershed management has changed significantly within the past 50 years, from a single-issue driven focus (e.g., flooding and drainage) to an integrated ecosystem-based approach. The current watershed management process aims to protect and manage natural resources (including their functions and linkages) for current and future generations; reflects the local environmental and social context; uses an integrated, interdisciplinary approach; considers the environment, the economy and communities; uses a partnership approach to plan and manage; and, uses adaptive environmental management approaches that aim for continuous improvement (Conservation Ontario 2003).

To ensure that the Nonquon River Watershed Plan is consistent with the provisions within the Oak Ridges Moraine Conservation Plan, the approach in formulating the Nonquon River Watershed Plan is based on guidance provided in the Oak Ridges Moraine Conservation Plan Technical Paper 9: Watershed Plans (Province of Ontario 2007). This document is part of a series of technical reports that were developed to assist upper-tier and single-tier municipalities in preparing watershed plans that conform to the requirements of the Oak Ridges Moraine Conservation Plan. Much of the information contained within this technical report builds upon proven best management practices and lessons learned from similar watershed management projects in Ontario (Conservation Ontario 2003).

Figure 1.1 illustrates the four main phases in the watershed management process: plan, implement, monitor and report, and review and evaluate. Within the planning phase, there are eight key steps: (1) scoping; (2) characterizing the watershed system; (3) set goals, objectives and working targets; (4) develop management alternatives; (5) evaluate management alternatives; (6) select preferred management alternatives; (7) finalize targets; and, (8) develop implementation and monitoring plan.

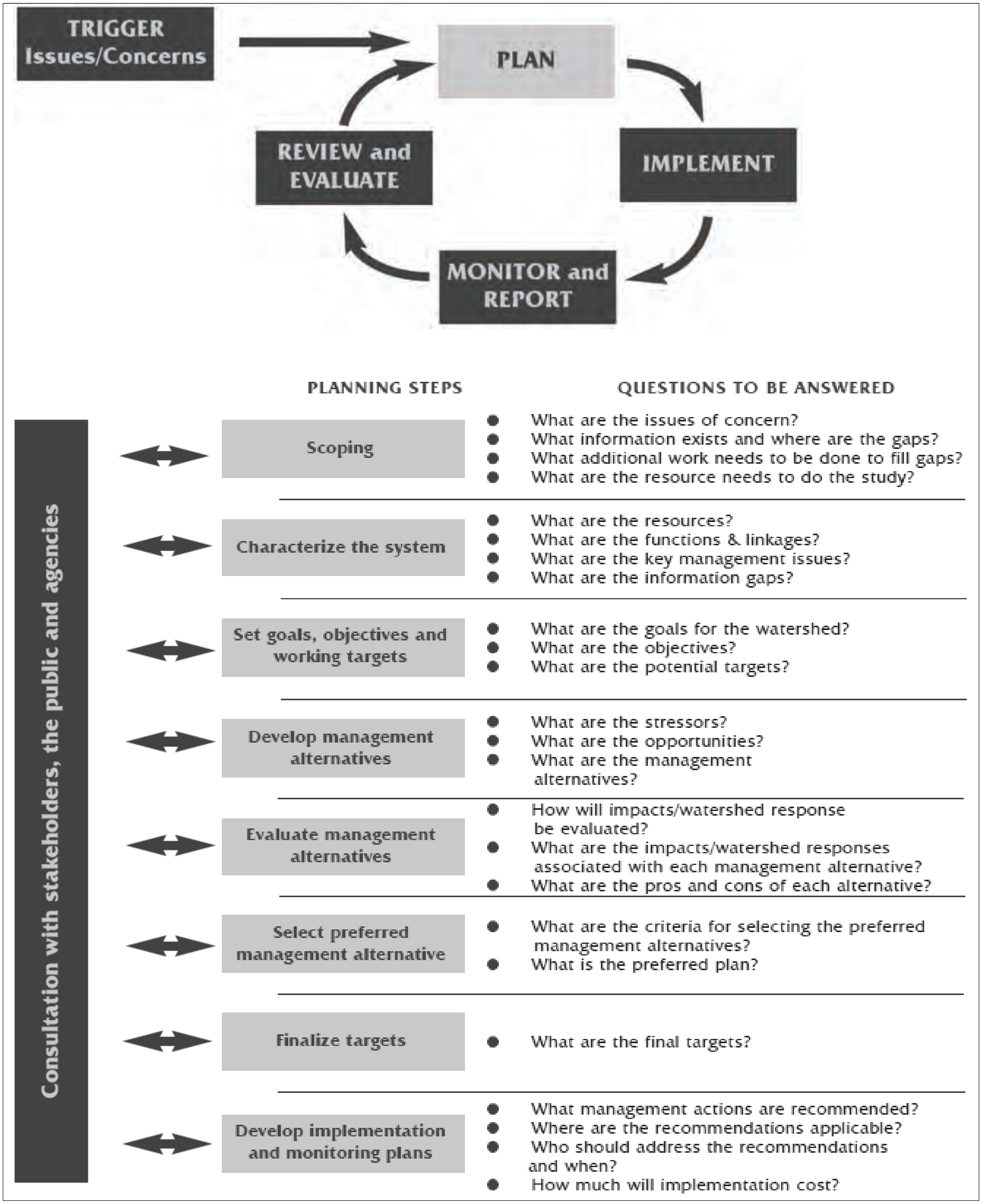
Step 1 (scoping), is outlined in the project terms of reference (Kawartha Conservation 2010a). The Nonquon River Watershed Characterization Report addresses step 2 (characterization). The purpose of this step in preparing the watershed plan is to identify, analyze, and evaluate watershed-specific constraints and opportunities in land-use. In particular, this document presents all available and relevant information with respect to watershed resources, functions and linkages, key management issues and information gaps. In characterizing the Nonquon River watershed, Kawartha Conservation has drawn upon all available data, studies and sampling results and combined this information into up-to-date report that can be reviewed and updated as required. This "background" information will ultimately help inform management decisions and recommendations that will be developed through steps 3 to 8.

The Nonquon River is the largest watershed flowing into Lake Scugog, thus, maintaining the health of the Nonquon River watershed is also crucial for maintaining the ecological integrity of the larger Lake Scugog watershed. Lake Scugog is an extremely significant resource within the area, in terms of its natural values (e.g., important habitat for wildlife), social values (e.g., vibrant history), and economic values (e.g., tourism).

1.4 Planning Area Boundaries

The Nonquon River watershed is identified in the Oak Ridges Moraine Technical Papers as existing within the Oak Ridges Moraine Planning area. The extent of the study area that is characterized within this report is shown in **Figure 1.2**, and includes all lands that exist within the Nonquon River watershed. The watershed boundaries and watercourse network were delineated using the ArcHydro tool, which is based on digital elevation mapping.

The Nonquon River watershed is located immediately west of Lake Scugog near Port Perry, which is approximately 50km north-east of Toronto, Ontario. The watershed drains 194.43km^2 of land into the Nonquon River and outlets into the north-western section of Lake Scugog, which in turn flows north through the Scugog River and into the chain of lakes known as the Kawartha Lakes. The Nonquon River watershed is bounded by the Mariposa Brook watershed to the north, Beaver River watershed to the west, Lynde Creek watershed to the south, and the watersheds of several Lake Scugog tributaries to the east. The Layton River is the largest named tributary within the Nonquon River watershed, draining 52.3km^2 of land, that outlets into the Nonquon River just north of Scugog Line 12. The Oak Ridges Moraine Conservation Plan planning area exists within the south-western portion of the Nonquon River watershed, encompassing approximately 27.85km^2, or 14.3% of the watershed.



PLANNING STEPS	QUESTIONS TO BE ANSWERED
Scoping	● What are the issues of concern? ● What information exists and where are the gaps? ● What additional work needs to be done to fill gaps? ● What are the resource needs to do the study?
Characterize the system	● What are the resources? ● What are the functions & linkages? ● What are the key management issues? ● What are the information gaps?
Set goals, objectives and working targets	● What are the goals for the watershed? ● What are the objectives? ● What are the potential targets?
Develop management alternatives	● What are the stressors? ● What are the opportunities? ● What are the management alternatives?
Evaluate management alternatives	● How will impacts/watershed response be evaluated? ● What are the impacts/watershed responses associated with each management alternative? ● What are the pros and cons of each alternative?
Select preferred management alternative	● What are the criteria for selecting the preferred management alternatives? ● What is the preferred plan?
Finalize targets	● What are the final targets?
Develop implementation and monitoring plans	● What management actions are recommended? ● Where are the recommendations applicable? ● Who should address the recommendations and when? ● How much will implementation cost?

From Conservation Ontario (2003)

Figure 1.1: Key steps in the watershed management planning process.

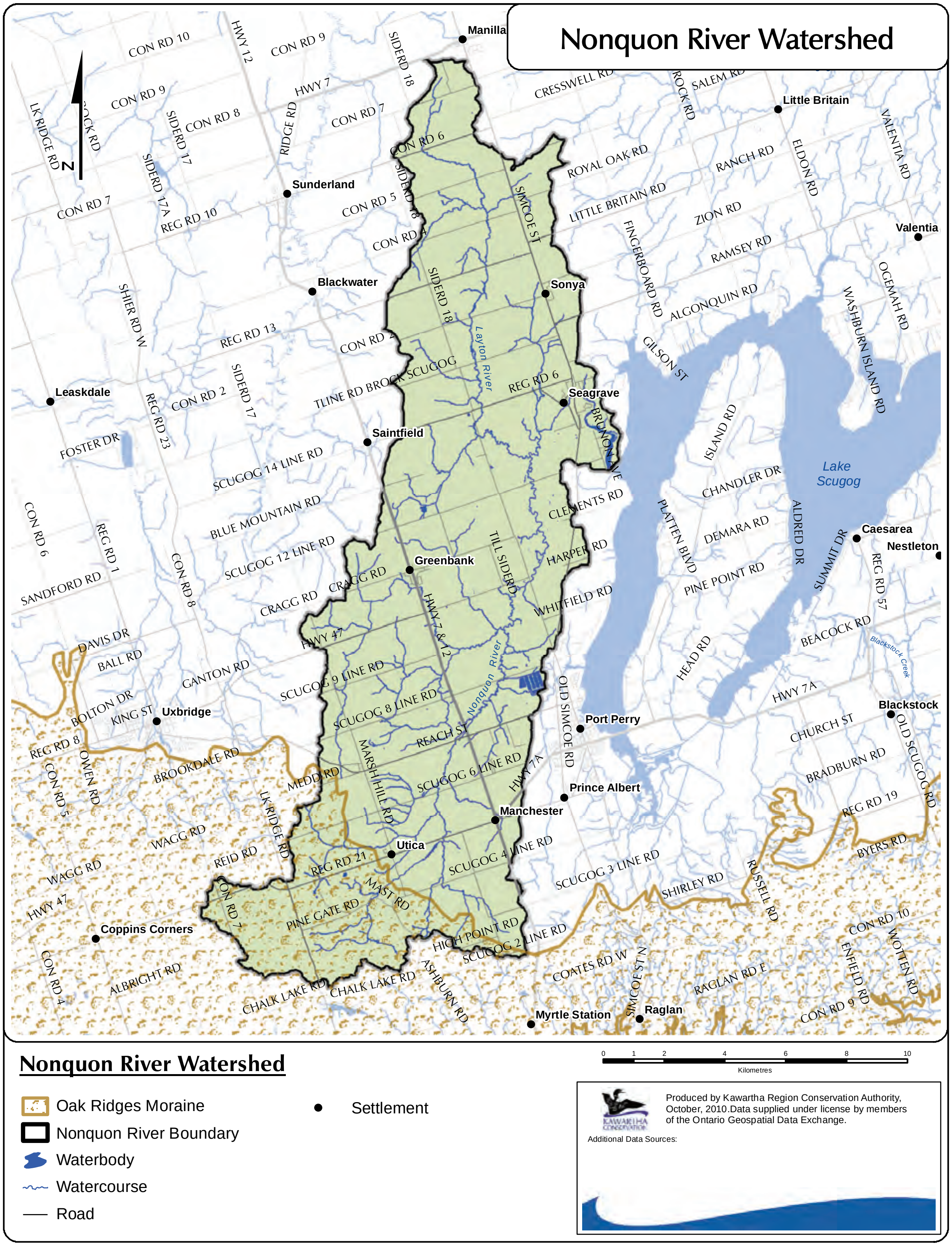


Figure 1.2: Nonquon River watershed planning area.

2.0 Physical Landscape

Nonquon River watershed landscape, on the Oak Ridges Moraine

2.1 Introduction

The physical features of the landscape are key determinants of watershed resources, influencing the fundamental properties of the drainage network and watershed ecosystems. The landform features that currently dominate the landscape are a relic of the most recent period of glacial activity. The movement and melt waters of these large ice masses carved and deposited large amounts of earthen material, ultimately forming the Nonquon River watershed as it exists at present. In this chapter, the physical characteristics of the landscape are summarized in terms of its geologic setting, physiography, soils and topography.

2.2 Geologic Setting

The information presented in this section is summarized from a report by GENIVAR (2011), that was recently completed for Kawartha Conservation to characterize groundwater resources within the Nonquon River watershed, as well as three other watersheds (Southern Lake Scugog Tributaries, Blackstock Creek and East Cross Creek). This section describes the geologic setting in the Nonquon River watershed from the oldest deposits (i.e., bedrock) to youngest deposits (i.e., recent sediments in stream valleys). The study area consists of varying thicknesses of unconsolidated, sediments that have been shaped and altered by glacial and post-glacial activities. The overburden is deposited on top of the shale and limestone bedrock.

Bedrock Geology

Bedrock across the watersheds consists of a thick sequence of Middle to Late Ordovician shale and limestone that unconformably overlies the Precambrian basement at depth. The Precambrian rock found in this area consists of metamorphic rocks of the Grenville Province. This bedrock is typically described as pink to grey, medium-grained granitic gneiss. The Precambrian rock is known from deep borehole and geophysical information and is not known to be exposed in outcrops within this study area.

Overlying this Precambrian rock are the Ordovician sedimentary rocks of the Blue Mountain and Lindsay Formations (**Figure 2.1**). These formations are relatively un-deformed and dip gently to the south or southwest. The Blue Mountain Formation is found in southern portions of the watershed. The Blue Mountain Formation is the youngest of the Ordovician age rock units found in this area. The formation is characterized by rocks that are blue-grey, poorly fossiliferous, noncalcareous shale, with minor limestone. The Lindsay Formation underlies the Blue Mountain Formation and a sharp contact has been observed between the two formations. The Lindsay Formation has been subdivided into two member units. The lower member unit is characterized by argillaceous, fine to coarse-grained limestone with a nodular appearance and is very fossiliferous. The upper member, called the Collingwood Member, consists of high fossil content and thick interbeds of black organic-rich limestone and shale.

Overburden Geology

The unconsolidated sediments that overlay the bedrock have been deposited by glacial, fluvial, and lacustrine processes associated with glacial advance and retreat over the past 135,000 years. Thick, laterally extensive deposits of till often represent the periods of glacial advance. Granular sediments, ranging from silts to coarse sands and gravels, are deposited by glacial melt waters. In the latter stages of glaciations, the deposits are typically observed as thick sequences of fine grained sediments.

The basic geological sequence is illustrated in **Figure 2.2** as derived from studies by the Geologic Survey of Canada and EarthFx (2006). This geological sequence represents up to six periods of glacial advance. The most recent, extensive glacial advance is represented by the Newmarket Till between 25,000 and 15,000 years ago. The majority of the sediments observed at surface were either deposited during or after this glacial advance. In general, earlier deposits are known only from exposure on incised stream valleys and shore bluffs along Lake Ontario. In general, the hydrostratigraphy is better defined for the more recent sediments associated with the last glaciations. The earlier sediments have been collectively referred to as the Lower Sediments.

The Lower Sediments reflect several cycles of glacial advance and retreat and can contain deposits from the York, Don, Scarborough, Sunnybrook, and Thorncliffe Formations. The older York and Don formations are considered to be of limited lateral extent. The Scarborough, Sunnybrook, and Thorncliffe Formations are more widely observed and stratigraphic interpretations have extended into the study area.

The Scarborough Formation is a coarsening upward sequence of sediment deposited by glacial runoff in a delta. Soil textures range from clay/silt rhythmites (fine) to channelized cross-bedded sands (coarse). The Scarborough Formation Sediments tend to be observed in bedrock valleys and are not always continuous.

The Sunnybrook Drift consists of fine grained material deposited in glacial and proglacial lacustrine depositional environments. The Sunnybrook Drift is considered to represent a deep lacustrine environment with deposits including varved silt and clay.

The Thorncliffe Formation is composed of stratified sand, silt, and clay of glaciolacustrine and glaciofluvial origin. These deposits are considered to have been deposited by drainage along the southern margin of an extensive ice sheet in the Hudson Bay Lowlands. The depositional environment of the Thorncliffe Formation is highly variable and is best described as fine grained, with interbedded coarse grained material. Areas of the Thorncliffe Formation that contain coarse grained sediment are productive regional aquifers.

The Newmarket Till is a distinct, dense glacial deposit with a fine grained matrix and up to 15% stones, deposited by the Simcoe lobe of the Wisconsinan glacier. In the field, the Newmarket Till is readily recognized by its relative hardness. The Newmarket Till is considered to be a regionally significant marker horizon and provides protection to the groundwater resources beneath it. Since the interpretation presented in 2006 (Earthfx 2006), the CAMC has conducted further work and have subsequently subdivided the Newmarket Till into three units: The Lower Newmarket Till; Inter-Newmarket Sediments; and the Upper Newmarket Till. The Lower Newmarket Till is considered to be regionally extensive. The Inter-Newmarket Sediments are typically fine to medium grained sediments deposited by meltwaters between two stages of active glaciation. At this time the CAMC has not provided more detailed descriptions of the subunits of the Newmarket Till.

The top of the Newmarket Till is recognized as a regional erosional unconformity. This unconformity provided an opportunity for removal of parts of the Newmarket Till, either in conjunction with later glacial processes (tunnel channels) or by subaerial exposure. The upper surface of the Newmarket Till exhibits large-scale erosion by channels that have subsequently been infilled by a fining upward sediment sequence. The erosion of these channels is considered to have developed beneath the glacial ice and hence are referred to as tunnel channels. An initial surge of glacial meltwater beneath the ice is considered to have cut these channels. As flow waned in these channels, they were partly infilled with water-borne sediments, which typically fine upwards from a cobble or boulder lag. The tunnel channels deeply dissected the Newmarket Till plain, leaving the discrete till upland areas mentioned above. Tunnel channel erosion and sedimentation was followed by or was formed at a similar time to the deposition of the east-west trending Oak Ridges

Moraine, which is an important regional physiographic and hydrogeologic feature. Many tunnel channels created low-lying areas and several rivers in southern Ontario, including the Nonquon River and East Cross Creek, currently flow through these former tunnel channels, which have been filled in with recent organic deposits.

The Oak Ridges Moraine Sediments are a complex package of dominantly coarse grained proximal glaciofluvial and terminal outwash material. These deposits generally become finer, and typically become thinner and eventually pinch out away from the original outlets of meltwater. The Oak Ridges Moraine sediments were deposited by meltwater flowing between two glacial lobes, with ice blocking the Lake Ontario basin and another ice sheet in the Simcoe basin.

The Halton Till is a dense glacial deposit with a fine-grained matrix and fewer stones compared to the Newmarket Till. The Halton Till was deposited in the late stages of the last glaciation by a minor advance of the Lake Ontario lobe after the sedimentation cycle that deposited the Oak Ridges Moraine Sediments. The Halton Till unit overlaps and caps portions of the Oak Ridges Moraine. The Halton Till typically is not observed north of the Oak Ridges Moraine.

As the glaciers retreated, large lakes formed in regional basins. Thick sequences of lacustrine sediment were deposited in these lakes above the glacial units. These lacustrine deposits are observed extensively in the Lake Scugog basin. After these meltwaters retreated, erosion has been the dominant force with some sedimentation associated with river channels, and accumulations of organic material in poorly drained areas as deposits of peat and muck.

Further information that outlines water movement through these geologic materials (i.e., hydrostratigraphy), is summarized in Section 6.5: Groundwater Characterization.

2.3 Physiography

The physiography within the Nonquon River watershed has been characterized by Chapman and Putnam (1984). Regions of similar physiography are shown in **Figure 2.3** and distinct physiographic features that exist on the landscape are shown in **Figure 2.4**.

The Oak Ridges Moraine physiographic region is located in the south of the Nonquon River watershed, occupying approximately 25.2 km^2 of the total watershed area. It is part of a continuous range of rolling hills extending from the Niagara Escarpment to Trenton. The Oak Ridges Moraine consists mainly of permeable sands and gravels with some impermeable deposits of till, silt and clay. These sediments are of optimal configuration to retain and store precipitation, which is slowly released as cold, flowing surface waters into the southern parts of the Nonquon River watershed. Within this physiographic region, there tends to be a lack of streams because the permeable sand and gravel that makes up the Moraine, allows water to drain vertically into the moraine, rather than along the surface. Water infiltrating the moraine is forced to move horizontally when it reaches less permeable geologic layers. Springs and headwaters for many of the watersheds flowing off the moraine can be found.

The Peterborough Drumlin Field physiographic region occupies the majority (132.6km^2) of the Nonquon River watershed and extends north from the Oak Ridges Moraine. It is part of a rolling till plain extending from Hastings County in the east to Simcoe County in the west. Drumlins typical to this area are elongated, low-lying hills composed of highly calcareous glacial till consisting of sands and gravels. This physiographic region is notable for its drumlins, but also for it eskers. An esker exists in the northern portion of the watershed, as part of the large Cannington Esker, in the upper reaches of the Layton River.

The Schomberg Clay Plain physiographic region occupies 33.2km^2 of the Nonquon River watershed and extends along its eastern flanks. These materials consist of stratified clay and silt deposits that overlays a drumlinized till plain. Some large drumlins have escaped complete burial by these sediments and hence, many still exist within this region. The majority of the deposits throughout this physiographic region measure an average depth of 5m in thickness; in some locations the thickness of the sediment layers reaches a depth of up to 8m.

2.4 Soils

The uppermost sediment layer within the Nonquon River watershed is described by soil type. Soils are classified based on their structure, texture, permeability, material composition, and topography. A number of physical factors including: local topography, vegetation, parent material, climate, chemical weathering and bedrock materials affect soil formation. This complex interplay of factors over time has created soil structures as we know them today.

The naming and distribution of soils within the Nonquon River watershed is complex. For the purposes of this report, soils can be classified into four hydrologic soil groups based on their infiltration and runoff potential: A, B, C, and D (USDA 1986) as described in **Table 1.1**. Hydrological soil groups within the study area are shown in **Figure 2.5**.

Soils with a high infiltration rate (Group A) are most common in the southern portion of the Nonquon River watershed, especially on the Oak Ridges Moraine. Soils with moderate infiltration rates (Group B) occur throughout the majority of the Nonquon River watershed whereas only small pockets of soils with low infiltration rates (Group C) are evident. Soils with very low infiltration rates (Group D) exist along the valleys and low-lying areas in the central portion of the watershed.

Table 1.1: Hydrologic soil groups.

Soil Group	Infiltration Rate	Description	Water Transmissivity	Soil Types
A	High infiltration rates and low runoff potential even when thoroughly wet	Chiefly deep, well to excessively drained sands or gravels	High rate of water transmission (>0.75cm/hr)	Sand, loamy sand, sandy loam
B	Moderate infiltration rates when thoroughly wetted	Chiefly moderately deep to moderately well drained soils with moderately fine to moderately coarse textures	Moderate rate of water transmission (0.40-0.75cm/hr)	Silt loam, loam
C	Low infiltration rates when thoroughly wetted	Chiefly soils with a layer that impedes downward movement of water, or soils with moderately fine to fine textures	Low rate of water transmission (0.15-0.40cm/hr)	Sandy clay loam
D	Very low infiltration rates and high runoff	Chiefly clay soils with a high swelling potential, soils with a permanent high	Very low rate of water transmission	Clay loam, silty clay loam, sandy

Soil Group	Infiltration Rate	Description	Water Transmissivity	Soil Types
	potential when thoroughly wetted	water table, soils with a clay pan or clay layer at or near the surface or shallow soils over nearly impervious material	(0-0.15cm/hr)	clay, silty clay, clay

From USDA (1986)

2.5 Topography

The ground-surface elevations within the watershed generally slope from south-to-north and west-to-east. The highest elevations in the Nonquon River watershed occur in the southern section of the watershed as a result of the Oak Ridges Moraine feature that creates a regional surface water divide. Based on a 10m^2 digital elevation grid, elevations range from approximately 400 metres above sea level in the south-western portion of the watershed and declines to a minimum elevation of approximately 245 metres above sea level at the watershed outlet into Lake Scugog (**Figure 2.6**). The average slope of the terrain is approximately 4.5%

Areas of topographic lows are located in the central portion of the watershed, associated with the valley of the main channel of the river, and at the watershed outlet near Lake Scugog. Slopes are significantly higher along the southern, northern and western flanks of the watershed than in the low-lying central and eastern portions.

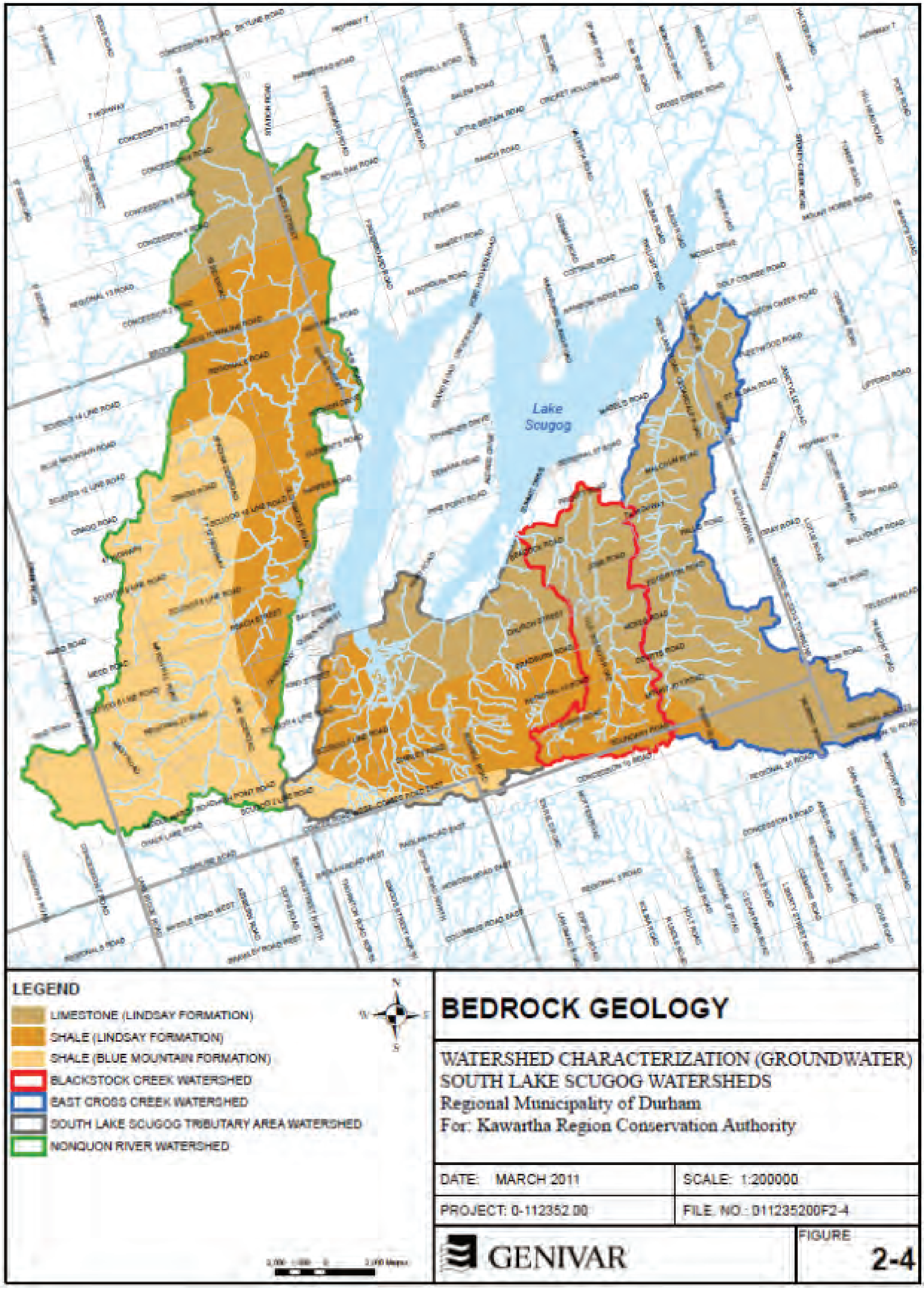
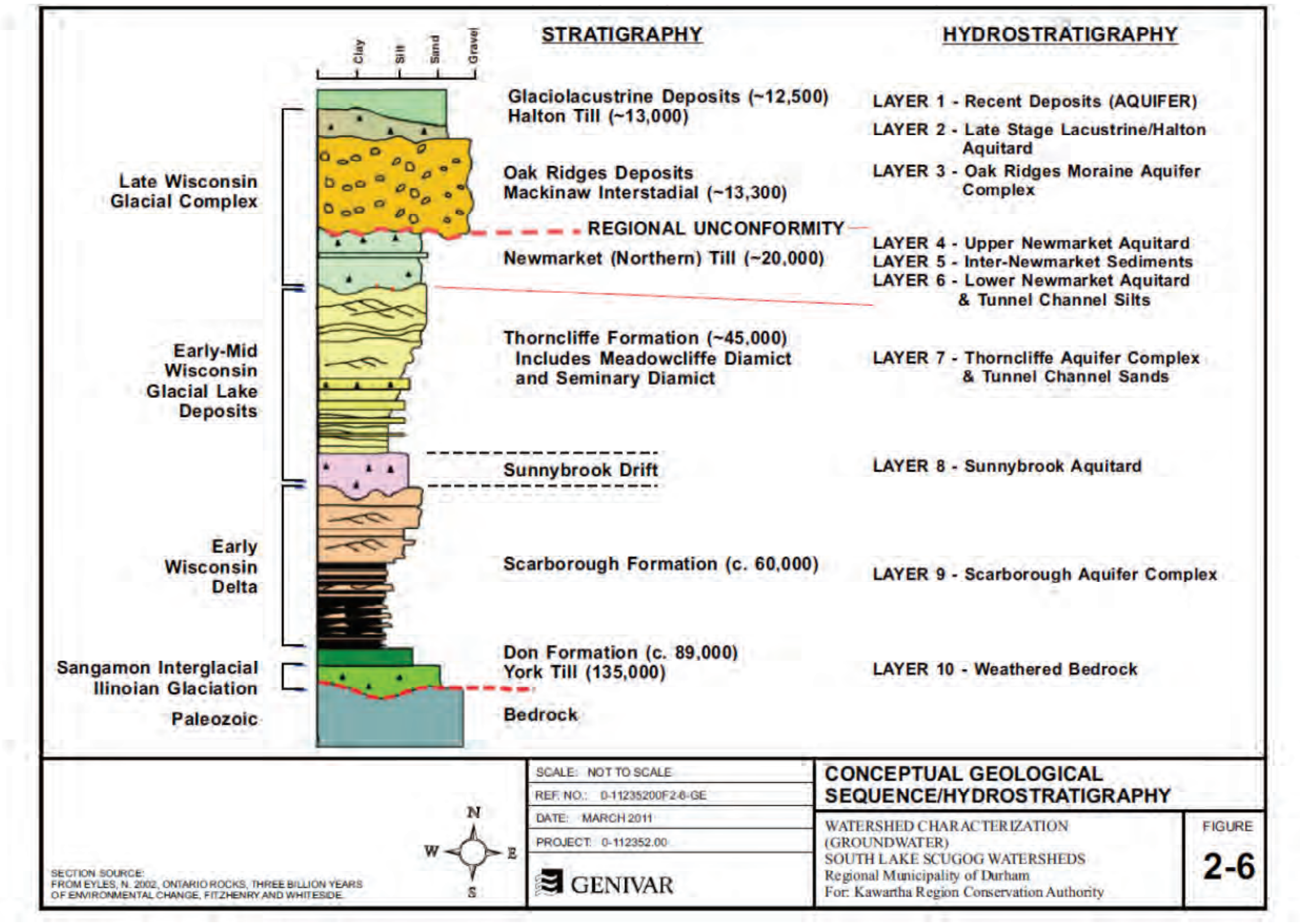


Figure 2.1: Bedrock geology.



From GENIVAR (2011)

Figure 2.2: Geological profile of Pleistocene sediments.

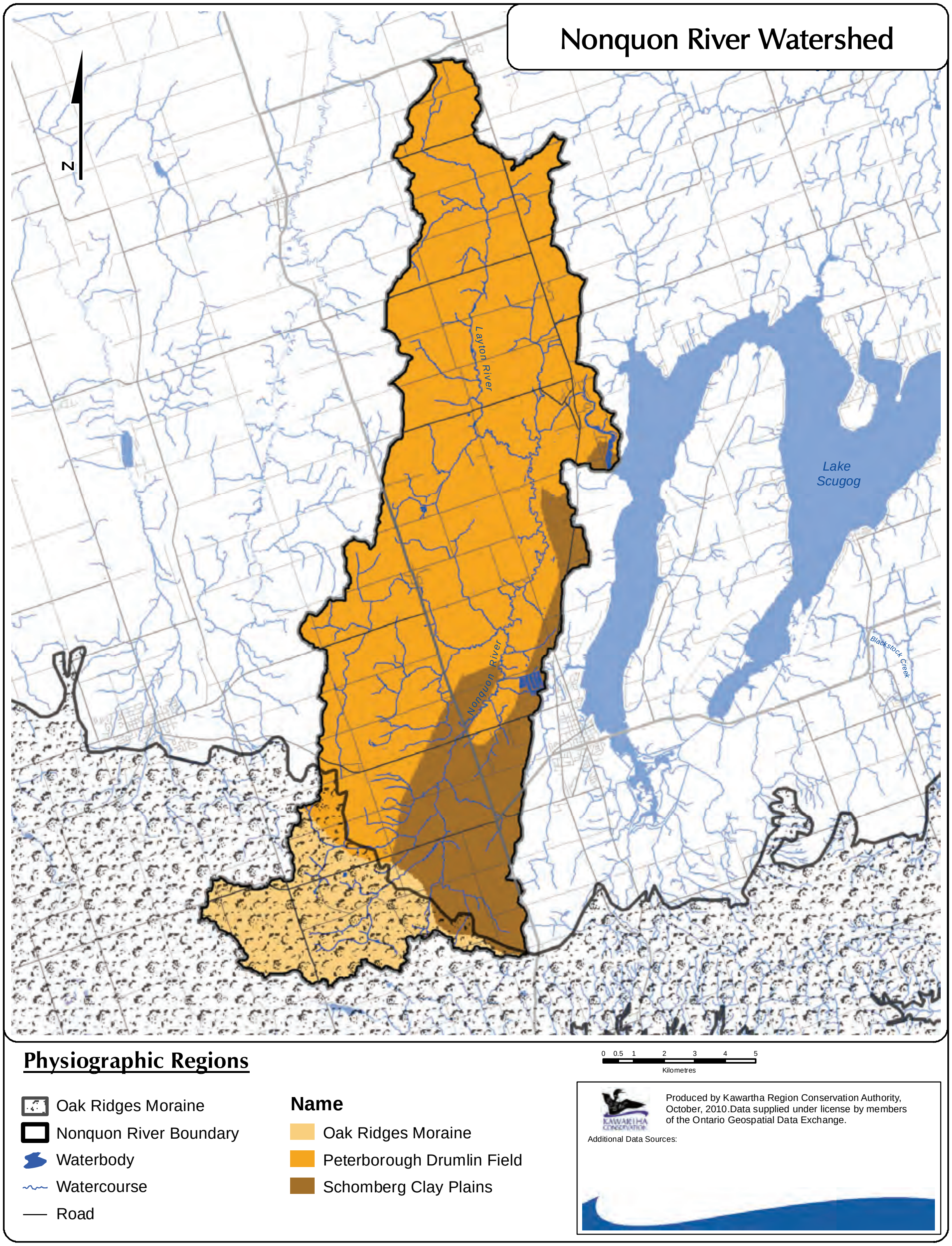


Figure 2.3: Physiographic regions.

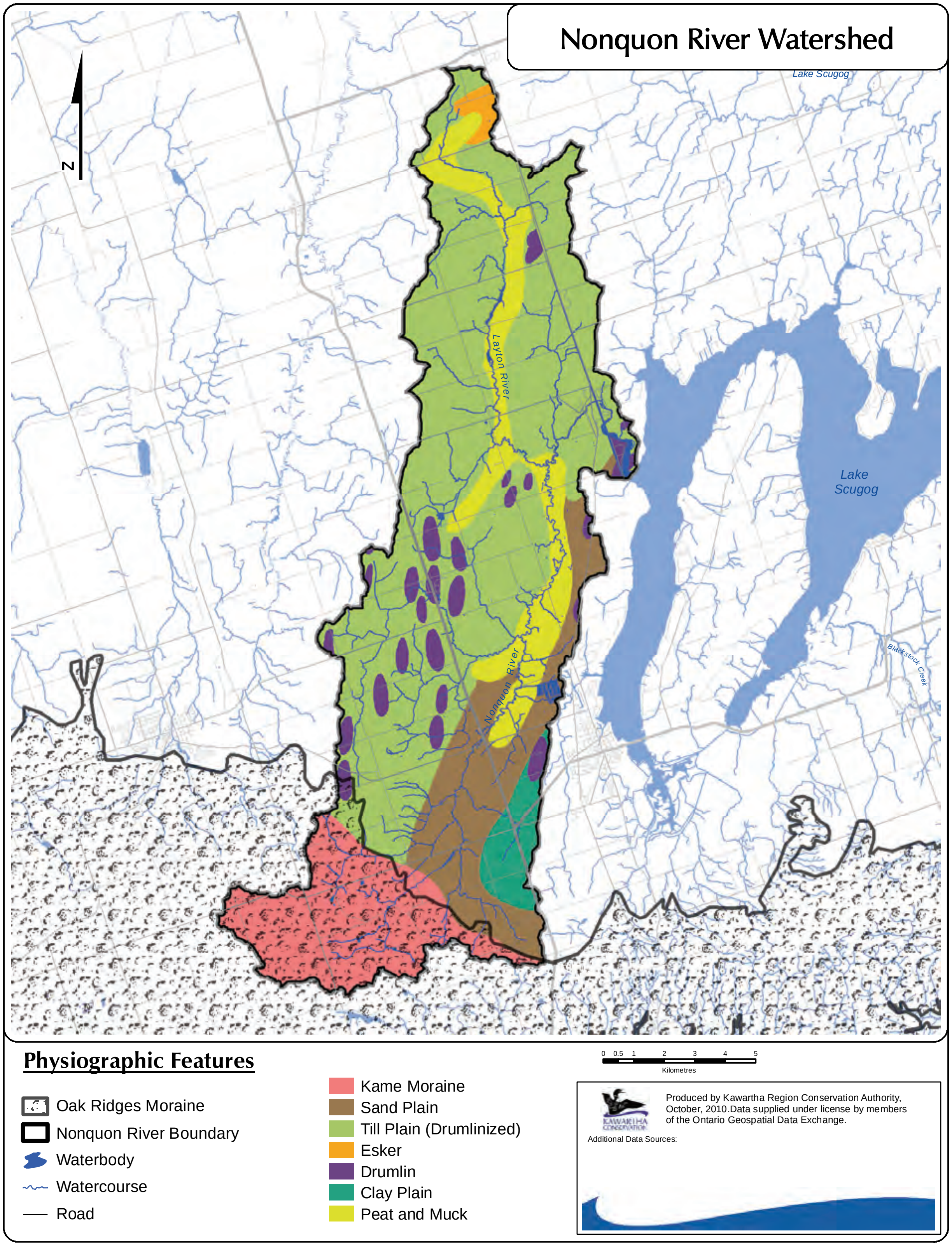


Figure 2.4: Physiographic features.

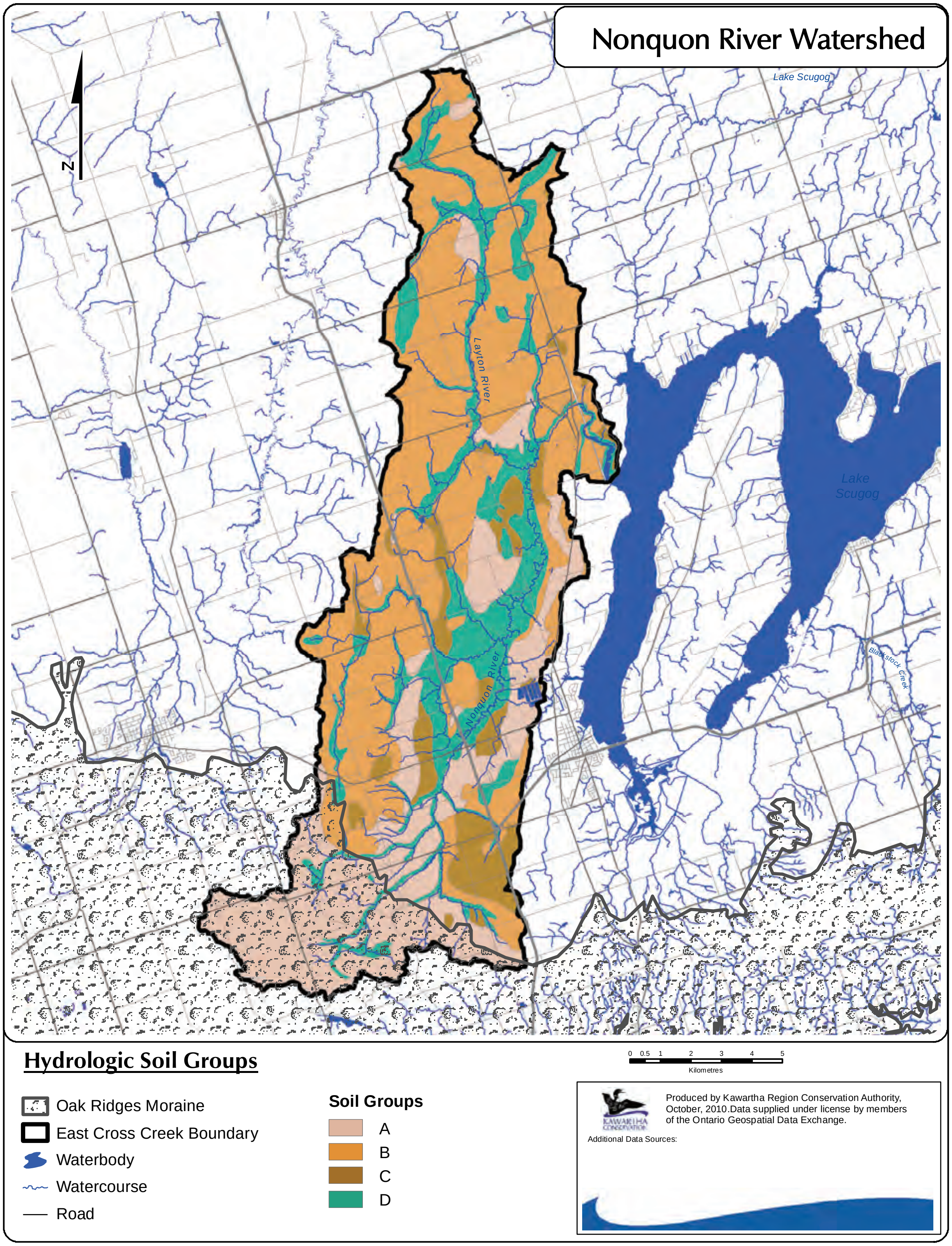


Figure 2.5: Hydrologic soils groups.

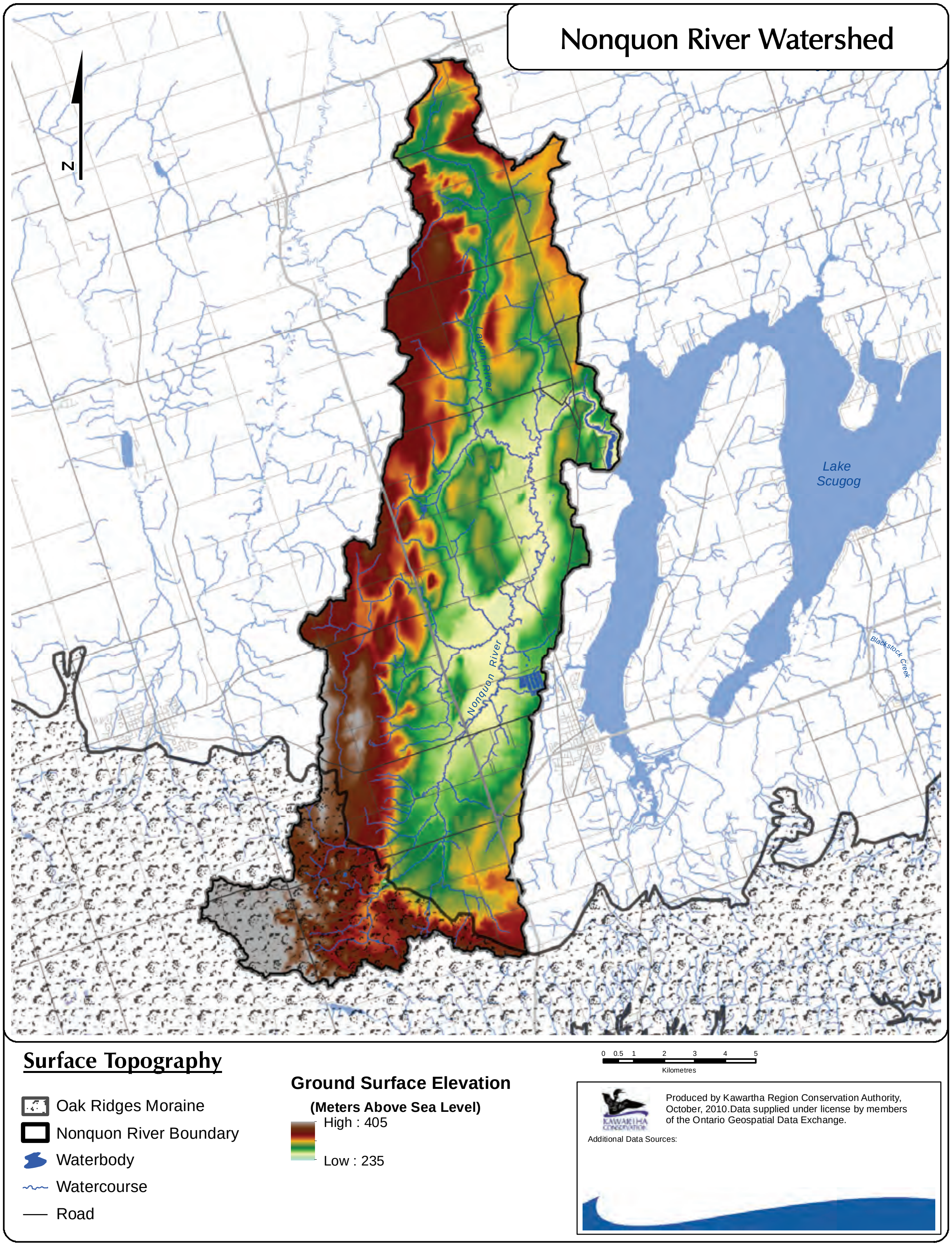


Figure 2.6: Surface topography.

3.0 Regional Climate

Layton River, east of Old Simcoe Road

3.1 Introduction

Regional climate can be defined as the expected weather conditions within a region determined from averaging site-specific weather data. Characterizing climatic conditions is key to developing water budgets and understanding the linkages between the hydrological and ecological conditions of the watershed.

The Nonquon River watershed is located within a humid-continental climate zone. This zone represents the majority of east-central Ontario, which is characterized by large seasonal temperature differences with hot, often humid summers, and cold winters. The Great Lakes have a significant influence on the climate within southern Ontario; however, the presence of the Oak Ridges Moraine tends to limit their moderating effect within the region. As a result, spring usually begins later (on average about one week later) and fall usually begins earlier (about one week earlier) within the study area than along the shore of Lake Ontario (Adams and Taylor 2009).

To characterize local climatic conditions within the Nonquon River watershed, weather data were summarized from available monitoring stations in-and-around the study area. Data from five of these stations are particularly important for characterizing local climate conditions (**Figure 3.1**). The Janetville, Lindsay Frost, and Burketon McLaughlin climate stations have provided enough long-term weather data between 1971 and 2000 to establish "normal" conditions according to Environment Canada standards. These stations are no longer actively recording data. The remaining two stations, Blackstock and Sonya Sundance Meadows, have a limited period of record but are significant as they are the only active climate stations (recording since 2001). **Table 3.1** describes the period of record and data availability at these stations.

Table 3.1: Climate station information.

Station Name	Station ID	Status	Beginning	End	Elevation (masl)	Station Owner
Burketon McLaughlin	6151042	Inactive	1969	2002	312	Environment Canada
Janetville	6153853	Inactive	1981	2005	297	Environment Canada
Lindsay Frost	6164433	Inactive	1974	2006	262	Environment Canada
Blackstock	6150790	Active	2001	-	291	Environment Canada
Sonya Sundance Meadows	6168100	Active	2001	-	275	Environment Canada

3.2 Air Temperature and Precipitation

Air temperature and precipitation normals (i.e., calculated between 1971 and 2000) for each long-term monitoring station are shown in **Table 3.2** with monthly summaries provided in **Figure 3.2**, **Figure 3.3**, and **Figure 3.4**.

Among the three climate stations, average daily air temperatures range from 6.3 to 6.6ºC. January is the coldest month, with average daily temperatures ranging from -7.7 to -8.9ºC. Average monthly temperatures rise above freezing in April and reach a peak of about 20ºC in July, the warmest month. Temperatures tend to fall below freezing again in December. In general, there is little variability in average air temperatures between monitoring stations; the difference in average values never exceeds 1.2ºC.

In contrast to air temperatures, precipitation is quite variable between monitoring stations. Average annual precipitation ranges from 881.6mm at Lindsay Frost station to 926.2mm at Janetville station, the majority of which falls as rain. September is generally the wettest month of the year whereas February is the driest.

Table 3.2: Air temperature and precipitation normals.

	Burketon McLaughlin	Janetville	Lindsay Frost
Air Temperature - daily average (ºC)	6.4	6.6	6.3
Air Temperature - daily maximum (ºC)	10.8	11.9	11.3
Air Temperature - daily minimum (ºC)	2.0	1.2	1.3
Precipitation - yearly total (mm)	909	926.2	881.6
Precipitation - yearly rainfall (mm)	774.1	745.7	718.8
Precipitation - yearly snowfall (mm)	135.0	181.1	162.8

3.3 Evapotranspiration

Evapotranspiration is the combination of two separate processes, evaporation and transpiration, that results in liquid water being lost to the atmosphere. Evaporation is the process by which liquid water in streams and lakes turns into vapour whereas transpiration is the process by which liquid water is absorbed by plant materials and released into the atmosphere. These two processes occur simultaneously and as such, there is no easy way of distinguishing between the two processes.

Evapotranspiration is a key component of the water budget, and is particularly influenced by solar radiation, air temperatures and length of the growing season. More detailed information on evapotranspiration can be found in Section 6.6: Water Budget.

3.4 Climate Change

Climate change refers to a change in the state of the climate that can be identified by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer (IPCC 2007). Climate change has been observed at a global (IPCC 2007), national (Government of Canada 2006), and provincial-scale (Colombo et al. 2007). Global warming (the increase in average air and ocean temperatures), is regarded as a significant driver of climate change. It is generally accepted that global warming is fueled by increases in greenhouse gas emissions at a global scale. Since climatic processes are key drivers of hydrological and ecological properties of watersheds, it is important to understand the implications of a changing climate in terms of watershed management.

The Expert Panel on Climate Change Adaptation (2009) has summarized recent modelling projections for Ontario in 2050. Some of the key predictions include:

- middle-of-the-road reductions in greenhouse gas emissions show an increase in the annual average air temperature of 2.5ºC to 3.7ºC compared to 1961-1990 average values;

- the range of the projections, from minimum change to maximum change, is from 2.3ºC to 3.0ºC in the south of the province, to 3.2ºC to 4.0ºC in the Far North;
- total precipitation shows little change in the south of the province but an increase of about 5-15% in the Far North;
- southern Ontario, like the Far North, is also projected to see the greatest seasonal increase in precipitation in winter, much of it likely to fall as rain;
- the combination of increased evaporation with little change in precipitation raises the likelihood of more intense dry periods with low run-off water and low soil moisture; and, more frequent and possibly more intense extreme events (e.g., droughts, severe rainstorms, etc.).

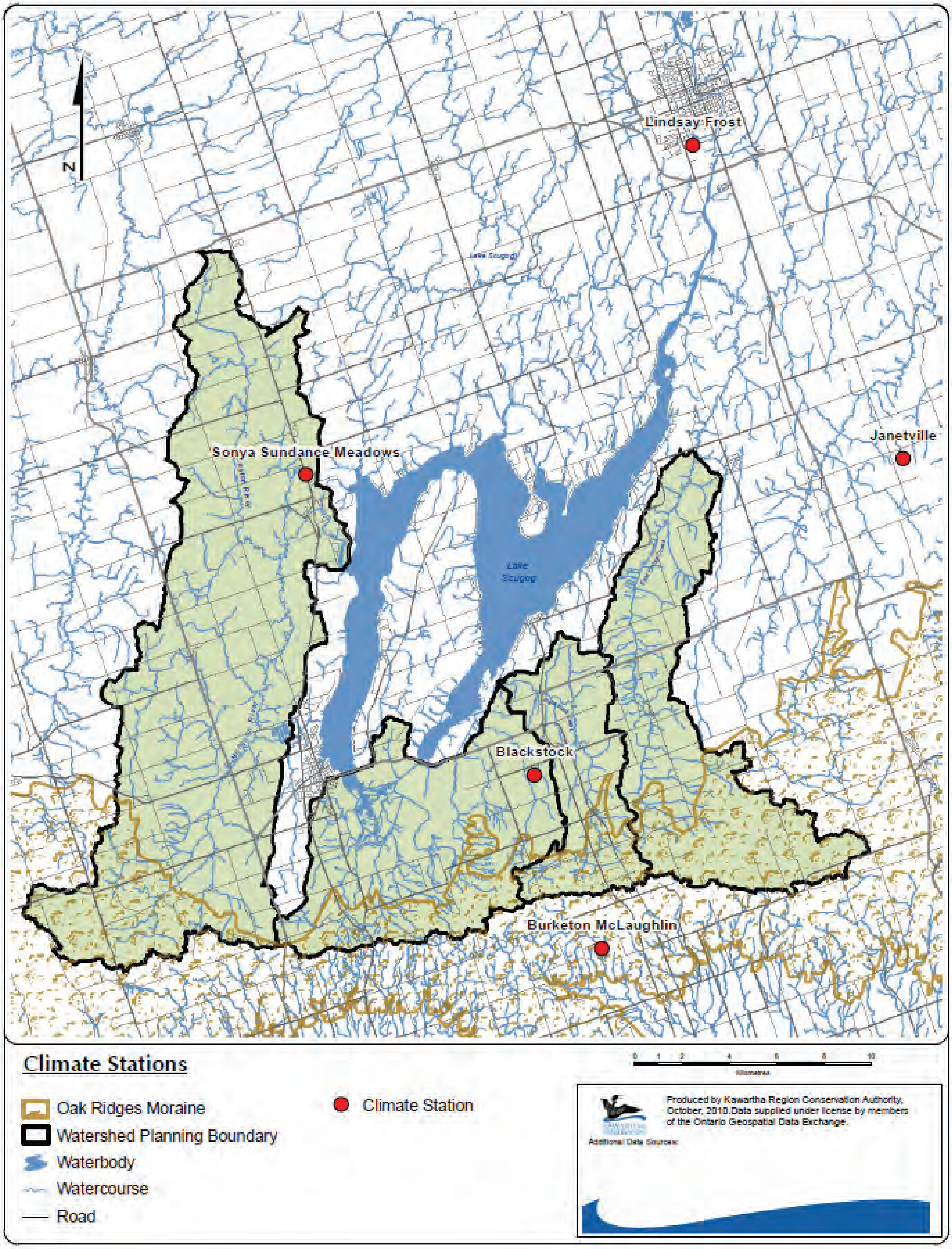
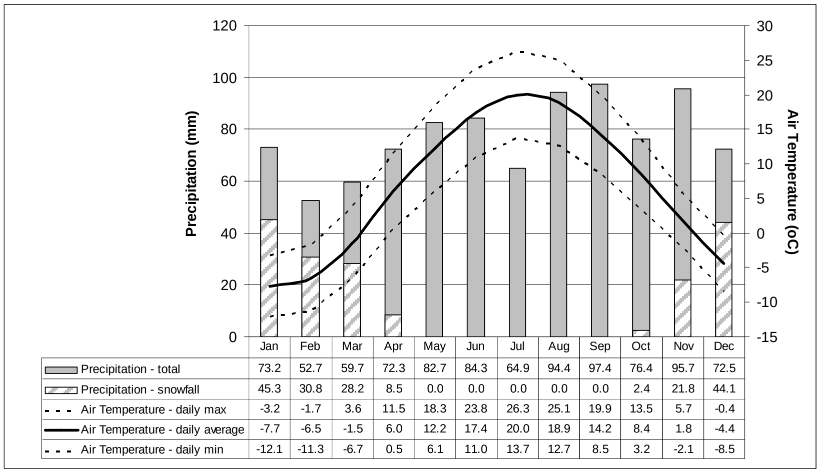
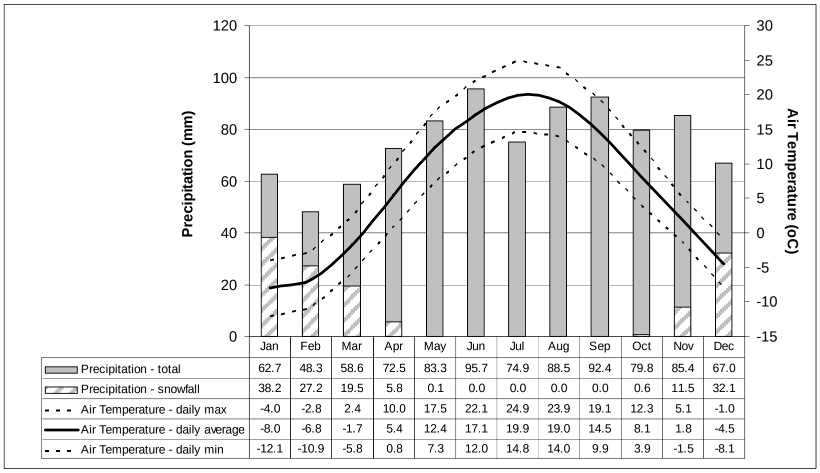


Figure 3.1: Climate stations.



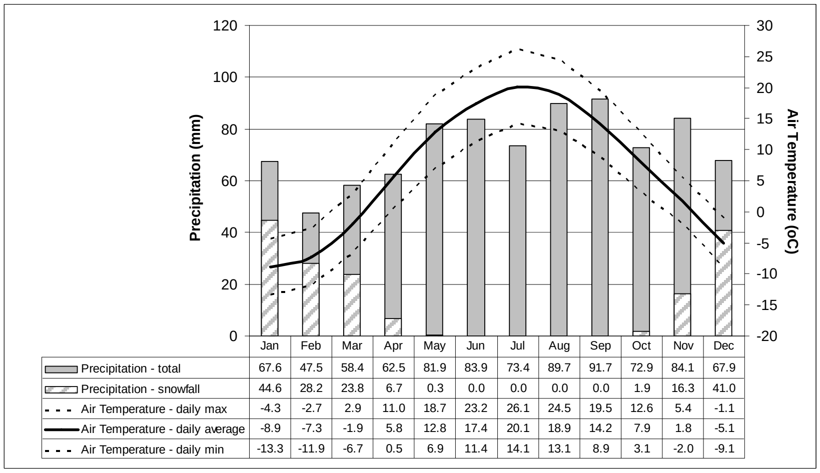
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
▭ Precipitation - total	73.2	52.7	59.7	72.3	82.7	84.3	64.9	94.4	97.4	76.4	95.7	72.5
▨ Precipitation - snowfall	45.3	30.8	28.2	8.5	0.0	0.0	0.0	0.0	0.0	2.4	21.8	44.1
- - - Air Temperature - daily max	-3.2	-1.7	3.6	11.5	18.3	23.8	26.3	25.1	19.9	13.5	5.7	-0.4
—— Air Temperature - daily average	-7.7	-6.5	-1.5	6.0	12.2	17.4	20.0	18.9	14.2	8.4	1.8	-4.4
- - - Air Temperature - daily min	-12.1	-11.3	-6.7	0.5	6.1	11.0	13.7	12.7	8.5	3.2	-2.1	-8.5

Figure 3.2: Janetville climate station normals.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
▭ Precipitation - total	62.7	48.3	58.6	72.5	83.3	95.7	74.9	88.5	92.4	79.8	85.4	67.0
▨ Precipitation - snowfall	38.2	27.2	19.5	5.8	0.1	0.0	0.0	0.0	0.0	0.6	11.5	32.1
- - - Air Temperature - daily max	-4.0	-2.8	2.4	10.0	17.5	22.1	24.9	23.9	19.1	12.3	5.1	-1.0
—— Air Temperature - daily average	-8.0	-6.8	-1.7	5.4	12.4	17.1	19.9	19.0	14.5	8.1	1.8	-4.5
- - - Air Temperature - daily min	-12.1	-10.9	-5.8	0.8	7.3	12.0	14.8	14.0	9.9	3.9	-1.5	-8.1

Figure 3.3: Burketon McLaughlin climate stations normals.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
▭ Precipitation - total	67.6	47.5	58.4	62.5	81.9	83.9	73.4	89.7	91.7	72.9	84.1	67.9
▨ Precipitation - snowfall	44.6	28.2	23.8	6.7	0.3	0.0	0.0	0.0	0.0	1.9	16.3	41.0
- - - Air Temperature - daily max	-4.3	-2.7	2.9	11.0	18.7	23.2	26.1	24.5	19.5	12.6	5.4	-1.1
—— Air Temperature - daily average	-8.9	-7.3	-1.9	5.8	12.8	17.4	20.1	18.9	14.2	7.9	1.8	-5.1
- - - Air Temperature - daily min	-13.3	-11.9	-6.7	0.5	6.9	11.4	14.1	13.1	8.9	3.1	-2.0	-9.1

Figure 3.4: Lindsay Frost climate station normals.

4.0 Land Use

Nonquon River, west of Marsh Hill Road

4.1 Introduction

The major connecting link in a watershed ecosystem is the flow of water. As water travels through the watershed it flows above and below land in the form of surface water and groundwater. Therefore, the way humans influence the landscape often directly relates to changes in the hydrological and ecological integrity of the watershed. This chapter outlines past land use activities, current land uses and key elements of the planning framework that is currently is place.

4.2 Human Settlement and Growth

Following the last period of glacial activity, the landscape in-and-around the Nonquon River watershed remained as large tracts of natural unbroken forest and wetlands. The landscape changed dramatically with the onslaught of European settlement in the early 19th century, which revolved around two main activities: agriculture and forestry. By the early 20th century the settled landscape in-and-around the Nonquon River watershed began to resemble what we see today; agricultural lands surrounding small communities that support a variety of industry.

Settlement History

The European history of the area surrounding Lake Scugog dates back to 1809, when Major Wilmot surveyed Reach Township to the west of the lake. Wilmot was also responsible for surveying Cartwright Township, to the east of Lake Scugog. Prior to this time, Mississauga First Nations, who made use of the wild rice growing in Lake Scugog, inhabited the area around the lake.

The formation of hamlets was often a function of proximity to water and the milling power it provided. Gristmills and sawmills played an important role in the development of communities throughout the Lake Scugog watershed. Sawmills were the first industrial enterprises in the area. In Reach Township the first sawmills were constructed in 1831 and in Cartwright Township in 1851.

The most consequential mill construction was the Lindsay gristmill. Constructed in approximately 1837 by William Purdy, the dam significantly changed the landscape around Lake Scugog. Prior to the mill's construction, Lake Scugog was described as merely a “mass of marsh and grass” (Weir 1927). The dam caused a four-foot rise in water levels and made Lake Scugog a navigable waterway. This rise in water levels benefited the more isolated townships of Cartwright and Mariposa, making transportation to the “front” (Oshawa and Whitby) much easier.

In the mid-1800s, the towns of Manchester, Port Perry and Prince Albert, all within a 5km distance of each other, were competing to become major trade centres in Reach Township. The Town of Manchester was positioned further away from Simcoe Street (present-day Old Simcoe), the main corridor to Whitby, and did not thrive to the same extent as Port Perry or Prince Albert. Still, the mid-1800s was a time of extensive population growth. The 11 years between 1840 and 1851 saw the population of Reach Township grow by over 400%, from 771 to 3,897 residents (Johnson 1973). **Table 4.1** lists the various hamlets that were formed during these periods. **Figure 4.1** shows a historical map of the former Ontario County.

Following European settlement, large areas on the Oak Ridges Moraine were discovered to be unsuitable for long-term farming due to topography or poor soil types. With faster snowmelt, downstream flooding, erosion and dust storms, thousands of acres of cleared land were subsequently abandoned. Large areas of wasteland on the Oak Ridges Moraine became common with deep, eroded gullies and sand dunes. Once-productive forest soils were depleted of nutrient rich soils that had blown or washed away.

Forests were once abundant throughout the Lake Scugog watershed, blanketing most of the area. However, other than scattered remnants of the original forest, contemporary woodlands are the result of human settlement activities since the first quarter of the 1800s. The original forest was viewed mostly as an impediment to settlement and travel, something to be conquered or exploited for any kind of value, rather than managed. In fact, the volume of product was so enormous that there was no market for much of it during the intensive period of land clearing. The dominant land use throughout the Lake Scugog watershed has since become agriculture, with only small areas of forest remaining.

Table 4.1: Areas of settlement and approximate year formed.

Hamlet/Community	Approximate Year Formed
Seagrave	1831
Epsom	1832
Greenbank	1833
Utica	1834
Manchester	1850
Port Perry	1851
Sonya	1858

Current Demographics

The Nonquon River watershed is not densely populated. Most residents live either in small hamlets or scattered across the rural portions of the watershed. The Durham Regional Official Plan Amendment No. 128 (2009) estimates a population growth for the Township of Scugog of approximately 3,950 persons between 2006 and 2031, comprising a total population of 25,390 in 2031.

Currently the Township of Scugog has a total population of 21,439 persons (Statistics Canada 2007), with 45% living in the urban area of Port Perry (Township of Scugog 2009). The Township of Scugog Official Plan estimates that in the future, population growth will occur mainly in urban areas (60% of the total population increase), while the surrounding rural and shoreline areas will accommodate 40% of the total increase. Currently, further development in Port Perry is limited by the treatment capacity of the Nonquon River Water Pollution Control Plant (Port Perry lagoons). The City of Kawartha Lakes has an even less dense population than the Township of Scugog. With only 24 persons per square kilometre, it is considered a more rural municipality.

In the foreseeable future, land use within the Nonquon River watershed will stay rural and agriculture-based. As the Township of Scugog and City of Kawartha Lakes continues to promote tourism in the area, it is evident that recreational activities will also play a significant role in the economy of this part of the Lake Scugog watershed.

4.3 Current Land Cover

Current land cover with the Nonquon River watershed was interpreted using 2008 aerial photography of the landscape. Natural vegetative cover (e.g., forests, wetlands, etc.) were classified according to Ecological Land Classification methodology (Lee et al. 1998). The remaining land cover were classified into Urban and Rural Development, Manicured Open Space, Intensive Agriculture, and Non-intensive Agriculture following methods developed by Credit Valley Conservation (1998). **Figure 4.2** depicts the total amount and relative percentages of these land cover types. **Figure 4.3** shows the distribution of these land cover types across the watershed.

Natural Cover

Natural Cover exists within 79.3km^2 or 41.8% of the watershed. These areas mainly consist of natural forests, wetlands and cultural plantations that are concentrated within the central, low-lying areas of the watershed. The Nonquon Provincial Wildlife Area, a large tract of Crown land that is managed by the Ontario Ministry of Natural Resources, is a significant area of natural cover within the watershed. Areas of extensive natural cover also exist in the southwestern portion of the watershed on the Oak Ridges Moraine, including a small area that is within the Durham Regional Forest, and along the main channel of the Layton River. These natural areas on the landscape are considered natural heritage features, and are extremely important for contributing to the hydrological integrity (e.g., permitting groundwater recharge, reducing peak flows, etc.) and ecological integrity (e.g., providing fish and wildlife habitat, stabilizing stream banks, etc.) of the watershed. Please refer to section 9.0 Terrestrial Natural Heritage for more detailed information on the locations and significance of specific natural cover types.

Urban Development

Areas considered urban development exist within 2.3km^2 or 1.2.% of the watershed and include the hamlets of Seagrave, Greenbank, Sonya, Epsom, Utica, and Manchester. These are small urban communities that consist of dense residential lots, some of which (e.g., in Seagrave) are located on the main channel of the Nonquon River. Wastewater within these urban areas are treated through private septic systems.

Rural Development

Areas considered rural development account for 8.8km^2 or 4.6% of the watershed and generally include single or small groups of rural lots (i.e., rural-residential) or other small-scale developments that dot the landscape. These areas also include the Nonquon Industrial Tributary Area (a small industrial complex just off Reach Street), King's Bay (cluster of large residential lots near watershed outlet) and the hamlet of Manchester.

Agriculture - Intensive

Intensive agriculture refers to lands that are annually cultivated and planted with row crops. These areas account for 90.1km^2 or 47.3% of the land area, which is the dominant land cover type within the watershed. Major crop production within the area includes alfalfa and alfalfa mixtures, corn, soybeans, and wheat (Statistics Canada 2007).

Agriculture - Nonintensive

Nonintensive agriculture refers to lands that are currently in use for pasture. These areas account for 8.2km^2 or 4.3% of the total land cover. Livestock production is dominated by cattle in these areas, but there are numerous equine operations as well.

Manicured Open Space

Areas of manicured open space account for 1.0km^2 or 0.5% of the watershed. They consist of "regularly-maintained" open grassy areas that are primarily used for recreational purposes. Golf courses account for the majority of manicured open space, three of which are located within the watershed. These include: Crestwood Golf Club (on Little Britain Road), Oak Ridges Golf Club (extreme south-west of watershed), and King's Bay Golf and County Club (at the outlet of the watershed). The grassy runways at the Greenbank Airport are also part of this land cover type.

Aggregate

This land cover type includes areas defined by recent aggregate extraction activity or where aggregate extraction no longer occurs, but lands continue to be defined by historic aggregate extraction activity. These are heavily disturbed, open quarry areas that account for 0.6km^2 or 0.3% of the total land cover. Small operations exist in the extreme south-west portion of the watershed within the Oak Ridges Moraine. These areas closely resemble their corresponding "licensed extraction areas", therefore, it is expected that expansion of current aggregate land cover will be minimal.

4.4 Transportation Network

Within the Nonquon River watershed there are 208km of roads, with a density of 1.1km/km^2. These include two provincial roads (Highway 7A and Highway 7/12), several regional and county roads (2, 6, 8, 13, 21), and numerous minor roads. Generally, roads intersect the watershed in a north-south, east-west grid pattern. The provincial and regional roads are all asphalt whereas the minor roads are gravel-sand surfaces. Bridges exist where the road network intersects the Nonquon River main channel.

In the past, a rail network existed within the watershed, however, it has long-been abandoned. In the northern portion of the Layton River subwatershed, a recreational trail now exists along the old rail bed.

The watershed also contains the Greenbank Airport, a small airport with two grassy runways, located near the hamlet of Greenbank.

4.5 Impervious Surfaces

Impervious surfaces refers to hardened areas (e.g., driveways, parking lots, rooftops, etc.) that increase rates of surface water runoff and reduce groundwater infiltration. In developed areas, runoff often carries with it contaminants from roads, lawns and driveways, directly into the tributaries of river systems. Research suggests that significant impacts to fish and benthic macroinvertebrate communities, water temperature, width, depth and stability of banks occur when cumulative impervious surfaces within a watershed exceeds 10 percent (Environment Canada 2004).

To obtain an estimation of the amount of impervious cover within the watershed each rooftop, swimming pool, driveway, accessory building, and paved roads were delineated from aerial photography taken in 2008.

These results indicate that total impervious cover of all permanent, hard surfaces within the Nonquon River watershed accounts for 4.1km^2 or 2.1% of the total watershed area. The existing road network accounts for the majority of the total. This value is relatively low compared to other watersheds originating on the Oak Ridges Moraine, especially when compared to watersheds draining south to Lake Ontario. This can be attributed to the lack of wide-spread urban development in the Nonquon River watershed.

4.6 Waste Disposal Sites

There are two known waste disposal sites within the Nonquon River watershed, both of which are now closed. The Scugog Municipal Landfill site, which is located along Reach Street west of Highway 7/12, was active between 1972 and 1989 and was closed in 1992. Currently, the Region of Durham operates a transfer station at the entrance to the site. The other abandoned landfill site is located west of Seagrave, near Saintfield Road and Coryell Road. Although leachate from landfill sites can be a significant water quality threat in some areas, these sites are not known to be negatively impacting watershed resources.

4.7 Land Use Planning

Land use planning and policy within the Nonquon River watershed is guided by various initiatives at the federal, provincial and municipal level. The following are key overarching land use policies that should be considered during the watershed management planning process.

Oak Ridge Moraine Conservation Plan

The Oak Ridges Moraine Conservation Plan was introduced by the province in 2002, with the primary purpose of protecting the hydrological and ecological features and functions of the Oak Ridges Moraine (OMMAH 2002). The land use provisions contained within the plan apply to lands within the Oak Ridges Moraine Planning Area, which extends 1900km^2 across south-central Ontario. Areas within the Oak Ridges Planning Area have been divided into four land use designations that have varying levels of development restrictions and/or permitted land use activities. They include Natural Core Areas, Natural Linkage Areas, Countryside Areas and Settlement Areas. In total, the Oak Ridges Moraine Conservation Plan covers 27.9km^2 or 14.6% of the entire watershed. The Oak Ridges Moraine portion of the Nonquon River watershed includes: Natural Core Areas (16.4km^2), Natural Linkage Areas (2.6km^2), and Countryside Areas 8.8km^2) (**Figure 4.4**). There are no Settlement Areas.

Greenbelt Plan

The Greenbelt Plan was introduced by the province in 2005, with the primary purpose of sustaining productive agricultural lands and preserving natural heritage features that exist in-and-around the Greater Toronto Area (OMMAH 2005a). Although the Plan area includes the Niagara Escarpment and the Oak Ridges Moraine, the land use provisions contained within the Plan apply to the area designated as "Protected Countryside" in the Plan. Protected Countryside land falls into one of the following policy areas: Prime Agricultural Areas, Rural Areas, Towns/Villages, Hamlets, or Shoreline Areas. Lands may also be subject to the policies of a Natural Heritage System, which is an overlay on the Protected Countryside designation. In total the Greenbelt Plan covers 155.6km^2 or 80.1% of the entire watershed. Within the Greenbelt lands in the watershed, 76.2km^2 is Natural Heritage System, and 79.4km^2 is Protected Countryside (**Figure 4.4**).

Provincial Policy Statement

The Provincial Policy Statement was introduced by the province in 2005, with the primary purpose of providing for appropriate development while protecting resources of provincial interest, public health and safety, and the quality of the natural environment (OMMAH 2005b). Ultimately, it sets the general land use policy framework throughout all Ontario. The Provincial Policy Statement identifies various natural heritage features (e.g., fish habitat, significant wetlands, significant valleylands, etc.), that should be protected from incompatible development.

Municipal Official Plans

The Nonquon River watershed is located within the jurisdiction of five municipalities (**Figure 4.5**). These include the Regional Municipality of Durham, Scugog Township, Brock Township, Uxbridge Township and City of Kawartha Lakes. The upper tier Regional Municipality of Durham jurisdiction covers 183km^2 or 94.7% of the Nonquon River watershed, which includes the lower tier municipalities of Township of Scugog (140.5km^2), Brock Township (35.2km^2) and Uxbridge Township (7.8km^2). The single tier municipality of City of Kawartha Lakes covers 11.2km^2. Municipal Official Plans and their associated updates (e.g., amendments) and by-laws, contain land use policies that provide direction on development and other activities within that respective municipality. The Official Plan of lower-tier municipalities (e.g., Scugog Township) are consistent with their upper tier municipality (e.g., Durham Region). All Official Plans must conform with provincial planning policies (where they apply), such as the Provincial Policy Statement, Oak Ridges Moraine Conservation Plan, Greenbelt Plan, and the Growth Plan for the Greater Golden Horseshoe.

The Regional Municipality of Durham Official Plan (Region of Durham 2008a) designates most of the land throughout the Nonquon watershed as Major Open Space and Prime Agricultural Areas (**Figure 4.6**). Land designated as Major Open Space is intended for conservation, agriculture and agriculture related activities, and recreation. Any development that occurs within the area must ensure that the disturbed area does not exceed 25% and impervious surface does not exceed 10%. Prime Agricultural Land is intended to encourage continual farming practices and restrict severances that may fragment the farming landscape.

Within the Township of Scugog Official Plan (Township of Scugog 2009), a large portion of land within the watershed is designated as Greenlands System (**Figure 4.7**). Accepted use of these lands include: agriculture, single detached dwellings, recreation that has no adverse affect on the environment, forestry, fisheries and watershed management activities. Other areas are designated Agricultural Reserve, established to maintain prime agricultural lands and General Agriculture. Other areas, not considered prime agricultural, permit more diverse land uses such as commercial development and industry.

Conservation Authority Regulations

The Nonquon River watershed is within the jurisdiction of Kawartha Conservation, one of 36 Conservation Authorities in the province. In 2006, the province of Ontario approved the Kawartha Region Conservation Authority: Regulation of Development, Interference and Alteration to Shorelines and Watercourses (O.Reg 182-06) consistent with Ontario Regulation 97/04 of the *Conservation Authorities Act*. The Act gives Kawartha Conservation administrative authority to regulate development and other land use activities within its jurisdiction, including:

- development in river or stream valleys, wetlands, shorelines and hazardous lands and associated allowances;
- the straightening, changing, diverting or interfering in any way with the existing channel of a river, creek, stream, watercourse or for changing or interfering in any way with a wetland; and,

- other areas where, in the opinion of the Minister, development should be prohibited or regulated or should require the permission of the authority.

Kawartha Conservation Watershed Planning Policies (Kawartha Conservation 2012) provide a decision-making framework for the review of applications under the Regulations. Kawartha Conservation has developed Regulation Limit mapping for the purpose of provincial policy and regulations implementation (**Figure 4.8**). The Regulation Limit mapping is a key tool in protecting public and property against natural hazards such as flooding and regulating activities that could impact floodplains, shorelines, wetlands, watercourses, and unstable slopes and soils.

Nonquon River Subwatershed Study and Nonquon Industrial Tributary Area Master Drainage Plan

The Nonquon River Subwatershed Study and Nonquon Industrial Tributary Area Master Drainage Plan (Palmer 2005) provide detailed recommendations and an implementation framework to protect key watershed features within the Nonquon River watershed. A significant focus of this document is providing alternatives for managing drainage within the Nonquon Industrial Tributary Area, including detailed designs of recommended stormwater management facilities.

Nonquon River Fisheries Management Plan

In 2009, Kawartha Conservation, in partnership with Ontario Ministry of Natural Resources, Regional Municipality of Durham, Townships of Scugog and Brock, Fisheries and Oceans Canada and local stakeholders developed the Nonquon River Fisheries Management Plan (Kawartha Conservation 2009). The plan provides detailed information on the state of aquatic resources within the watershed and identifies specific fisheries management recommendations that are applicable at a watershed-level and zone-specific (5 in total) level.

Lake Scugog Environmental Management Plan

The purpose of the Lake Scugog Environmental Management Plan (Kawartha Conservation 2010b) is to ensure the long-term environmental and social sustainability of Lake Scugog and its resources. This plan provides an overall stewardship strategy for the lake and its watershed for the next ten years, with estimated costs for its implementation. The Implementation Plan actions are designed to cover all aspects of human activities and are grouped under six strategies: Watershed Planning, Regulation and Enforcement Strategy; Communications and Education Strategy; Stewardship Strategy; Agricultural Land Use Strategy; Urban Land Use Strategy; and, Monitoring and Scientific Studies Strategy.

Ontario Drinking Water Source Protection Planning

In 2005, the province of Ontario introduced the *Clean Water Act*. The purpose of this Act is to protect municipal drinking water at the source, which includes surface water and groundwater. A key component of this legislation is the requirement for the development of local and science-based Source Water Protection Plans. The Nonquon River watershed exists within the Kawartha-Haliburton Source Protection Area, which is part of the larger Trent Conservation Coalition Source Protection Region. Various studies and reports developed through this planning process provide background information on watershed resources, especially within the context of protecting water quality and quantity of municipal drinking water systems. These data are summarized in the Kawartha Conservation Watershed Characterization Report (Kawartha Conservation 2008) and the Trent Assessment Report (TCCSPC 2011). Source Water Protection Plans are expected to be finalized in 2012.

Trent-Severn Waterway

The bed of Lake Scugog, including the upper navigation limit of the lake, is federal crown land that is managed by Trent-Severn Waterway (Parks Canada). This area includes the mouth of the Nonquon River, as it transitions in the lake. Also, Trent-Severn Waterway operates a dam in the town of Lindsay, regulating the water levels in the lake and consequently, water levels at the outlet of the Nonquon River watershed.

4.8 Key Observations and Issues

- The dominant land use within the watershed is agriculture, which comprises approximately 52% of the total land area. No major urban growth and expansion is expected to occur within the next 25 years, and as such the watershed will remain distinctly rural in nature for the foreseeable future.

- Extensive areas of natural cover still exist within the watershed, comprising approximately 42% of the total land area. These include the Nonquon River Provincial Wildlife Area, which exists within a large wetland complex in the central portion of the watershed and large forested areas that exist within the Oak Ridges Moraine.

- The watershed is located within the jurisdiction of 5 municipalities. These include the Region of Durham (95% of the total land area, which includes Scugog Township, Brock Township, and Uxbridge Township) and the City of Kawartha Lakes (5% of the total land area).

- The southern portion of the watershed lies within the Oak Ridges Moraine Conservation Plan planning boundary (15% of total watershed area), while the majority of the watershed lies within the Greenbelt Plan planning boundary (80% of total watershed area).

Figure 4.1: Historical map of Ontario County (circa 1880).

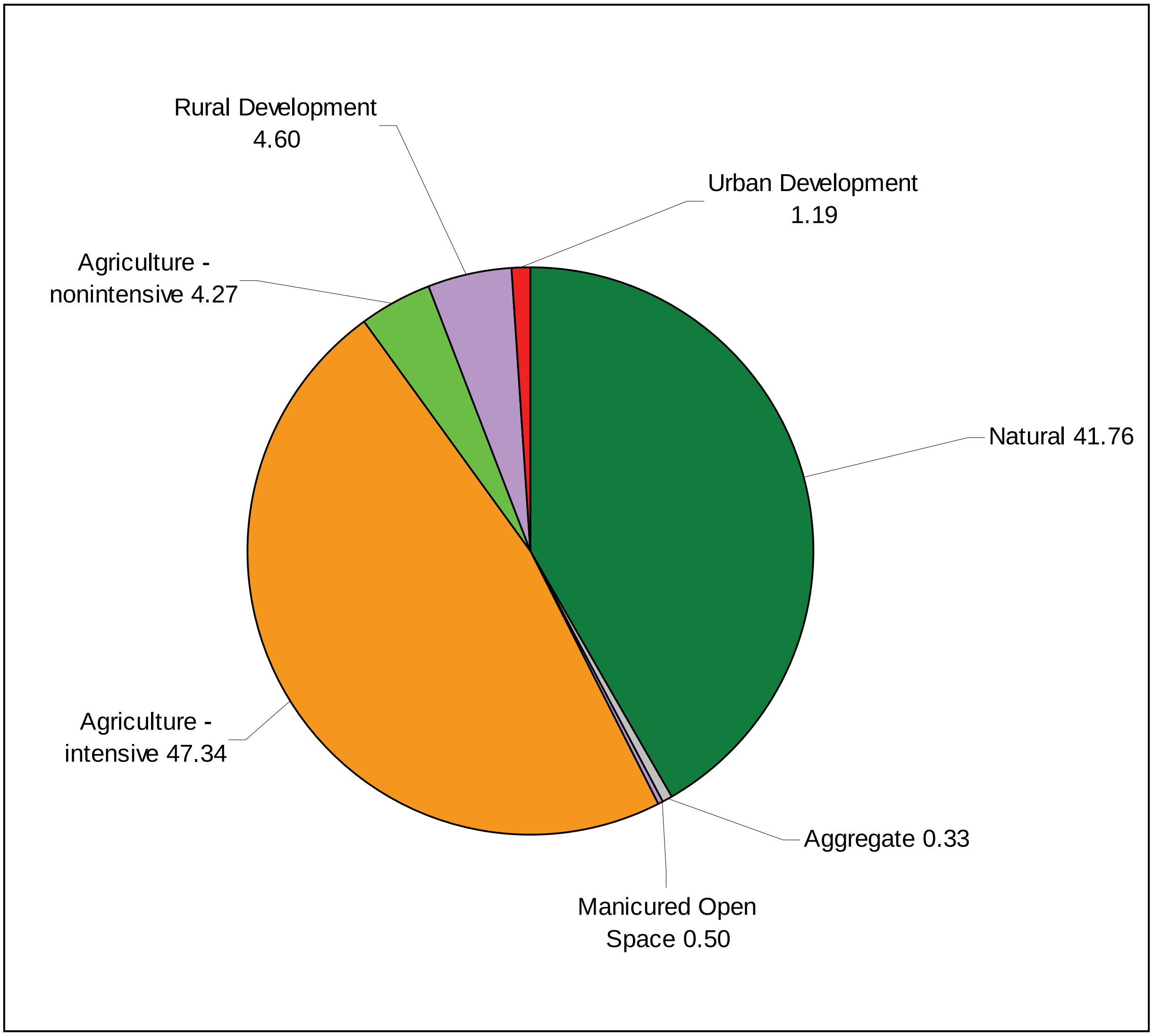


Figure 4.2: Percentage of major land cover types.

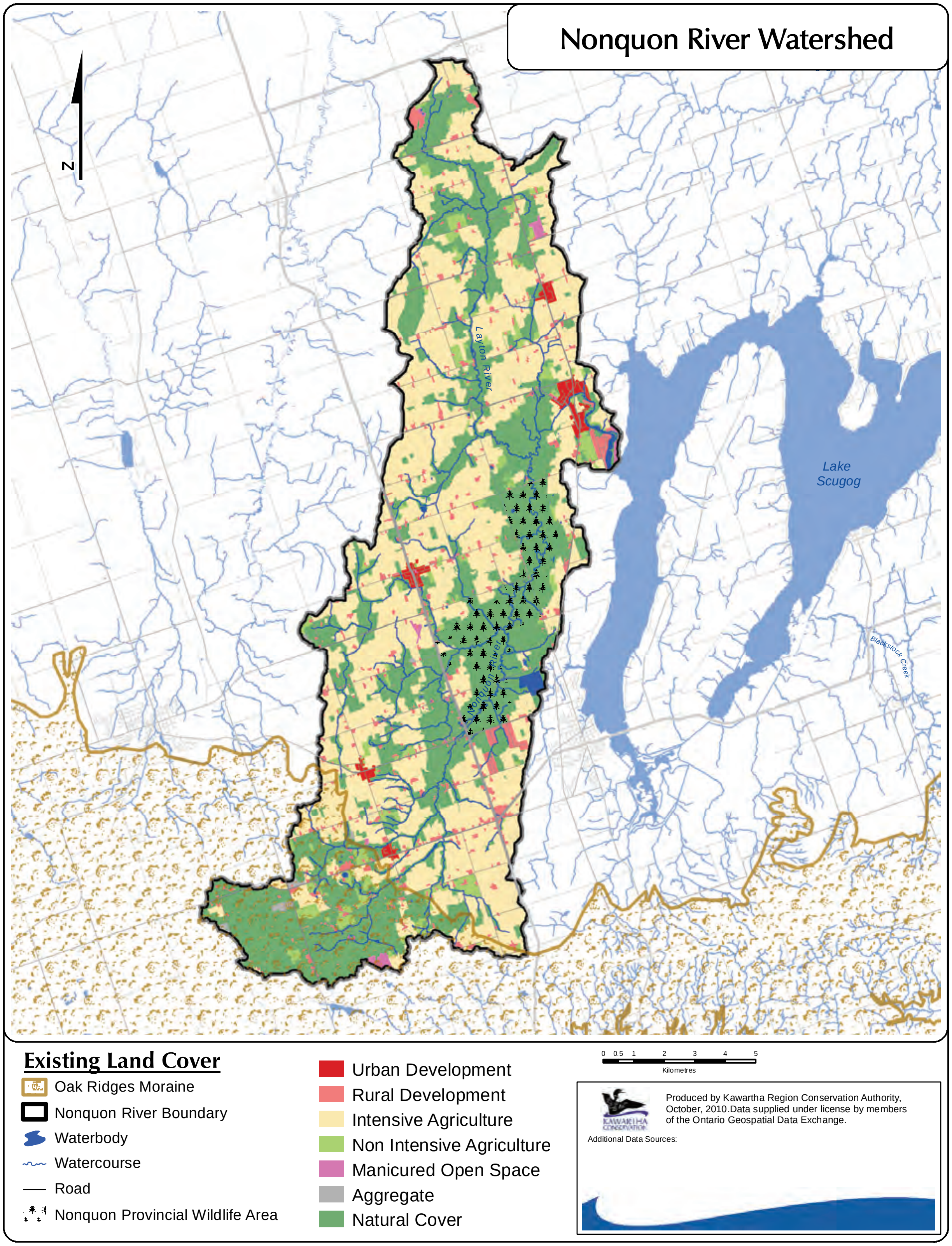


Figure 4.3: Existing land cover.

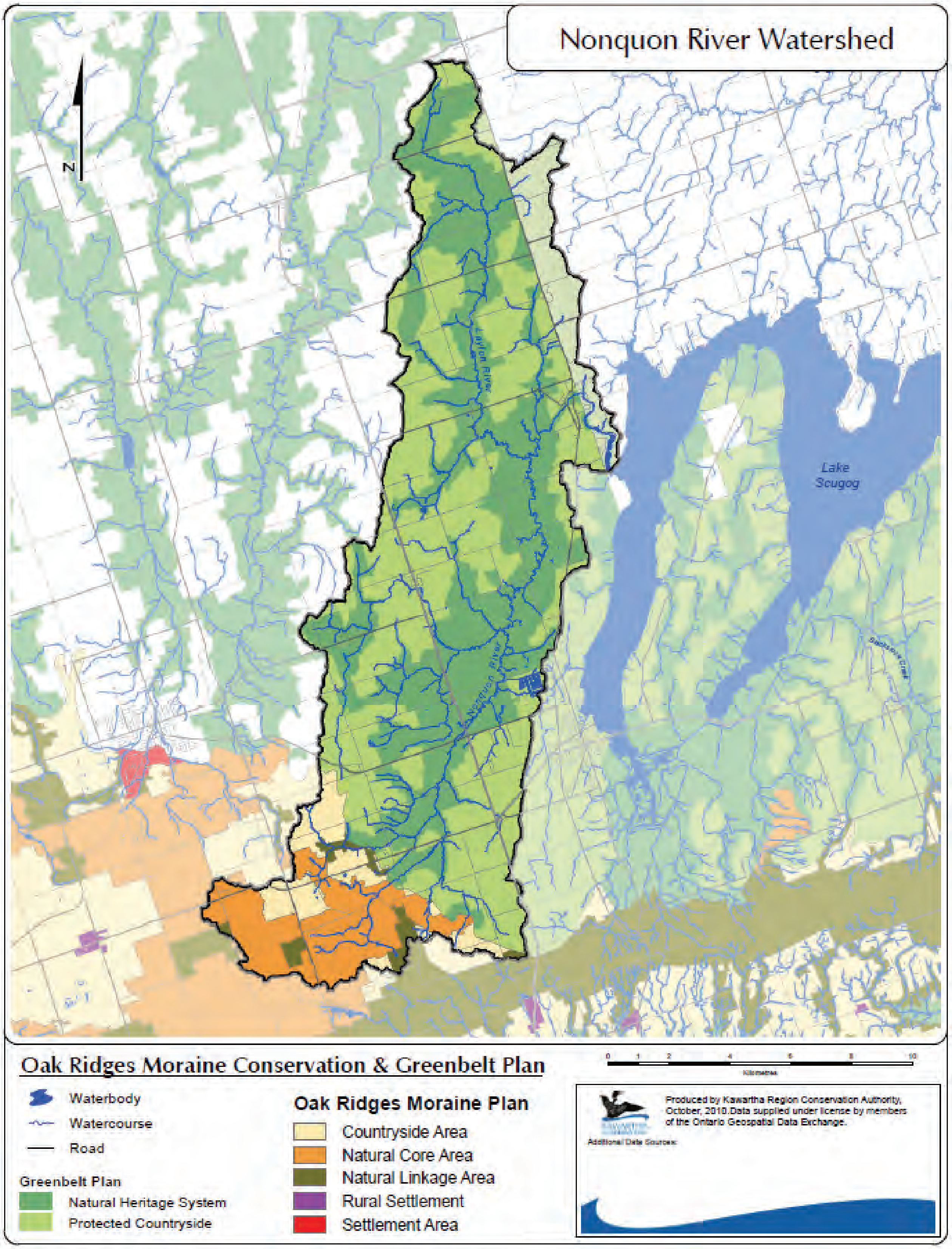


Figure 4.4: Oak Ridges Moraine and Greenbelt land use designations.

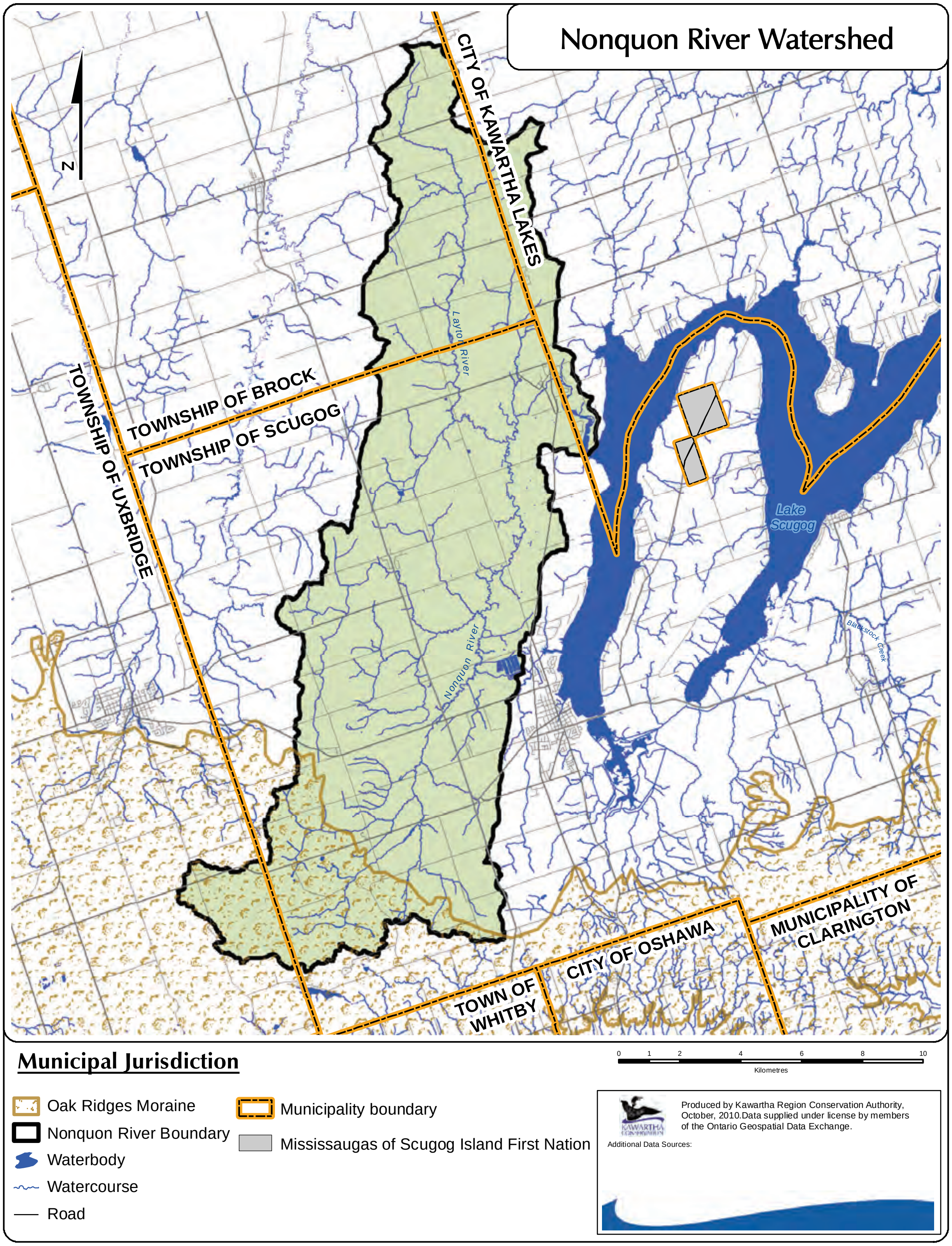


Figure 4.5: Municipal jurisdiction.

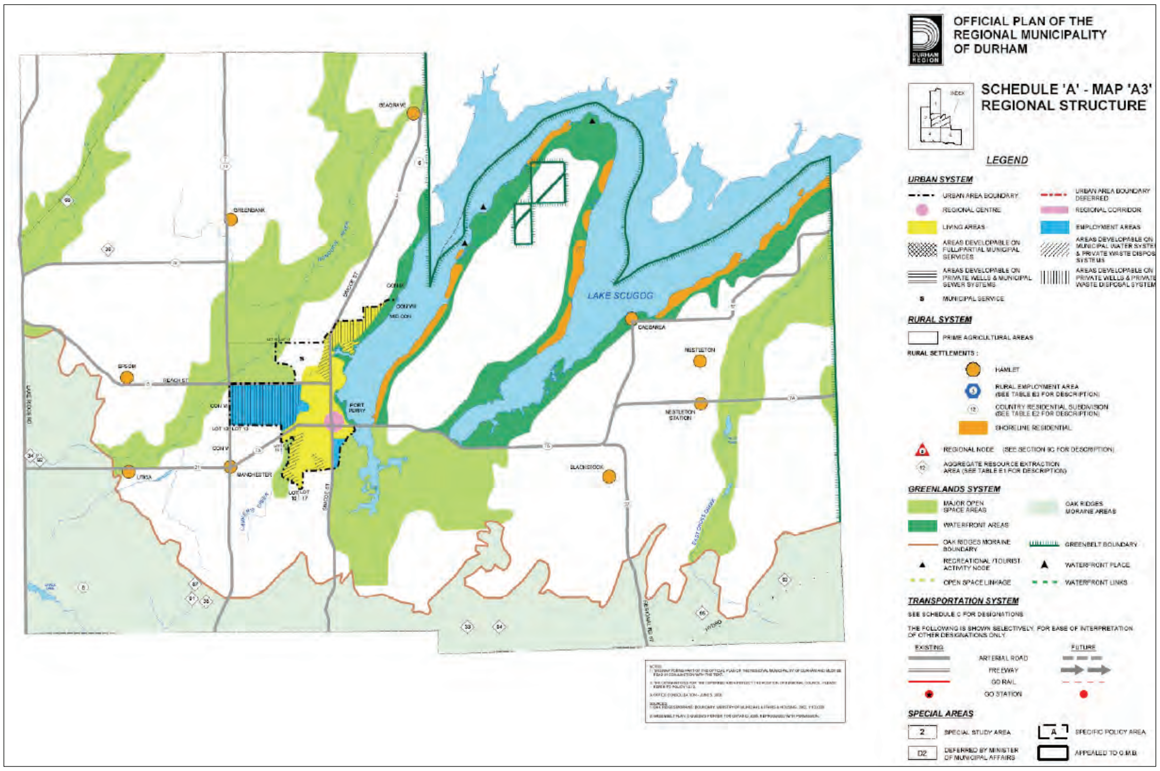


Figure 4.6: Regional Municipality of Durham Official Plan land use designations.

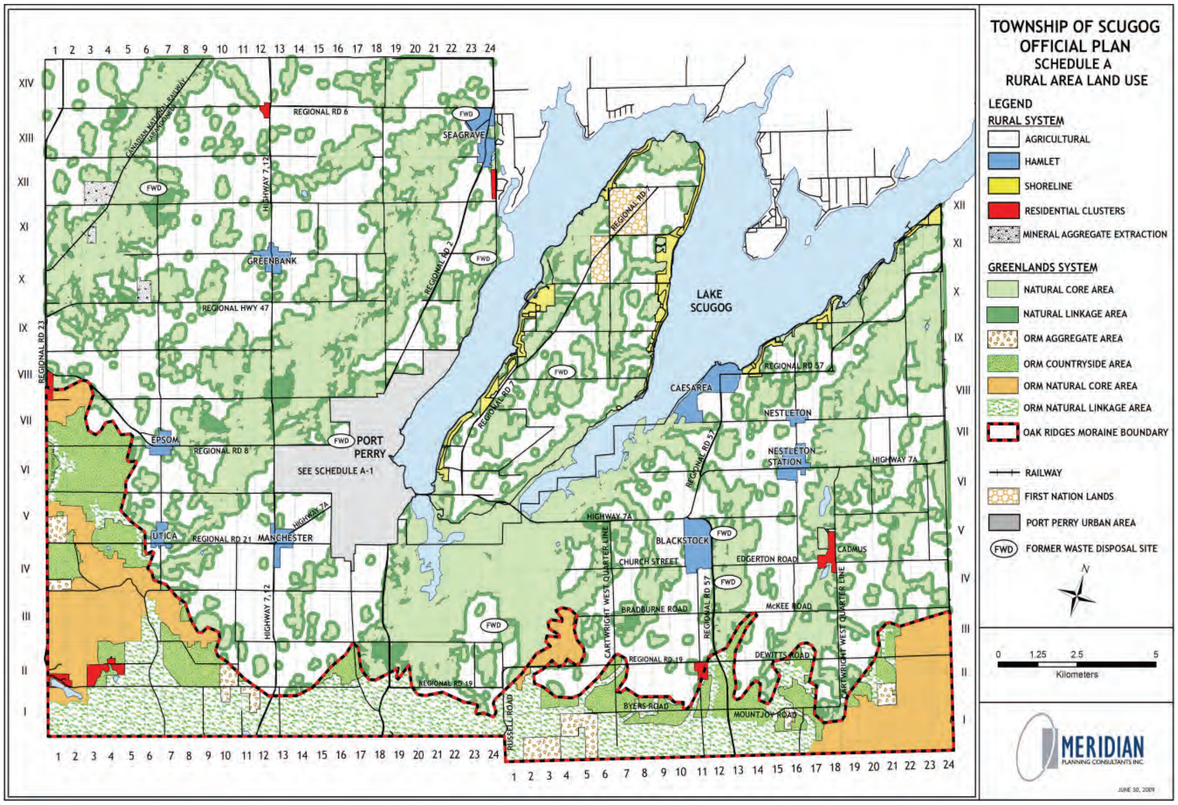


Figure 4.7: Township of Scugog Official Plan land use designations.

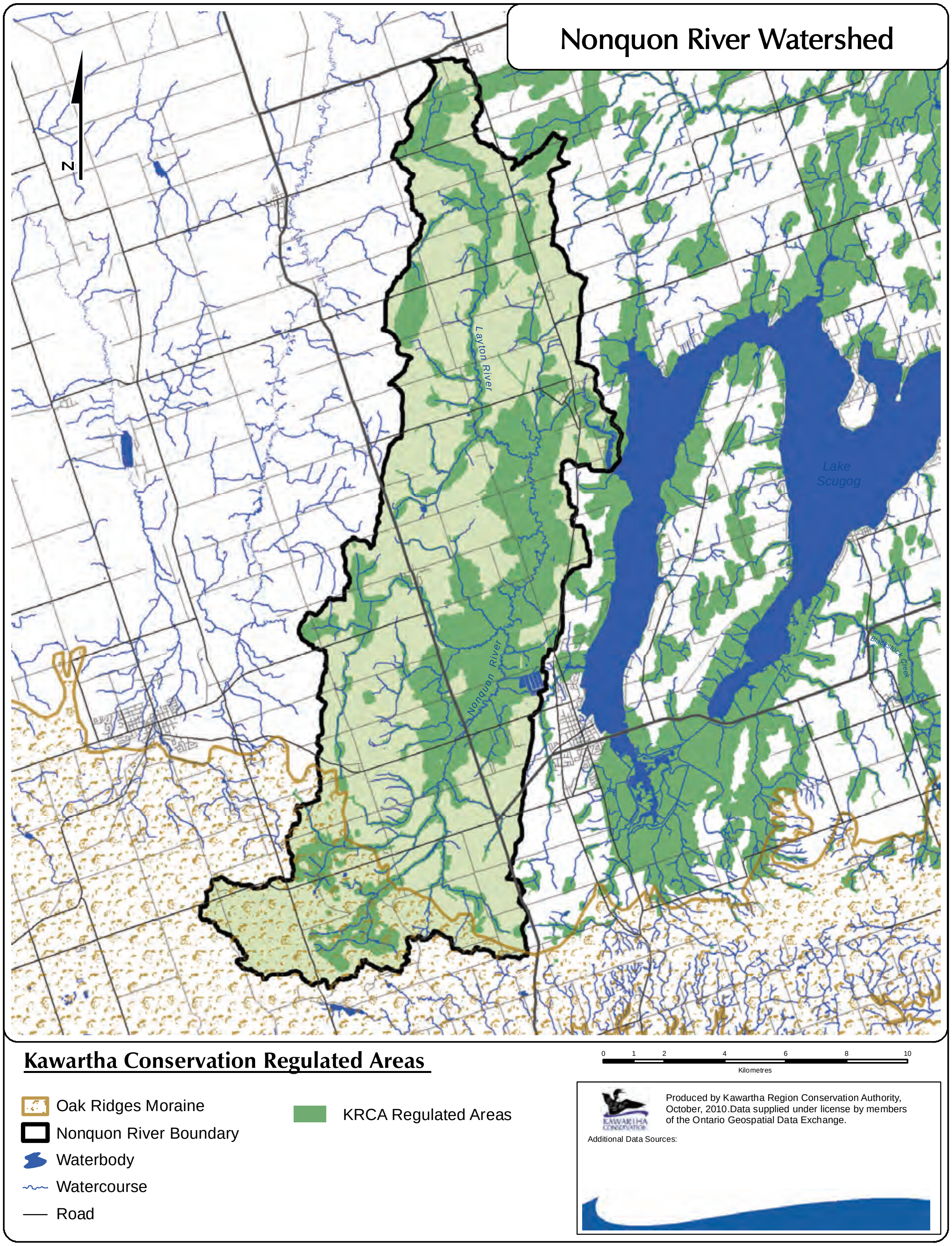


Figure 4.8: Conservation Authority regulated areas.

5.0 Water Use

Layton River, south of Brock Concession 5

5.1 Introduction

An abundant water supply is critical to maintaining both the hydrological integrity and ecological integrity of watersheds. Humans are also heavily dependent upon surface water and groundwater for drinking and potable purposes, agricultural use, industrial and recreational use. The intent of this chapter is to provide a summary of estimated water use within the Nonquon River watershed.

5.2 Major Water Takings

Water users that withdraw or holdback (e.g., through impoundments) more than 50,000 litres of water per day are considered major water takings. These activities require a Permit to Take Water (PTTW) from the Ontario Ministry of Environment and the amount of water used is documented and reported to the MOE. Water takings for domestic use, agriculture and emergency purposes (e.g., firefighting) do not require a permit. Major water taking information is managed in a provincial dataset, maintained by the Ministry of the Environment, which contains specific information including the name of permit holder, location of withdrawal, permitted purpose, maximum permitted water taking volumes and maximum number of water taking days per year. As of 2008, all major water takers are required to report the total volume of water taken each year.

The Ontario Ministry of Environment was contacted to provide current water taking information within the watershed. The best available data was provided for active permits within the watershed (as of May 2010). Some permits were removed from the analysis in order to give a better representation of water usage (e.g., pumping tests).

There are six active Permits to Take Water at the Nonquon River watershed (**Figure 5.1**, **Table 5.1**). Two of which use surface water as a source, and four allow withdrawal from groundwater. The surface water taking is used for wildlife conservation (impoundment of water in a tributary of Nonquon River) and for golf course irrigation at the maximum allowed value of 2,620 m^3/day, that is withdrawn from Lake Scugog. Golf course irrigation is considered as commercial use of water. Both wildlife conservation and irrigation are belong to non-consumptive category of water use.

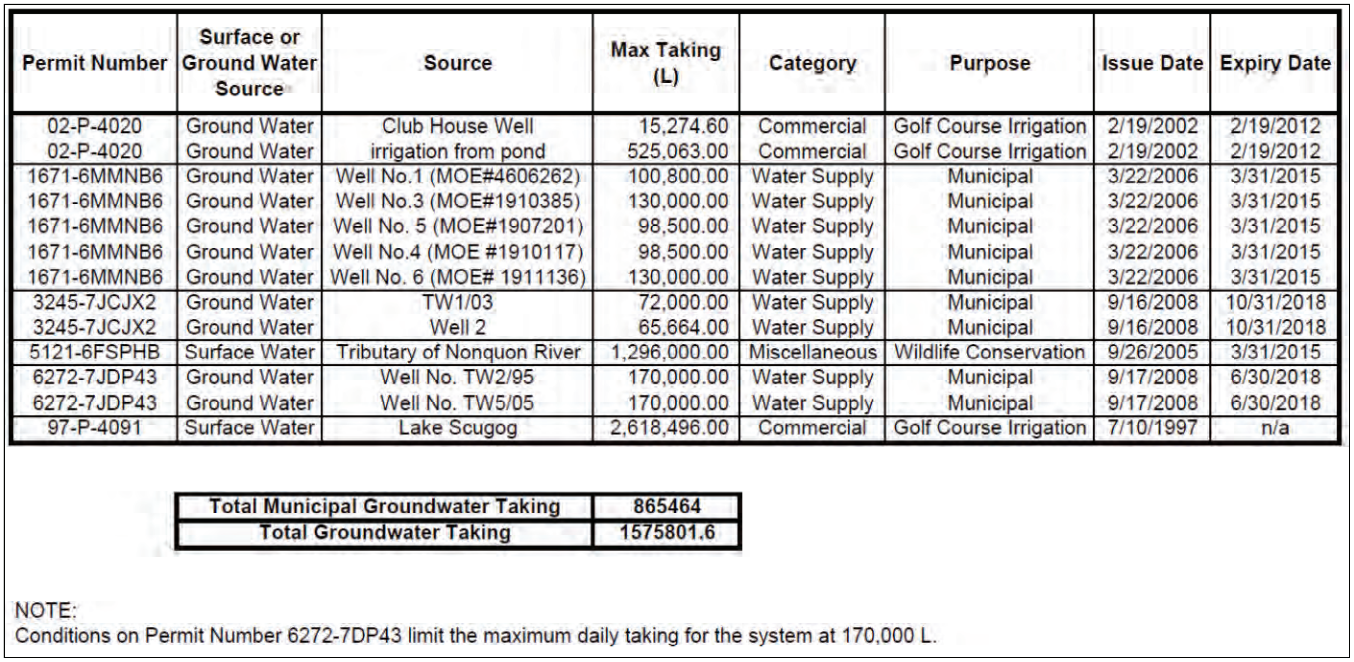
Three of four active PTTWs that employs groundwater, are for municipal drinking water supply. Greenbank municipal drinking water system is the only system that is maintained by the Regional Municipality of Durham within Nonquon River watershed. It provides water to the Hamlet of Greenbank, with a permitted maximum daily taking of 557.8 m^3/day from five active wells. Municipal drinking water supply systems that serve subdivisions of Sonya and Mariposa Estates are located within the City of Kawartha Lakes. The permitted maximum daily taking values are 170 m^3 and 137.6 m^3, respectively.

One Permit To Take Water allows pumping up to 541 m^3/day for golf course irrigation. It is a seasonal, non-consumptive use of groundwater resources.

The total permitted groundwater withdraw from Nonquon River watershed is 1,406.4 m^3/day.

The permitted capacity for the existing wells in Greenbank is set to allow for planned growth and predicted maximum day usage. Maximum day usage is typically on the order of two times the average usage rate but can vary from system to system. The observed average daily rate for the Greenbank system in 2007 was 131 m^3/day. This represents approximately 24% of the quantity allowed under the Permit to Take Water. The average pumping rates for 2007 are used as this reflects a relatively dry year and therefore relatively high water usage by the community. Likewise, in 2009 the majority of permit holders took significantly less water (10 - 30%) than their maximum permitted amount. A similar proportion of average to permitted rates will likely be observed for the wells operated by the City of Kawartha Lakes.

Table 5.1: Permits to take water.



Permit Number	Surface or Ground Water Source	Source	Max Taking (L)	Category	Purpose	Issue Date	Expiry Date
02-P-4020	Ground Water	Club House Well	15,274.60	Commercial	Golf Course Irrigation	2/19/2002	2/19/2012
02-P-4020	Ground Water	irrigation from pond	525,063.00	Commercial	Golf Course Irrigation	2/19/2002	2/19/2012
1671-6MMNB6	Ground Water	Well No.1 (MOE#4606262)	100,800.00	Water Supply	Municipal	3/22/2006	3/31/2015
1671-6MMNB6	Ground Water	Well No.3 (MOE#1910385)	130,000.00	Water Supply	Municipal	3/22/2006	3/31/2015
1671-6MMNB6	Ground Water	Well No. 5 (MOE#1907201)	98,500.00	Water Supply	Municipal	3/22/2006	3/31/2015
1671-6MMNB6	Ground Water	Well No.4 (MOE #1910117)	98,500.00	Water Supply	Municipal	3/22/2006	3/31/2015
1671-6MMNB6	Ground Water	Well No. 6 (MOE# 1911136)	130,000.00	Water Supply	Municipal	3/22/2006	3/31/2015
3245-7JCJX2	Ground Water	TW1/03	72,000.00	Water Supply	Municipal	9/16/2008	10/31/2018
3245-7JCJX2	Ground Water	Well 2	65,664.00	Water Supply	Municipal	9/16/2008	10/31/2018
5121-6FSPHB	Surface Water	Tributary of Nonquon River	1,296,000.00	Miscellaneous	Wildlife Conservation	9/26/2005	3/31/2015
6272-7JDP43	Ground Water	Well No. TW2/95	170,000.00	Water Supply	Municipal	9/17/2008	6/30/2018
6272-7JDP43	Ground Water	Well No. TW5/05	170,000.00	Water Supply	Municipal	9/17/2008	6/30/2018
97-P-4091	Surface Water	Lake Scugog	2,618,496.00	Commercial	Golf Course Irrigation	7/10/1997	n/a

Total Municipal Groundwater Taking	865464
Total Groundwater Taking	1575801.6

NOTE:
Conditions on Permit Number 6272-7DP43 limit the maximum daily taking for the system at 170,000 L.

From GENIVAR (2011)

5.3 Private Water Supply

As water usage requiring less than 50,000 litres per day are not required to obtain a Permit to Take Water and thus no data is available on actual usage. Examples of these include: rural and residential domestic wells, non-business irrigation and livestock operations . Although each of these users withdraws relatively little water from the watershed (when compared to the major water takings), the cumulative amount of water taken may be high. However, because rates of use are not reported and thus it is difficult to accurately quantify the total amount extracted, rates are estimated. In addition, many of the private wells in the watershed have not been registered and many are no longer in active use.

Most rural residences within the watershed rely on water supplied by private wells. An estimated 858 private wells are recorded within the Nonquon River watershed (**Figure 5.2**). A typical private household will use on the order of 1,000 litres of water per day (Shrubsole and Draper 2007). This would equate to a total water use in the order of 858,000 litres/day or 858 m^3/day. In rural areas, this water is returned to the groundwater flow system as infiltration from the private sewage disposal system. The net consumption of water is minor. In many areas, the water is withdrawn from a deeper aquifer and returned to a shallow aquifer. A small percentage of these wells are considered communal wells, supplying groundwater to small rural subdivisions and other small-scale users.

Water usage for agricultural operations are usually not covered by the Permit to Take Water database. As the Nonquon River watershed is primarily rural in nature, agricultural activities are considered to be one of the major water uses in the study area. The extent to which water is used regionally is dependent on the nature of the agricultural activities (i.e., type of crop, livestock operation), as well as the amount of land cultivated. However, the agricultural operations do not require permits to take water unless water is brought into storage prior to use. As such, additional quantities of water may be used for animal watering and crop irrigation purposes without any record of volumes applied.

5.4 Municipal Drinking Water Supply

Three communities within the Nonquon River watershed are serviced by municipal drinking water systems. All of them rely on groundwater as sources of drinking water (**Figure 5.3**). Two of these systems (Sonya and Mariposa Estates) are operated by City of Kawartha Lakes and one system (Greenbank) is operated by the Regional Municipality of Durham. The groundwater wells that supply the King's Bay municipal drinking water system, are located just outside of the north-eastern watershed boundary but the well intake area extends into the Nonquon River watershed. As part of the Source Water Protection Planning process, detailed water use information for these systems has been summarized in the Trent Assessment Report (TCCSPC 2011). Hamlet of Greenbank is the largest settlement serviced by municipal groundwater among listed, and consequently has the highest water use rates of all systems (**Table 5.2**).

A wellhead protection area (WHPA) is an area of land surrounding a well, from which a well may draw its water. The WHPA is subdivided into four zones: WHPA-A, WHPA-B, WHPA-C, and WHPA-D. Except for WHPA-A zone, the delineation is based on the time it would take water to travel horizontally to the well. Zones WHPA-B, C, and D represent a 2-year time-of-travel, 5-year time-of-travel and 25-year time-of-travel of groundwater, respectively. Zone WHPA-A is assigned as a 100 m radius surrounding the well.

Table 5.2: Municipal groundwater systems.

Municipal Residential Groundwater System	Operating Authority	Safe Drinking Water Act classification	Serviced Population
King's Bay	City of Kawartha Lakes	Small municipal residential	225
Mariposa Estates	City of Kawartha Lakes	Small municipal residential	122
Sonya	City of Kawartha Lakes	Small municipal residential	127
Greenbank	Region of Durham	Large municipal residential	560

Greenbank Municipal Drinking Water System

The Greenbank municipal system consists of five wells that provides drinking water to approximately 560 people. Wells depth varies from 22.7 to 34 metres. The wellhead protection areas for these five municipal wells are distributed through an area to the northwest of the community and reflect groundwater flow from northwest to southeast to the municipal wells.

Sonya Municipal Drinking Water System

The Sonya municipal system consists of one primary well (main production well) and one secondary well (stand-by well) within the Nonquon River watershed. Only the main production well has a delineated wellhead protection area. The main production well is 16.8 metres in depth, and provides water to an estimated 127 people. The wellhead protection areas extend east of the community and reflect groundwater flow from east to west to the municipal wells.

Mariposa Estates Municipal Drinking Water System

The Mariposa Estates municipal system consists of two wells within the Nonquon River watershed. Both wells have delineated wellhead protection areas. Wells in the system are 15.5 metres and 25.2 metres in depth, and provides water to estimated 122 people. The wellhead protection areas for this well reflect groundwater flow from north to south to the municipal wells.

King’s Bay Municipal Drinking Water System

The King's Bay municipal system and three wells are located outside of the Nonquon River watershed. All wells have delineated wellhead protection area that extend into the watershed. Wells depth vary from 17.4 to 17.7 metres in depth, and provides water to approximately 225 people. The wellhead protection areas for these wells reflect groundwater flow from all directions around the municipal wells.

5.5 Wastewater Treatment

The Nonquon River watershed is separated into either serviced or non-serviced areas. Serviced areas are those where wastewater is discharged to municipal treatment facilities. Within non-services areas, wastewater is typically discharged to private septic systems.

There are two municipal wastewater treatment facilities within the Nonquon River watershed. One of them, the King's Bay Waste Water Treatment Facility, treats wastewater from the King's Bay subdivision and discharges to Lake Scugog. The other facility is the Port Perry Water Pollution Control Plant which is located on Scugog Line 8, just west of Simcoe Street. This facility receives wastewater from the town of Port Perry and discharges treated water into the Nonquon River, where the main channel crosses Scugog Line 8. This facility consists of several settling ponds (also called lagoons) and an aeration pond. Wastewater servicing for the town is currently a constraint on urban expansion. Due do these servicing limitations, a Class Environmental Assessment process began in 2010 to plan for additional wastewater treatment capacity to service the Port Perry urban area. It is anticipated that the study will be completed in the fall of 2012.

5.6 Key Observations and Issues

- Groundwater is the dominant source of municipal and private water supply.
- The majority of residents within the watershed obtain their water from private, individual groundwater wells. There are approximately 858 wells within the watershed. The estimated total amount of groundwater being extracted from these sources is 858,000 litres per day.
- Three communities within the watershed are serviced by municipal groundwater wells. These include: Greenbank, Sonya, and Mariposa Estates. The estimated total permitted amount of groundwater allocated for withdrawal from these sources is 865,464 litres per day.
- There are 6 active Permits to Take Water in the watershed. Four of these are allocated for groundwater extraction (3 for municipal systems and 1 for golf course irrigation) and 2 of these are allocated for surface water extraction (1 for golf course irrigation and 1 for wildlife conservation).
- The total estimated water taking for the watershed is 1,312,000 litres per day. This estimate considers the Permitted Water Taking rate for municipal residential systems in the City of Kawartha Lakes and Permits issued for non-municipal use plus the average water taking by the Regional Municipality of Durham and the private well taking.
- It is difficult to precisely quantify the amount of water that is being withdrawn from groundwater and surface water sources other than those requiring reporting. Only users requiring Permits to Take Water are required to report the actual amount being extracted.
- The Nonquon River Water Pollution Control Plant (located within the watershed), treats wastewater from the Town of Port Perry (located outside the watershed). Currently this facility is operating at full capacity. As such, the Regional Municipality of Durham is currently pursuing options to upgrade this facility.

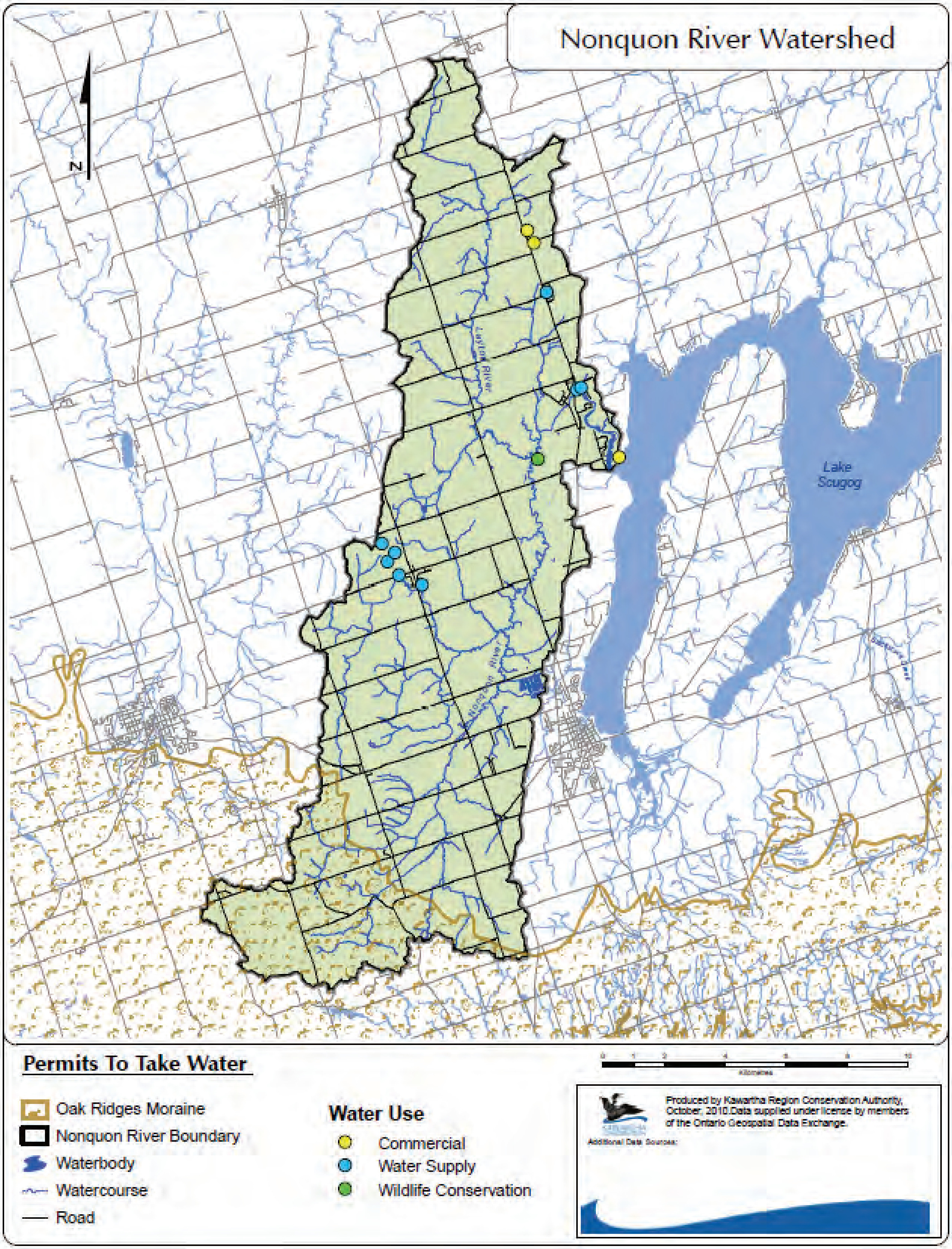


Figure 5.1: Permits to take water.

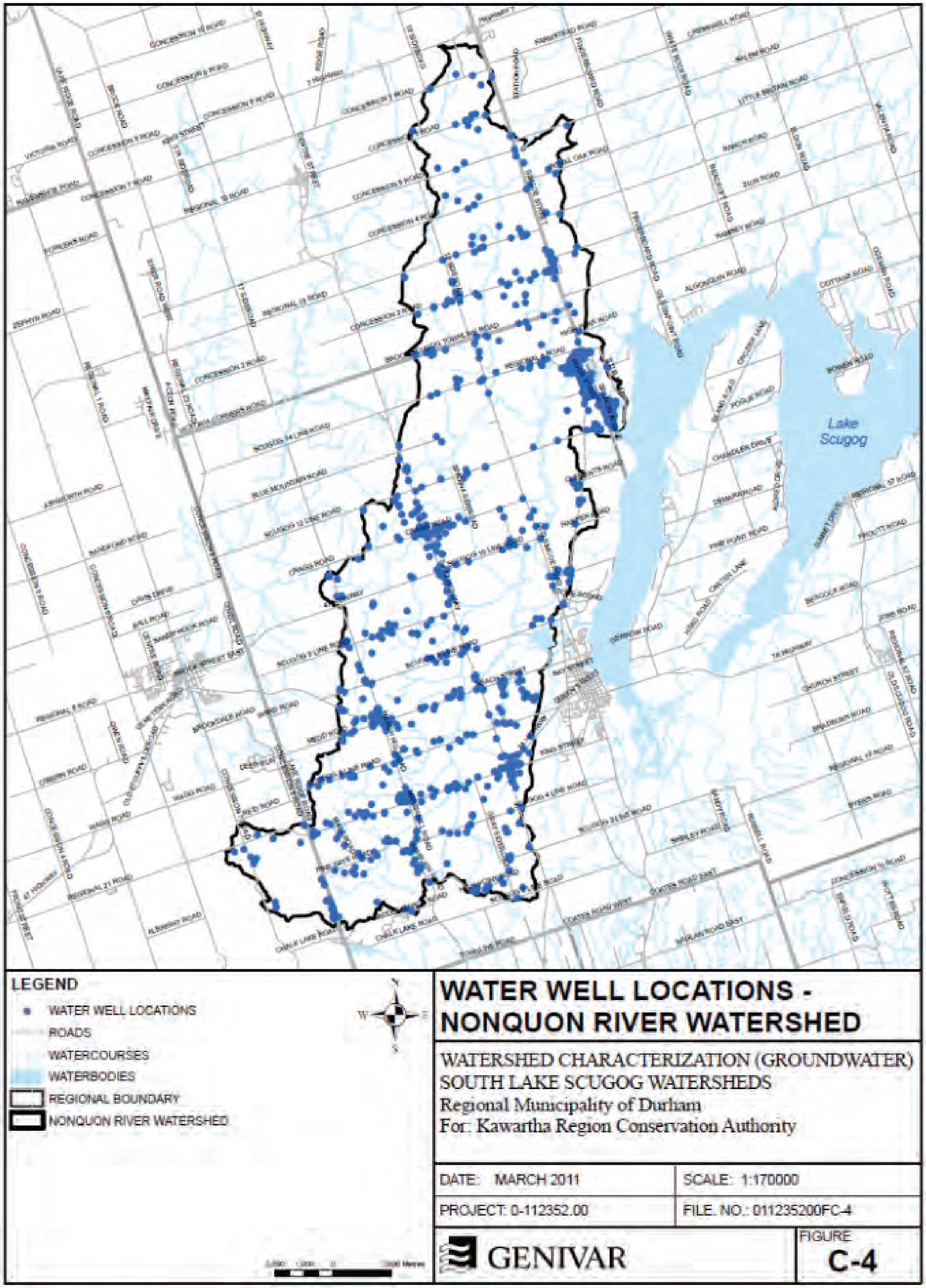


Figure 5.2: Water well locations.

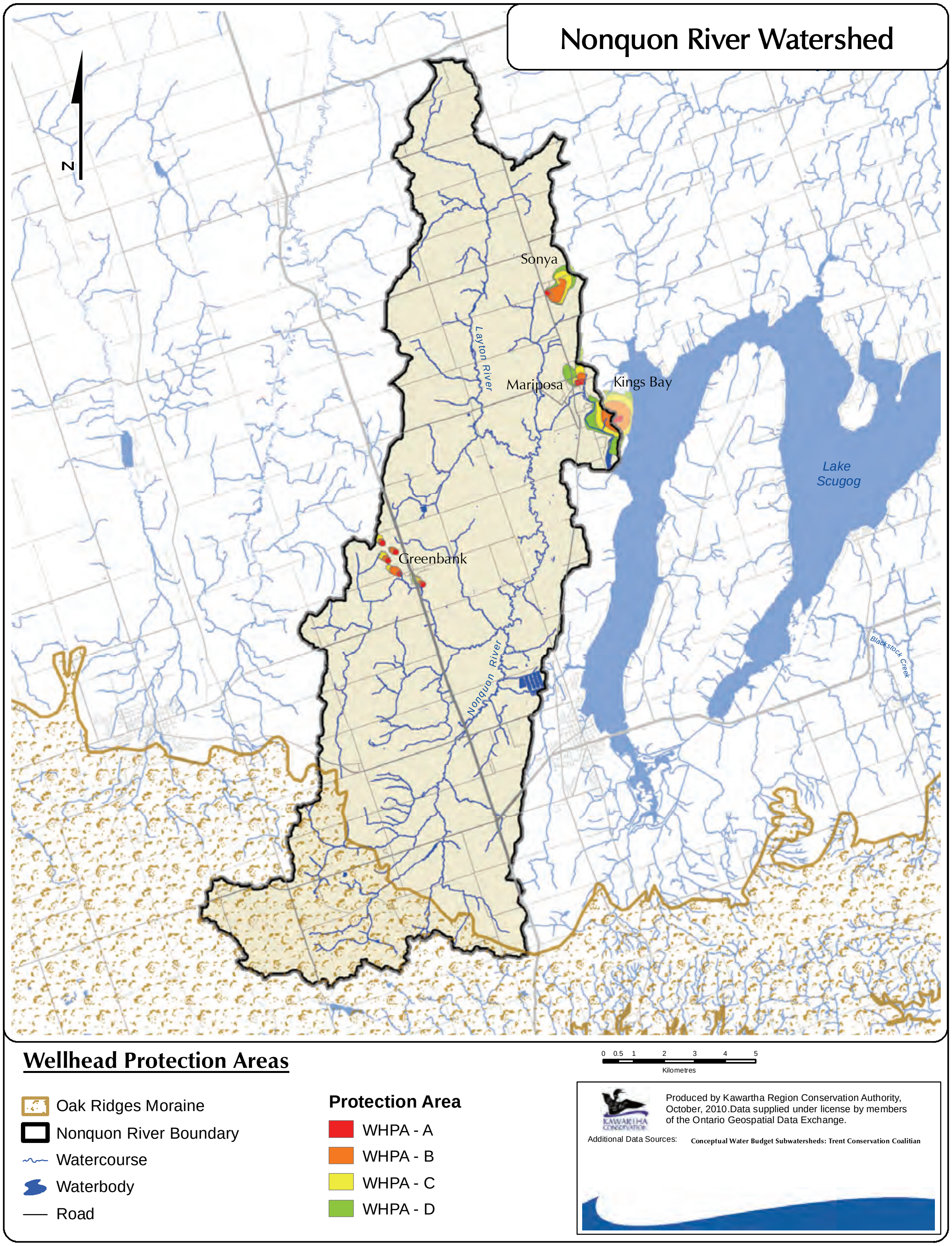


Figure 5.3: Municipal Drinking Water Systems.

6.0 Water Quantity

Nonquon River, west of Simcoe Street

6.1 Introduction

Water quantity refers to components of the hydrological cycle that move overland and within streams, wetlands and lakes (surface water), and that are present below the earth's surface (groundwater). The physical features of the Nonquon River watershed, including drainage area, topography, geology, and land and water use, influence the distribution of water and thus the hydrological and ecological processes within the watershed.

6.2 Drainage Network

The Nonquon River watershed has a drainage area of 191km^2, and contains approximately 220km of flowing watercourses. The Nonquon River originates from a small wetland on the Oak Ridges Moraine at an elevation of 320 masl in the Township of Scugog and flows north toward the lake Scugog joined by numerous tributaries on its way. The largest tributary of the Nonquon River is the Layton River that joins the Nonquon River from north, just upstream of the Hamlet of Seagrave. After crossing Simcoe Street (Hwy 2) the Nonquon River dramatically changes its direction and, for the last few kilometres, flows in a southeasterly direction before it inflows into Lake Scugog. The Nonquon River is the largest tributary and largest catchment of Lake Scugog, comprising approximately 35% of the total lake watershed area.

While flowing through the Oak Ridges Moraine, the Nonquon River and its tributaries are characterized by steep valley slopes, well-defined channels and narrow floodplains. The average slope of the terrain within this portion of the watershed is 9.07%. Throughout the rest of the catchment area, the watershed slopes are not as steep (approximately 4%), the floodplain is wide and the main channel has considerably lower gradient, averaging 0.8m/km. The main channel length of the Nonquon River is 36km, with an average gradient of 2.10m/km.

A large portion of the Nonquon River watershed, more than 18%, is occupied by the wetlands that are mostly located at middle and lower portion of the watershed. It provides significant benefits to the river, as wetlands provide peak flow mitigation and flood storage as well as assist in improving water quality by sediment trapping, nutrient retention and removal. Additional benefits to the Nonquon River come from the forested areas, that occupy about 18.6% of river’s watershed. Similarly to wetlands, forest helps to moderate streamflow, provides high and low flow mitigation and assists in groundwater recharge.

Nonquon River watershed is highly used for agriculture. While agricultural activities impact the water quality the most, they change some aspects of streamflow as well, including higher velocity of run-off over tilled soils that alters peak flows.

The watershed characteristics of the entire Nonquon River watershed, as well as it's portion that lies within the Oak Ridges Moraine, and the Layton River subwatershed are shown in **Table 6.1**.

Table 6.1: Watercourse and watershed characteristics.

Watershed/ Catchment Name	Drainage Area (km^2)	Stream Network Length (km)	Main Channel Length (km)	Main Channel Gradient (m/km)	Natural Cover (%)	Agriculture (%)	Urban Development (%)
Nonquon River	190.9	220.0	36.0	2.10	41.8	51.6	1.2
Nonquon River within the Oak Ridges Moraine	27.9	22.2	-	-	64.6	28.0	0.0
Layton River	52.3	53.7	14.1	1.1	36.0	59.2	<0.1

6.3 Surface Water Flows

Surface water quantity (volume of available water in watercourses and water bodies) assessments are usually achieved through flow and water level monitoring. Data that are collected assists in identifying changes that may affect the aquatic health, geomorphic stability and water quality of a watercourse as well as providing invaluable data for modeling of water resources, water budget calculation, and water use. Changes in flow conditions may reflect changes in climate (precipitation, evapotranspiration), water demand, land use or natural cover. Water level monitoring data also provide base information for flood forecasting and warning.

Water quantity information has been collected by means of continuous and spot flow monitoring. Continuous monitoring is performed at three gauge stations along the lengths of the Nonquon River, located at Marsh Hill Road, Scugog Line 6 and in the hamlet of Seagrave (**Figure 6.1**). All monitoring gauges consist of a sensor that measures water level on a preset interval (1 hour or 30 minutes) and a data logger that records measured values. **Table 6.2** lists the details of these gauges, as well as the catchment characteristics upstream of each gauge station.

The gauge station at Marsh Hill Road is particularly important because it provides information on flow values and regime for the Oak Ridges Moraine portion of the Nonquon River watershed. This temporary station was installed in 2006 and is maintained by Kawartha Conservation. The monitoring location on Scugog Line 6 is a part of the Environment Canada streamflow monitoring network. Flow data is available at this permanent location since 1993. The gauge station at River Road is located near the watershed outlet in the village of Seagrave. This location is also particularly important as it measures the total volume of flow discharging from the Nonquon River into Lake Scugog. This volume is essential in the calculation of the Lake Scugog water budget, as well as spatial flow and baseflow distribution, and net flows. This temporary station was installed in 2005 and is maintained by Kawartha Conservation.

In order to convert the recorded water levels to discharge (i.e., the amount of water that passes through the given transect in one second), a rating curve is developed. Discharge and water levels are measured numerous times at the monitoring location and graphed to develop a rating curve. A wide range of water levels and flow (from the highest to the lowest) are targeted in order to establish reliable relationships. Once the rating curve (and an equation that describes it), are developed water levels can be converted to discharges that characterizes the amount of water flowing through the gauging location. An example of a rating curve is shown in **Figure 6.2**. The dashed line demonstrates how the curve can be used to translate the measured water level into a discharge rating.

Since only three years of data exist for the gauges at Marsh Hill Road and Seagrave, they are not considered long-term data sets. Therefore, statistical summaries on these datasets should be interpreted with caution.

Table 6.2: Continuous flow monitoring stations.

Location	Data Interval	Data Record	Type	Ownership	Drainage Area (km^2)	Natural Cover (%)	Agriculture (%)	Urban Development (%)
Marsh Hill Road	30 min	2006 - present	Temporary, pressure transducer	Kawartha Conservation	17.7	79.7	13.5	0.0
Near Port Perry (at Scugog Line 6)	30 min	1993 - present	Permanent, steeling well	Environment Canada (WSD - 02HG002)	38.9	54.0	39.1	0.5
Seagrave (at River St)	1 hour	2005 - present	Temporary, pressure transducer	Kawartha Conservation	186.3	42.3	51.8	0.8

Flow Regime

Flows varies over time and space. Floods and low-flow periods may occur in a predictable seasonal pattern, and sometimes less predictably. Rivers in variable climates with no significant groundwater inflow tend to have variable flows, and watercourses that are groundwater fed tend to have more constant flows. Flow regime describes the average seasonal flow variability for a particular watercourse and reflects climatic and physiogeographic conditions in a watershed.

The best way to explore the flow regime of a watercourse is to study its long-term average flow. However, since monitoring locations at Marsh Hill Road and Seagrave do not have sufficient data to determine long-term average discharges, average monthly flows for all three gauging locations on the Nonquon River as observed in 2007 are used for interpretation purposes (**Table 6.3**, **Figure 6.3**). Monthly flows gradually increase from Marsh Hill Road to Seagrave for the most part of the year. This is due to increases in drainage areas that contributes to increases in flow. For example, the highest average monthly flow observed at Marsh Hill Road monitoring location is 0.124 m^3/sec; for the location at Scugog Line 6 it is 0.681 m^3/sec and 7.311 m^3/sec for the location in Seagrave. For minimum average monthly flow observed in August 2007, the lowest discharge was recorded at the stream gauge on Scugog Line 6. This fact requires further investigation, since no reasonable explanation can be derived from the limited existing data.

Figure 6.4 displays yearly trends of average (mean), maximum and minimum monthly discharges for the monitoring location at Scugog Line 6 calculated from 1993 to 2009. Mean monthly flows are the normal, or expected, flow in the Nonquon River for each month. 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 in the watercourse.

Both **Figure 6.3** and **Figure 6.4** confirm that the Nonquon River has a well-defined seasonal pattern along its length, reflecting seasonal variations of water inflow. The highest flows are typically observed in March, which is generally caused by a spring freshet (snowpack thaw). However, in recent years high water levels caused by mid-winter thaw events have reached values that are comparable to those of the spring freshet on a number of occasions. These events are reflected as elevated flow in December of 2007. Such anomalies may become more frequent in the future as a result of climate change.

The lowest flows are usually observed in August, when limited precipitation and high evapotranspiration rates bring the surface run-off component of stream flow to a minimum. The main source of water supply to the watercourse during this period is groundwater. Water levels stay low in September-October and rise in November-December, responding to higher precipitation levels and lower rates of evapotranspiration. During the winter months (December-February), ice cover establishes on most of the Nonquon River and its tributaries, except for areas of high groundwater inputs. Groundwater inflow is the only source of water supply to the river system during the winter season, which results in low water levels and flow.

With respect to the spatial distribution of flow. The gauging location at Marsh Hill Road demonstrates that the ratio of flow during the summer season (generally a dry period with no substantial surface run-off) to the spring flow (which is generated by both abundant surface run-off and groundwater inflow), is the smallest ratio among the three gauges (1:3). At Scugog Line 6, this ratio increases to 1:7 and is the greatest at the monitoring location at Seagrave (1:33). This indicates that the groundwater inflow is the most significant component of stream flow in the southern portion of the Nonquon River watershed. The importance of this component weakens along the river length, becoming minor compared to surface run-off at Seagrave monitoring location.

Table 6.3: Monthly flow (m^3/sec) for monitoring locations along Nonquon River, 2007.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Nonquon River at Marsh Hill Rd.	0.021	0.056	0.123	0.124	0.084	0.074	0.054	0.041	0.043	0.055	0.051	0.056	0.065
Nonquon River at Scugog Line 6	0.276	0.136	0.681	0.525	0.18	0.239	0.212	0.038	0.038	0.074	0.11	0.329	0.237
Nonquon River at Seagrave	2.162	0.566	7.311	4.204	1.196	0.606	0.438	0.233	0.235	0.422	0.678	1.818	1.656

High and Low Flows

The highest flows on the Nonquon River typically occur in springtime as a result of the melting of snow that is sometimes accompanied by rain. The spring snowmelt and rain combination frequently results in very high water levels that can cause flooding of low-lying areas, areas with insufficient drainage, or road crossings that can impede flow. Although no significant flood damage has occurred within the Nonquon River watershed, road overtopping and washouts create dangerous situations for motorists. Areas susceptible to flooding this kind of situation should be monitored closely. Flooding and flood vulnerable areas are discussed in further detail later in this chapter.

Table 6.4 shows all available highest instantaneous and daily discharges for monitoring locations on the Nonquon River. Out of 21 total recorded high water events, 13 (62%) occurred from March to May and four (19%), from December to January. Therefore, 81% of the yearly highest water flows have most likely resulted from snowmelt, possibly combined with a rain event.

Low-flow periods generally occur during summer or early fall, as 17 records (81%) out of the total 21, took place during July-September. Only two instances of the lowest yearly water flow occurred during the winter months (January and February). The fact that there has always been some amount of flow present at all three locations also indicates that there is sustained groundwater supply to the watercourse. Data on low flows are also provided in **Table 6.4**.

To further investigate periods of low flow conditions, the Baseflow (groundwater component of streamflow) Index was calculated as a part of baseflow separation analysis performed for the Nonquon River at Marsh Hill Road and Scugog Line 6 monitoring locations. The baseflow index indicates the proportion of baseflow in the total runoff of a catchment. Values range between 0 and 1, indicating the range of conditions from an absence of groundwater inflow to complete groundwater fed watercourses, respectively (**Table 6.5**).

Results of analyses indicate that baseflow at the gauge at Marsh Hill Road can be as high as 75 % of the total streamflow, as it was observed in 2007. It is important to note that 2007 was a year with significantly lower than normal precipitation (i.e,. a dry year). During 2008-2009, years when amounts of precipitation were above the normal (i.e., wet years), approximately 70% of total streamflow was from groundwater. For the monitoring location at Scugog Line 6, the portion of the groundwater component in the total streamflow is lower, varying from 56% (2003) to 65% (2007). The average value of the Baseflow Index for Nonquon River at Scugog Line 6, recorded between 1993 and 2009, is 0.610.

Table 6.4: Maximum and minimum discharge at monitoring locations.

Year	Maximum instantaneous discharge		Maximum daily discharge		Minimum daily discharge	
	m^3/sec	Date	m^3/sec	Date	m^3/sec	Date
Nonquon River at Marsh Hill Road						
2007	0.793	4-Apr	0.500	4-Apr	0.010	26-Jan
2008	0.743	9-Jan	0.432	9-Jan	0.020	26-Aug
2009	1.408	27-May	1.086	4-Apr	0.054	4-Feb
Nonquon River at Scugog Line 6						
1993	7.59	4-Jan	3.69	5-Jan	0.05	26-Sep
1994	N/A	N/A	2.1	22-Mar	0.011	23-Sep
1995	6.5	11-Nov	2.64	12-Nov	0.012	30-Aug
1996	4.39	30-Jun	2.51	30-Jun	0.042	4-Sep
1997	N/A	N/A	N/A	N/A	0.047	30-Jul
1998	10.2	26-Mar	3.32	26-Mar	0.025	14-Jul
1999	2.66	3-Nov	1.82	3-Nov	0.014	13-Aug
2000	3.88	25-Jun	2.28	13-May	0.049	10-Aug

Year	Maximum instantaneous discharge		Maximum daily discharge		Minimum daily discharge	
	m^3/sec	Date	m^3/sec	Date	m^3/sec	Date
2001	2.19	4-Apr	1.72	8-Apr	0.006	6-Aug
2002	2.45	14-May	1.91	14-May	0.014	12-Sep
2003	3.18	19-Nov	1.98	24-Dec	0.012	28-Jun
2004	8.4	5-Mar	3.89	5-Mar	0.044	25-Sep
2006	4.37	13-Mar	3.7	10-Mar	N/A	N/A
2007	N/A	N/A	3.7	14-Mar	0.007	18-Sep
2008	6.58	1-Apr	4.50	28-Dec	0.56	26-Aug
2009	N/A	N/A	4.00	12-Feb	0.066	19-Sep
Nonquon River at Seagrave						
2006	31.95	14-Mar	22.75	14-Mar	0.298	8-Sep
2007	23.29	28-Mar	18.33	28-Mar	0.114	1-6-Aug
2008	22.86	5-Apr	19.83	4-Apr	0.367	15-May

Table 6.5: Yearly Baseflow Indexes.

	2007	2008	2009	Average
Nonquon River at Marsh Hill Road	0.746	0.693	0.697	0.712
Nonquon River at Scugog Line 6	0.649	0.576	0.637	0.610

Flow Duration

A flow-duration curve represents the relationship between the magnitude and frequency of daily, weekly, monthly (or some other time interval of) streamflow for a particular watershed. This provides an estimate of the percentage of time a given streamflow was equaled or exceeded over the monitoring period. Applications of flow duration curves include, but are not limited to, water control structure design, hydropower planning, water-quality management, river and reservoir sedimentation studies, habitat suitability, and low-flow augmentation (Vogel and Fennessey 1994). Although flow duration curves have a long and rich history in the field of hydrology, they are sometimes criticized because, traditionally, their interpretation depends on the particular period of record on which they are based.

The shape of a flow duration curve in its upper and lower portions is particularly significant in evaluating watercourse and catchment characteristics. The shape of the curve in the high-flow portion indicates the type of flood regime the basin is likely to have, whereas the shape of the low-flow region characterizes the ability of the basin to sustain low flows during dry seasons. A very steep curve (high flows for short periods) would be expected for rain-caused floods on small watersheds. Snowmelt floods, which last for several days, or regulation of floods with reservoir storage, will generally result in a much flatter curve near the upper limit. In the low-flow portion, an intermittent stream would exhibit periods of no flow, whereas, a very flat curve indicates that flows are sustained throughout the year due to natural or artificial streamflow regulation, or due to a large groundwater capacity which sustains the base flow to the stream.

Some researchers separate flow duration curves into the following zones (Cleland 2003):

- high flows zone includes flow which probability is less than 10%;
- moist conditions are characterized by flow within 10-40 % probability interval;
- mid-range flows zone includes probability of 40-60 %;
- dry conditions zone of flow are described by flows of 60-90 % of probability; and,
- low flow zone includes flows that happen in more than 90 %.

Figure 6.5 shows the semi-log plot of flow duration curves for monitoring locations on the Nonquon River at Marsh Hill Road and Scugog Line 6. **Figure 6.6** and **Figure 6.7** show the flow duration curves whereas **Table 6.6** contains the flow values that correspond to the probabilities.

Both flow duration curves are characterized by very similar, fairly steep upper, high flow portions, what means the high stream flows on Nonquon River are typically driven by rain or/and quick snow-melting events. The lower portions of the curve are slightly different, being more flat for monitoring location at Marsh Hill Road and steeper at Scugog Line 6. It means that flows of high probability (low flows) for the catchment basin upstream of Marsh Hill Road are sustained by ground water and existing storage capacity to larger degree than for the portion of the Nonquon River subwatershed upstream of Scugog Line 6.

This situation is not typical for a watercourse. Usually, the storage capacity increases downstream and a flow duration curve becomes more flat for monitoring sites, located further downstream. The fact that it happens opposite way for the Nonquon River emphasizes that area upstream of Marsh Hill Road is the area of substantial groundwater discharge to the river, which is supported by the baseflow index calculation as well. Therefore, the well-being of the portion of the watershed upstream of Marsh Hill Road to a large degree defines the well-being of the watershed as a whole.

Table 6.6: Flow values as per probability gradation for monitoring locations.

	Discharge of certain probabilities (m^3/sec)				
	High Flows <10 %	**Moist Conditions 10-40 %**	**Mid-Range Flows 40-60 %**	**Dry Conditions 60-90 %**	**Low Flow >90 %**
Nonquon River at Marsh Hill Road	>0.165	0.165-0.079	0.079-0.055	0.055-0.028	<0.028
Nonquon River at Scugog Line 6	>0.619	0.619-0.212	0.212-0.137	0.137-0.052	<0.052

Flood Vulnerable Areas

Extreme weather events such as heavy rainfall and snowmelt can result in dangerous flood conditions, erosion and slope failure. The most common occurrences of flooding within the Nonquon River watershed are during the spring freshet and mid-winter rain events that occur when drainage channels and rivers are blocked by snow and ice. Severe flooding conditions can threaten property and humans.

A partial inventory of flood vulnerable roads was completed as part of the Nonquon River Subwatershed Study and Nonquon Industrial Tributary Master Drainage Plan (NRSS) (Palmer 2005) in-and-around the Nonquon Industrial Tributary Area and a section of the Layton River that has historically been subject to flooding. The NRSS examined five road crossings of the watercourse within the watershed to determine the current level of service and comment on whether the existing structures could cause adverse backwater effects to the surrounding lands. In this survey it was determined that the culvert downstream of the Nonquon Industrial Tributary Area watercourse was only designed for a 5-year storm event, and as a result has the potential to cause flooding upstream. To address potential flooding issues, the Regional Municipality of Durham is investigating stormwater management options in the area. The NRSS also found that there are no documented municipal drains constructed within the Nonquon River watershed, however there are numerous tile drains.

Kawartha Conservation maintains a database of the potential and observed flood prone areas within the watershed as a part of the Flood Forecasting and Warning Program. **Figure 6.8** depicts those locations within the Nonquon River watershed. The observed sites include: Scugog Townline Rd, just east of Old Simcoe Rd, Scugog Line 10, approximately 1km west of Till Side Road, and two locations on Scugog Line 6; one just west of highway 7/12 and the other less than a kilometer west of the main Nonquon Tributary crossing. Most of the flooding can be attributed to insufficient culvert capacity, or plugged culverts.

6.4 Baseflow

Baseflow is the portion of flow in a watercourse that comes from groundwater discharge or seepage, rather than direct runoff related to rain or snowmelt events. During most of the year, stream flow is composed of both groundwater discharge and surface runoff. Baseflow conditions are deemed to exist when groundwater provides the entire flow of a stream. When evaluating the health of a watercourse, baseflow is an important characteristic. In terms of aquatic life, one of the most important factors is the amount of sustainable flow in the channel. Streams with adequate baseflow can support fish and aquatic organisms during prolonged dry periods. Furthermore, groundwater temperatures are nearly uniform year-round, so groundwater discharge provides insight into temperature stability in surface water.

Natural land cover plays an important role in recharging aquifers and hence sustaining baseflow. Human activities such as urbanization, wetland drainage, deforestation, and an increase in impervious surfaces within a watershed can significantly affect recharge to groundwater and subsequently, baseflow conditions.

Baseflow monitoring provides baseline data and long-term trends of baseflow rates throughout the watershed. Monitoring also allows for the determination of the spatial distribution of baseflow, including areas and stream reaches of significant groundwater discharge.

Methodology

Baseflow monitoring involves measuring the discharge (volume of water that flows through a cross section of a watercourse in one second) at designated locations during prolonged periods of dry weather. In general, the sample sites were located at every stream-roadside crossing.

Criteria for site selection include:

- Accessibility – preference was given to easily accessible, public sites;
- Hydrological features – it is important to locate sites upstream and downstream of the confluence of tributaries, and suggested groundwater discharge areas etc; and,
- Water use features – upstream and downstream of water taking or discharge locations.

Baseflow sampling was conducted following standardized procedures outlined in Hinton (2005). Two flow measurement techniques were utilized: the area-velocity method and volumetric method. In the area-velocity method, stream velocity and water depth measurements are taken along a transect perpendicular to the stream flow direction. Total discharge is calculated by integrating the stream velocities with the cross sectional area of the stream profile defined by the transect. The volumetric method involves measuring the amount of time taken for a container of known capacity to be filled. This is a simple method for measuring small streams where all of the flow is concentrated and a container can be filled in a reasonable amount of time. Stream discharge is calculated by dividing the total volume of water by the amount of time required to fill the container.

Weather conditions may pose significant limitations to baseflow measurements. In order to collect comparable and reliable data, the measurements were taken under consistent groundwater inflow conditions (i.e., the volume of groundwater storage did not experience significant change). The summers of 2008 and 2009, with abundant precipitation, did not allow for the collection of quality baseflow data.

Findings and conclusions

The most comprehensive baseflow dataset for the Nonquon River watershed was obtained during the summer of 2006. In total, 38 sites throughout the Nonquon River watershed (including Layton River) were visited during August 8-11, 2006. No precipitation was recorded over these 3 days, allowing for comparison and analysis of discharge measurements to interpret the spatial distribution of baseflow. Twenty-three sites were found flowing, but 7 were unsuitable for sampling (either they were too deep for wading, or the bottom was unsafe for walking). All seven sites were located within Nonquon River watershed, on the main channel of the Nonquon River. Eight sites were found dry or with standing water in the channel, indicating that no groundwater inflow is available upstream of the sampling location (**Table 6.7**). The values of flow and position of the monitoring sites within the drainage network as well as overall status of the watercourse reach (loosing or gaining) are shown in **Figure 6.9**. Further data analysis involved the calculation of net discharges per square kilometre of the upstream catchment (**Figure 6.10**).

Data collected during the baseflow survey illustrates the magnitude and distribution of baseflow discharge within the Nonquon River watershed. Baseflow analysis has revealed that:

- Layton River contributes approximately 15% of the total baseflow of the Nonquon River;

- the headwaters of Layton River (portion of watershed that is situated upstream of Brock Concession 5 Road) are an extremely important groundwater discharge area (this area generates a greater flow volume than the Layton River discharges at the confluence with Nonquon River);

- average flow rate per square kilometre at headwaters of the Layton River is 19.2 l/sec/km^2, the greatest observed within the Nonquon River watershed (the average flow rate for the Nonquon River watershed is 3.5 l/sec/km^2);

- 68% of the discharge produced in the upper portion of the watershed is lost between Brock Concession Road 5 and Regional Road 13 (the cause of this phenomenon needs further investigation; both anthropogenic (such as water taking) and natural factors (such as high evapotranspiration and water storage) may be contributing factors of flow loss);

- about 16% of the total flow of the Nonquon River is produced within the Oak Ridges Moraine portion of the watershed, situated upstream of Scugog Line 6 (the average flow rate for this area is 11.9 l/sec/km^2 per square kilometre); and,

- the west-central portion of the watershed is an area with no groundwater discharge and in fact, a loss of flow was observed in this area.

Further investigation, including measurements of locations on the main channel of the Nonquon River that were previously omitted, must be conducted to define the baseflow gains/loses in the central section of the Nonquon River watershed.

Table 6.7: Baseflow monitoring sites, 2006.

	Number of baseflow sites			
	Flowing		Dry / Standing Water	Total
	Measured	Unsuitable		
Nonquon River	12	7	6	25
Layton River	11	0	2	13
Total	23	7	8	38

6.5 Groundwater Characterization

The information presented in this section is taken from the executive summary from a report by GENIVAR (2011), that was recently completed for Kawartha Conservation to characterize groundwater resources within the Nonquon River watershed, as well as the other three watersheds (Southern Lake Scugog Tributaries, Blackstock Creek and East Cross Creek) that require watershed plans. Surficial geology plays an important role in the regional drainage and recharge patterns of the Nonquon River watershed. Normally, higher infiltration rates can be observed in the coarse grained deposits associated with the Moraine, as these deposits exhibit a higher permeability. Additionally, some of the geological units that underlie the Nonquon River watershed are partially or completely saturated with groundwater. The characterization presented herein is based on review of work performed by others with some additional interpretation and analysis using available data and tools.

Hydrostratigraphy

The four sub-watersheds share a similar hydrogeological setting and history. The stratigraphy and hydrostratigraphy presented herein has been based on interpretations provided by the Conservation Authorities Moraine Coalition/York-Peel-Durham-Toronto groundwater studies. This interpretation documents an inter-layered sequence of sedimentary deposits that are considered to be aquifers and silt, clay and till deposits that are considered to be aquitards. Groundwater flow in aquifers tends to be directed horizontally, while groundwater flow through aquitards tends to be directed vertically.

The GENIVAR (2011) report presents a series of figures and maps for each of the watershed areas that describe the general distribution and characteristics of each aquifer layer. **Figure 6.10** shows the locations of two representative cross-sections are provided for each subwatershed to show how the layers interrelate. **Figure 6.11** and **Figure 6.12** show these hydrostratigraphic layers.

The observed hydrostratigraphic layers observed from the surface to the bedrock at depth include:

- Layer 1 - Recent Deposits;
- Layer 2 - Late Stage Lacustrine/Halton Aquitard;
- Layer 3 - Oak Ridges Moraine Aquifer Complex (ORAC);
- Layer 4 - Upper Newmarket Aquitard;
- Layer 5 - Inter-Newmarket Sediments (INS) [Aquifer];
- Layer 6 - Lower Newmarket Aquitard or Tunnel Channel Silts;
- Layer 7 - Thorncliffe Aquifer Complex (TAC) or Tunnel Channel Sands;
- Layer 8 - Sunnybrook Aquitard;
- Layer 9 - Scarborough Aquifer Complex (SAC); and
- Layer 10 – Bedrock [Aquifer].

The Oak Ridges Moraine Aquifer Complex (ORAC) is a significant aquifer layer, particularly in the southern parts of each watershed. This layer is typically observed as a wedge that is thickest along the center of the Oak Ridges Moraine and thins north. This layer is not continuous across the watersheds. This layer is important hydrogeologically as it receives much of the groundwater recharge that then either flows to surface water, laterally through the edges of the watershed, or downward to another aquifer layer.

The lower portion of the Newmarket Aquitard is laterally extensive and represents the glacial till deposit associated with the main advance of the last glacial period. The upper portion of the Newmarket Aquitard and the layer of interpreted sediments deposited between the two till events are not continuous across the entire area. This may mean that they were either not deposited or removed by erosion prior to deposition of the ORAC deposits.

The Newmarket Aquitard is observed to have been partly removed by a series of channels that have subsequently been filled first with coarse sand and toward the top finer sand and silt. These channels have been interpreted as having formed beneath the ice sheets and are therefore referred to as "tunnel channels". These tunnel channels can have a significant role in the hydrogeological setting as they provide a conduit for lateral groundwater movement along their predominantly northeast orientation, or for groundwater movement up and down between the surface and deeper aquifer layers.

The Thorncliffe Aquifer Complex (TAC) is observed to be an important aquifer layer in the groundwater flow system. The TAC has been interpreted to be laterally extensive in the subsurface beneath the study area. Groundwater recharge from surface is observed to infiltrate downward to the TAC and then move laterally in conjunction with the regional drainage pattern. Groundwater flow then moves from the TAC upwards to surface beneath the observed surface water drainage features (streams, wetlands, etc). Groundwater can also move laterally between the north draining watersheds, and potentially to the south beneath the Oak Ridges Moraine.

The Scarborough Aquifer Complex (SAC) and the upper portion of the bedrock are typically considered to behave as one aquifer layer. This layer is also interpreted to be laterally extensive although there is considerably less information available on which to base these interpretations. The work has shown that in general the movement of groundwater in the groundwater flow system generally follows the regional ground surface topography. There is evidence presented that the flow divide within individual aquifer layers may not always correspond to the surface watershed divide. This is observed most notably along the Oak Ridges Moraine where a combination of conditions relating to the soil types and stratigraphic layers appears to result in groundwater flow being directed in a southerly direction from areas north of the surface watershed divide. The current numerical model suggests that the contribution of groundwater flow to the south draining watersheds may be significant. Further work is required to improve the confidence in this interpretation and to quantify the flux of water being directed to the South.

Regional groundwater flow model

A regional groundwater flow model previously constructed for use by Conservation Authorities Conservation Authorities Moraine Coalition/York-Peel-Durham-Toronto groundwater management strategy provided and adapted for use in evaluating the flux of groundwater movement and water budgets within the individual watersheds. Groundwater flow is typically directed in a northerly direction from the Oak Ridges Moraine towards Lake Scugog. The majority of recharge is directed downward to the Thorncliffe Aquifer Complex. Although the groundwater flow tends to be directed downward overall, groundwater moves both up and down between each of the identified hydrostratigraphic/model layers. The upward movement of groundwater tends to occur adjacent to and beneath streams and surface water features. There is a net downward movement of groundwater below the Thorncliffe Aquifer Complex, however the flux is a small proportion of the recharge that moves down to the lower overburden layers and bedrock (<1% of recharge). Additional work will be required to improve the ability of the models to estimate the flux across the north and south boundaries.

Simulated Water Budget – Nonquon River Watershed

The findings presented herein reflect interpretations and results of numerical model applications that are based on available data. The distribution, quantity, and quality of the available data to describe geology, hydraulic properties and groundwater elevations is variable. The interpretative studies and models are also being conducted on a regional scale and as such, it is not unusual that model results do not directly correspond with local data. This study has identified several attributes of the conceptual and numerical models that could potentially be improved but considerable effort may be required to balance the effects of changes of competing factors. The results presented herein are considered to be based on the currently best available tools and may change as more data becomes available or the capacity of these tools improves.

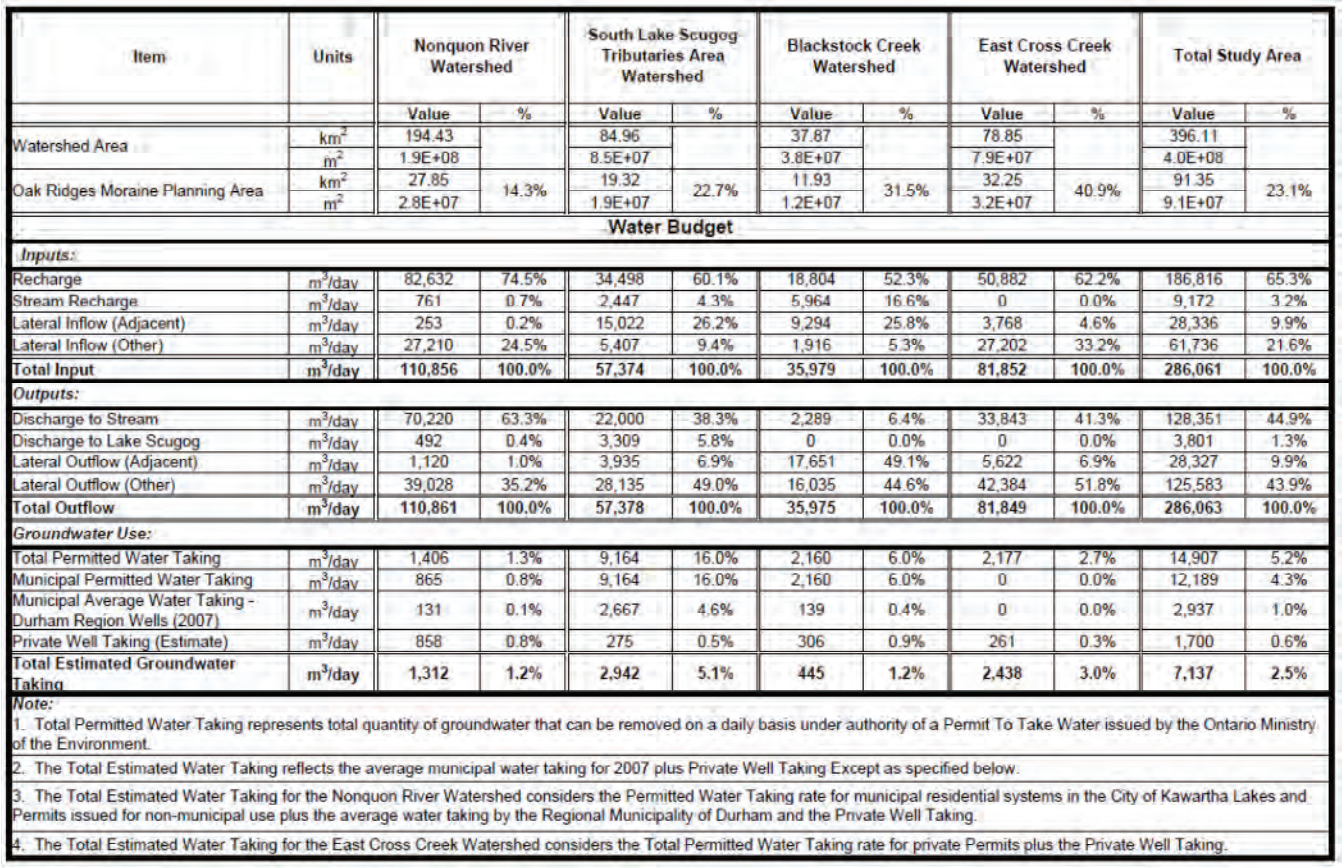
The findings of the water budget analysis are summarized in **Table 6.8**. The numerical groundwater flow model as described in GENIVAR (2011) was applied to quantify the components of the water budget equation for the Nonquon River watershed. The results of this analysis are summarized in **Figure 6.13**.

Figure 6.13 illustrates the flow into and out of each of the hydrostratigraphic layers considered in the numerical groundwater flow model. Flow in typically occurs through recharge, recharge in the streams, or lateral transfers from adjacent watersheds. Lateral transfers from the adjacent watershed that drains to Lake Scugog were quantified separately. The lateral transfers from watersheds on the north, west, and south sides of the Nonquon River watershed are presented as one value.

Some observations drawn from the analysis include:

- Recharge from infiltration is primarily received in the two upper hydrostratigraphic layers (Surficial/Weathered Till/Halton Till). Recharge accounts for 74.5% of the input to the groundwater flow system. Lateral inflow from adjacent watersheds accounts for 24.5% of the total inputs.
- Net groundwater flux appears to be downward from surface to the Thorncliffe Aquifer Complex.
- There is minor potential for downward flux of groundwater below the Thorncliffe Aquifer Complex. This flux is observed to be transferred laterally out of the system in the weathered bedrock layer.
- The quantity of water transferred downward to each underlying layer decreases with increasing depth.
- The majority of the discharge to streams occurs through the Surficial/Weathered Till and the Thorncliffe Formation. Discharge to streams accounts for approximately 63% of the flow out of the groundwater flow system.
- Lateral outflow accounts for approximately 36% of the flow out of the groundwater system. There is a net outflow on the order of 11,800 m^3/day transferred laterally to adjacent watersheds. The lateral transfer is primarily within the Oak Ridges Moraine Aquifer Complex and the Thorncliffe Aquifer Complex layers. The majority of this outflow is directed to the south.
- The total permitted groundwater taking is less than 2% of the estimated recharge to the groundwater system and less than 1.5% of the total input or output from the groundwater flow system. The removal of groundwater from aquifers as water taking would result in a reduction to either the discharge to streams or lateral outflow. The groundwater from municipal takings will ultimately be returned to the surface water system following treatment.
- The observed groundwater taking from the municipal wells for the Hamlet of Greenbank in 2007 was observed to be less than 0.15% of the estimated recharge to the groundwater system and approximately 0.1% of the total input or output from the groundwater flow system. The groundwater from municipal takings will ultimately be returned to the subsurface or to the surface water system after treatment.
- The total groundwater use for residential purposes by the private water wells is on the order of 1% of the estimated recharge to the groundwater system and less than 1% of the total input or output from the groundwater flow system. The water from private wells is typically nonconsumptive and returned as recharge to shallow aquifer units.

Table 6.8: Summary of groundwater budget analysis.



Item	Units	Nonquon River Watershed		South Lake Scugog Tributaries Area Watershed		Blackstock Creek Watershed		East Cross Creek Watershed		Total Study Area	
		Value	%	Value	%	Value	%	Value	%	Value	%
Watershed Area	km^2	194.43		84.96		37.87		78.85		396.11	
	m^2	1.9E+08		8.5E+07		3.8E+07		7.9E+07		4.0E+08	
Oak Ridges Moraine Planning Area	km^2	27.85	14.3%	19.32	22.7%	11.93	31.5%	32.25	40.9%	91.35	23.1%
	m^2	2.8E+07		1.9E+07		1.2E+07		3.2E+07		9.1E+07	
Water Budget											
Inputs:											
Recharge	m^3/day	82,632	74.5%	34,498	60.1%	18,804	52.3%	50,882	62.2%	186,816	65.3%
Stream Recharge	m^3/day	761	0.7%	2,447	4.3%	5,964	16.6%	0	0.0%	9,172	3.2%
Lateral Inflow (Adjacent)	m^3/day	253	0.2%	15,022	26.2%	9,294	25.8%	3,768	4.6%	28,336	9.9%
Lateral Inflow (Other)	m^3/day	27,210	24.5%	5,407	9.4%	1,916	5.3%	27,202	33.2%	61,736	21.6%
Total Input	**m^3/day**	**110,856**	**100.0%**	**57,374**	**100.0%**	**35,979**	**100.0%**	**81,852**	**100.0%**	**286,061**	**100.0%**
Outputs:											
Discharge to Stream	m^3/day	70,220	63.3%	22,000	38.3%	2,289	6.4%	33,843	41.3%	128,351	44.9%
Discharge to Lake Scugog	m^3/day	492	0.4%	3,309	5.8%	0	0.0%	0	0.0%	3,801	1.3%
Lateral Outflow (Adjacent)	m^3/day	1,120	1.0%	3,935	6.9%	17,651	49.1%	5,622	6.9%	28,327	9.9%
Lateral Outflow (Other)	m^3/day	39,028	35.2%	28,135	49.0%	16,035	44.6%	42,384	51.8%	125,583	43.9%
Total Outflow	**m^3/day**	**110,861**	**100.0%**	**57,378**	**100.0%**	**35,975**	**100.0%**	**81,849**	**100.0%**	**286,063**	**100.0%**
Groundwater Use:											
Total Permitted Water Taking	m^3/day	1,406	1.3%	9,164	16.0%	2,160	6.0%	2,177	2.7%	14,907	5.2%
Municipal Permitted Water Taking	m^3/day	865	0.8%	9,164	16.0%	2,160	6.0%	0	0.0%	12,189	4.3%
Municipal Average Water Taking - Durham Region Wells (2007)	m^3/day	131	0.1%	2,667	4.6%	139	0.4%	0	0.0%	2,937	1.0%
Private Well Taking (Estimate)	m^3/day	858	0.8%	275	0.5%	306	0.9%	261	0.3%	1,700	0.6%
Total Estimated Groundwater Taking	**m^3/day**	**1,312**	**1.2%**	**2,942**	**5.1%**	**445**	**1.2%**	**2,438**	**3.0%**	**7,137**	**2.5%**

Note:

1. Total Permitted Water Taking represents total quantity of groundwater that can be removed on a daily basis under authority of a Permit To Take Water issued by the Ontario Ministry of the Environment.
2. The Total Estimated Water Taking reflects the average municipal water taking for 2007 plus Private Well Taking Except as specified below.
3. The Total Estimated Water Taking for the Nonquon River Watershed considers the Permitted Water Taking rate for municipal residential systems in the City of Kawartha Lakes and Permits issued for non-municipal use plus the average water taking by the Regional Municipality of Durham and the Private Well Taking.
4. The Total Estimated Water Taking for the East Cross Creek Watershed considers the Total Permitted Water Taking rate for private Permits plus the Private Well Taking.

From GENIVAR (2011)

Recharge Flux – Nonquon River Watershed

Groundwater recharge is the process by which aquifers are replenished by the downward movement of water. The process occurs as water seeps vertically through unsaturated soils until it reaches a saturated layer or aquifer. Land surface characteristics play an important role in recharging aquifers and hence sustaining baseflow. Human activities such as urbanization, wetland drainage, deforestation and an increase in impervious surfaces can significantly affect this fragile balance and greatly affect groundwater quality and ecosystem health.

The total recharge to groundwater estimated for the Nonquon River watershed is 82,632 m^3/day. **Figure 6.14** illustrates the distribution of recharge to the groundwater system as obtained from the numerical groundwater flow model. The recharge was estimated by Earthfx (2006).

The spatial patterns of recharge correlate with the distribution of coarse and fine-grained sediments. The average recharge over much of the area is on the order of 90 mm/year. Recharge flux is higher in areas underlain by coarser sand and gravel deposits and low in areas underlain by low permeability silts and clays or glacial till. The recharge is observed to be highest in the south in association with the Oak Ridges Moraine. The observed recharge can be up to five (5) times the average values. The relative proportion of total groundwater recharge will be higher in the southern areas associated with the Oak Ridges Moraine.

In addition to the analyses provided by GENIVAR, groundwater recharge areas were assessed by a joint project of the Conservation Authorities Moraine Coalition (CAMC) and the municipalities of York, Peel, Durham and Toronto (YPDT) to fulfill the requirements of the *Clean Water Act*. The following is a summary of the CAMC-YPDT (2009) report.

Significant recharge areas were delineated by calculating a threshold rate above which an area would be considered a significant groundwater recharge area and comparing the recharge rates estimated across the Trent Conservation Coalition Source Protection Region to this threshold value. In accordance with the Technical Rules (OMOE 2009), this threshold value was calculated at 55% of the water budget surplus for each determined climate zone. Also, areas with shallow groundwater (water table less than 2 metres below the ground surface) were removed from the analysis because any recharge occurring within these low-lying areas is expected to would move laterally and discharge into adjacent streams and wetlands. The final delineation of significant groundwater recharge areas is shown in **Figure 6.15**.

Discharge Flux to Surface Water – Nonquon River Watershed

The total discharge to surface water within the Nonquon River watershed is calculated to be 70,712 m^3/day based on the numerical model outputs. The numerical model is considered to represent the average of observed baseflow measurements reasonably well but locally calculated measurements can be either higher or lower than the observed baseflow values. Baseflow is typically measured during a low flow period and may be less than the annual baseflow rate. Less than 1% of the calculated flux is directly discharged to Lake Scugog. A portion of the lateral transfer of water along the eastern boundary of the watershed will likely be transferred directly to Lake Scugog.

Figure 6.16 illustrates the observed distribution of the groundwater discharge to streams within the Nonquon River watershed. The grey circles represent locations where the numerical model calculates no flow to the surface water feature under steady-state conditions.

Aquifer Vulnerability

As part of the Technical Studies conducted under the *Clean Water Act*, 2006 to protect municipal sources of drinking water, two studies were completed for the Assessment Report to evaluate groundwater vulnerability for the Kawartha Haliburton Source Protection Region, including the Nonquon River watershed. The vulnerability assessments were carried out on a well to well basis, within the Wellhead Protection Area delineations to evaluate the immediate risk to contamination that may exist in that area to ensure the protection of the municipal water supply (GENIVAR 2010) and on a regional scale to understand the vulnerability of aquifers outside the delineated areas (AECOM 2009) to address groundwater source protection in areas that are not delineated as municipal Wellhead Protection Areas. The aquifer vulnerability assessment was conducted on a regional scale as part of the science-based Kawartha-Haliburton Assessment Report. The map illustrating the vulnerable areas is shown in **Figure 6.17**.

In addition to the above analyses, GENIVAR prepared vulnerability mapping for each individual aquifer within the Nonquon River watershed, as part of the groundwater characterization report (GENIVAR 2011). The regional groundwater vulnerability map, mentioned in the previous paragraph, does not reflect individual aquifer layers and thus is not consistent with the individual maps. Further discussions are ongoing to identify opportunities for consistency and watershed planning applicability.

6.6 Water Budget

A water budget is one of the major tools in describing and quantifying the various components of the hydrological cycle of the watershed. The hydrological cycle describes the constant movement of water above, on, and below the Earth's surface. The cycle operates across all scales, from the smallest stream catchment to a global scale. At all levels the cycle involves the movement of water through evapotranspiration, precipitation, surface runoff, subsurface flow and groundwater pathways (**Figure 6.18**).

Water is evaporated from the land, vegetation and bodies of water such as lakes, seas, and oceans to the atmosphere, using the radiant energy from the sun, and is returned back in the form of rain or snow. When precipitation falls to the ground surface, it becomes subdivided into different interconnected pathways. Precipitation can directly enter surface water or infiltrate into the ground to replenish soil moisture where it can be taken up by plants. Excess water percolates to groundwater aquifers or moves downward to sites of groundwater discharge. The rate of infiltration varies with land use, soil characteristics and the duration and intensity of the rainfall event. If the rate of precipitation exceeds the rate of infiltration the result is overland flow. Water reaching streams, both by surface runoff and groundwater discharge eventually moves to a larger body of water (lake, sea) where it is again evaporated to perpetuate the hydrological cycle.

Water takings from both surface and groundwater sources, as well as water discharges, spatial and temporal alterations of water flow and its regime, and the transfer of water between major watersheds are some of the ways humans influence the hydrological cycle.

A water budget analysis was recently conducted for the Nonquon River watershed as part of the Ontario Drinking Water Source Protection Program (XCG and Greenland 2008). However, an update was required to reflect newly obtained, watershed-specific values for evapotranspiration and groundwater.

Methodology

Since the hydrological cycle is a continuous process, the general water budget may be expressed as an equation, where the sum of water inputs is equal to the sum of water outputs plus changes in storage.

$$Inputs = Outputs + Change\ in\ storage \qquad (1)$$

When inputs and outputs are separated into components, equation (1) will look as following:

$$P + SWin + GWin + ANTHin = ET + SWout + GWout + ANTHout + \Delta S \qquad (2)$$

where:

P = precipitation;
SWin = surface water flow in;
GWin = groundwater flow in;

ANTHin = human input such as wastewater discharges;
ET = evaporation and transpiration;
SWout = surface water flow out;
GWout = groundwater flow out;
ANTHout = human removals and abstractions; and,
ΔS = change in storage.

When only a portion of a watershed is investigated the surface water input (SWin) from upstream sources in the watershed must be measured and accounted for in the water budget. If an entire watershed, subwatershed, or its headwaters portion is investigated, then the surface water input equals zero (SWin =0) and is removed from the calculation. However, groundwater inflow to the watershed still has to be calculated.

The groundwater fluctuation can be expressed as a difference between GWin and GWout (inputs and outputs) and is referred to as GWnet.

Anthropogenic influences such as water use, water removals and discharges can be expressed as ANTHnet, which represents the difference between ANTHin and ANTHout (inputs and outputs). As removals always exceed returning water, the ANTHnet should be placed in the output portion of the equation.

Therefore, equation 2 can be expressed as:

$$P + GWnet = ET + SWout + ANTHnet + \Delta S \quad (3)$$

A long-term water budget requires enough data to statistically determine a mean value, which is typically 25-30 years. For this period of time it is assumed that storage remains the same, thus ΔS will be equal to zero. Over a long period of time in a watershed with no or negligible groundwater pumping, the natural inputs will balance the natural outputs so the change in storage is assumed to be zero (Freeze and Cherry 1979). Soil moisture storage may vary considerably on a daily basis but the net change over an annual cycle and a long-term period will be negligible compared to other water budget components. Similarly, groundwater storage and land surface storage may fluctuate on a monthly or annual basis, but this variation will approach zero over an extended period of time provided other components of the water budget remain essentially constant.

The anthropogenic component (human withdrawals and returns) is considered negligible within the watershed. Therefore, the ANTHnet component of the equation is considered to be zero as well.

Since the area under investigation is the entire Nonquon River watershed, SWin is considered to be zero. The SWout component is quantified by discharge values (Q), measured at the Scugog Line 6 gauge station. Therefore, the symbol Q will be used further.

Considering the simplifications mentioned above, the water budget equation looks as following:

$$P + GWnet = ET + Q \quad (4)$$

The values for all components cannot be accepted without uncertainty. Hence, as a check on estimated values, it is useful to rearrange the equation to show estimated values and include the term “Residual”:

$$P + GWnet - ET - Q = Residual \quad (5)$$

Generally, water budget calculations require the use of long-term data sets. Since not enough data are available to calculate the long-term water budget for the whole watershed, the Canadian Nutrient and Water Evaluation Tool (CANWET) was used to generate the water budget. CANWET is a GIS-based software tool for estimating a water balance and nutrient loading (Greenland 2008).

The model allows consideration of multiple land use categories; each category is assumed to be uniform in distribution and parameters associated with land use. CANWET produces a continuous stream flow simulation using daily weather data and daily water balance. The surface runoff component of streamflow from each land use category is determined based on the Soil Conservation Services curve number approach. The curve number can be adjusted on a monthly basis to reflect variation of runoff characteristics throughout the year. The subsurface component of the streamflow is calculated using linear regression approach and can be adjusted on monthly basis as well.

Using total daily precipitation, daily maximum and minimum temperatures, the model can quantify the following characteristics on a monthly basis for a delineated drainage area: precipitation, evapotranspiration, surface runoff, sub-surface flow, total stream flow, and overall water takings.

Long term, average data for the water budget of the Nonquon River watershed were obtained from the following sources:

- Precipitation (P): is the mean annual total precipitation that was obtained from two Environment Canada climate stations in close proximity to the watershed (Blackstock and Burketon McLaughlin) for the period of 1984-2010.

- Net Groundwater value (GWnet): is the difference between lateral groundwater inflow and lateral groundwater outflow to the watershed, as determined by the groundwater modeling exercise by GENIVAR (2011).

- Evapotranspiration (ET): is the mean annual evapotranspiration that was obtained from the output of the Canadian Nutrient and Water Evaluation Tool (CANWET) from 1984-2010, and reflects physiography, soil type and land use inputs.

- Streamflow (Q): is the mean annual streamflow that was recorded at Scugog Line 6, obtained from the Water Survey of Canada database (HYDAT) from 1993-2009.

Findings

All components of the water budget are presented in depth (mm) over the watershed area. The long-term average annual values for the Nonquon River watershed are shown in **Table 6.9**.

As data demonstrate, 64% of precipitation that falls on the watershed evaporates back to the air from the ground surface or is transpired into the air by vegetation; about 31% of precipitation runs out of the watershed as stream flow and approximately 3% leaves the watershed as groundwater. The balance is available for many different uses of water including household, agricultural, industrial and recharge of groundwater.

As previous research shows, the groundwater flux is negative for the headwaters of the Nonquon River because the groundwater divide, is located further south and does not correspond to the surface water divide (GENIVAR 2011). As a result, some groundwater flows out of the Nonquon River watershed.

Additionally, a long-term monthly water budget was calculated for Nonquon River at Scugog Line 6 (refer **Table 6.10** and **Figure 6.19**).

Negative values of change in storage (ΔS) in March, June, July and August indicate that more water evapotranspires, and flows out of the watershed as streamflow and groundwater than comes into it with precipitation. As a result, there is a deficit in water budget during those months. Alternatively, the rest of the year (April, May, and September through February) is characterized by a surplus of water that accumulates in the watershed. That excess water percolates down the ground surface and replenishes groundwater, and is stored in lakes and wetlands. During those months when outputs of water resources to the watershed exceed input, the deficit is replenished from water, previously stored.

Table 6.9: Long-term, annual water budget components.

Catchment	Precipitation (mm)	Evapotranspiration (mm)	Groundwater Net (mm)	Surface Water Discharge (mm)	Residual (mm)
Nonquon River Watershed	913	582	-24	285	22

Table 6.10: Long-term, monthly water budget components.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
P (mm)	67	53	55	75	89	87	81	85	89	76	90	67	**913**
ET (mm)	1	1	14	22	43	111	174	116	69	22	7	2	**582**
GW (mm)	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	**-24**
Q (mm)	28	30	47	48	25	16	13	8	10	14	21	25	**285**
ΔS (mm)	36	20	-8	3	19	-42	-108	-41	8	38	60	38	**22**

6.7 Key Observations and Issues

- The Nonquon River is the largest tributary of Lake Scugog, comprising approximately 35% of the total lake watershed area.
- The Nonquon River watershed exhibits a natural flow regime, with well-defined seasonal flow patterns. High flows typically occur in the spring, associated with snowmelt, and throughout the year following high precipitation events. Low flows are typically observed in the summer and winter months.
- Climate change as it is forecasted has the potential to impact the flow regime of the Nonquon River and its tributaries, by reducing the duration and intensity of spring runoff and increasing potential for dry conditions and extreme high flow events during the summer.

- Vast wetlands and forested areas (up to 36% of the watershed), mostly located at middle and lower portion of the watershed, provide significant benefits to the surface water, moderating streamflow, providing high and low flow mitigation and assisting in groundwater recharge.
- The watershed contains significant areas where groundwater discharges to the watercourses. Of particular importance in providing groundwater inputs into the system is the headwaters of the Layton River and slopes of the Oak Ridges Moraine. The groundwater discharge supports baseflow and is a main component of the streamflow during the dry periods.
- Significant groundwater recharge areas are located at the Oak Ridges Moraine as well as throughout the watershed. Groundwater resources are replenished through those areas.
- As regional groundwater model demonstrates, the groundwater divide is likely located to the north of the surface water divide, and as such, portion of groundwater that is recharged in the Oak Ridges Moraine flows south, out of the watershed.
- The total permitted groundwater taking is less than 2% of the estimated recharge to the groundwater system and less than 1.5% of the total input or output from the groundwater flow system. The groundwater is withdrawn for municipal water supply and irrigation purposes, that is considered to be a non-consumptive use, that will ultimately be returned to the surface/groundwater system.
- According to the water budget, on the average, Nonquon River watershed receives 913 mm of precipitation. Five hundred and eighty two millimeters, or 64% of that is returned to the atmosphere through the evaporation and evapotranspiration. Two hundred and eighty five millimeters (31%) leaves the watershed as stream flow and approximately 24 mm (3%) as groundwater.
- Thirteen flood prone sites have been observed within the Nonquon River watershed. Most of the flooding can be attributed to insufficient culvert capacity, or plugged culverts.
- Some aspects of land use change, such as increasing of impervious surfaces, urban development and agricultural practices may influence the quantity of both surface and groundwater resources.

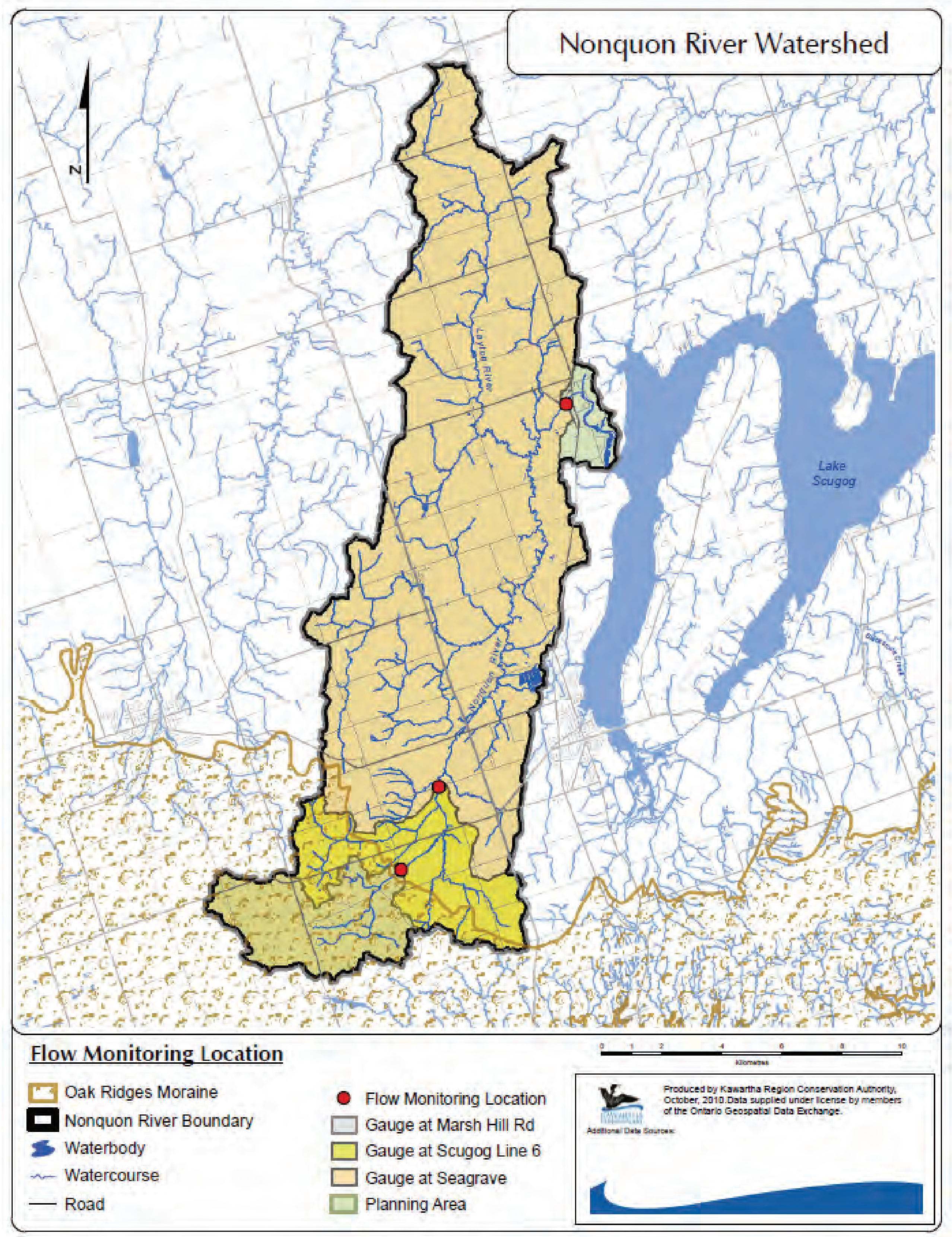


Figure 6.1: Continuous flow monitoring locations.

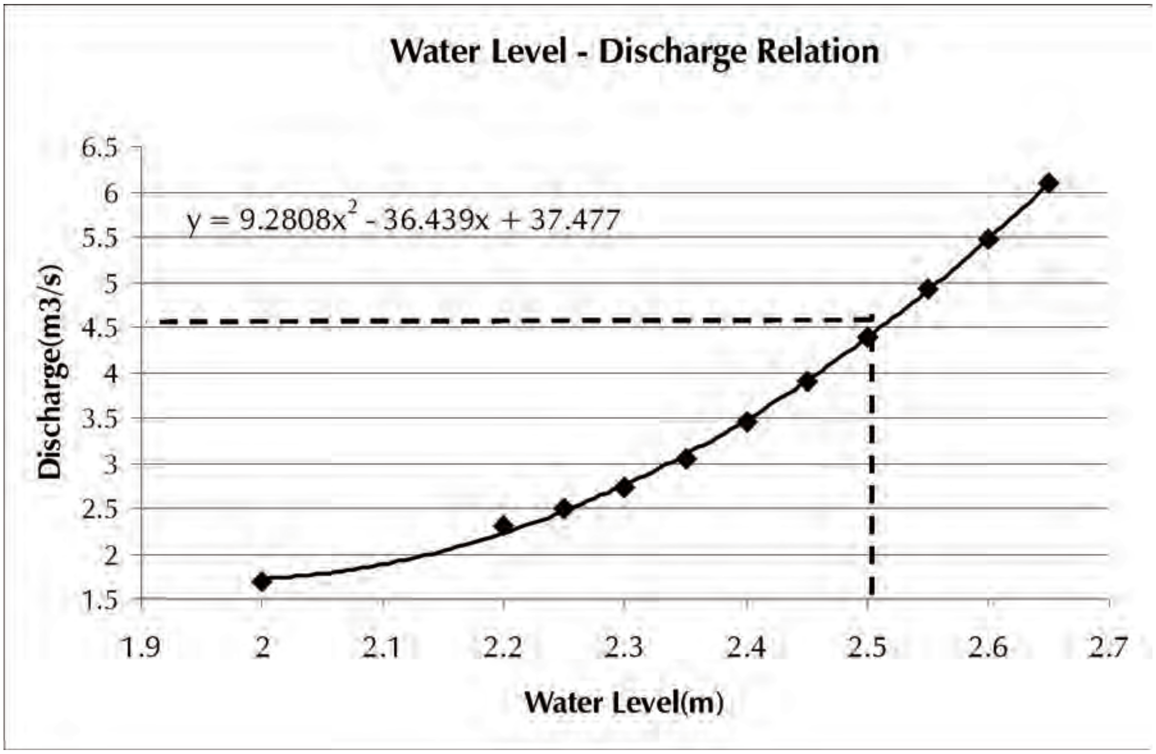


Figure 6.2: Sample rating curve.

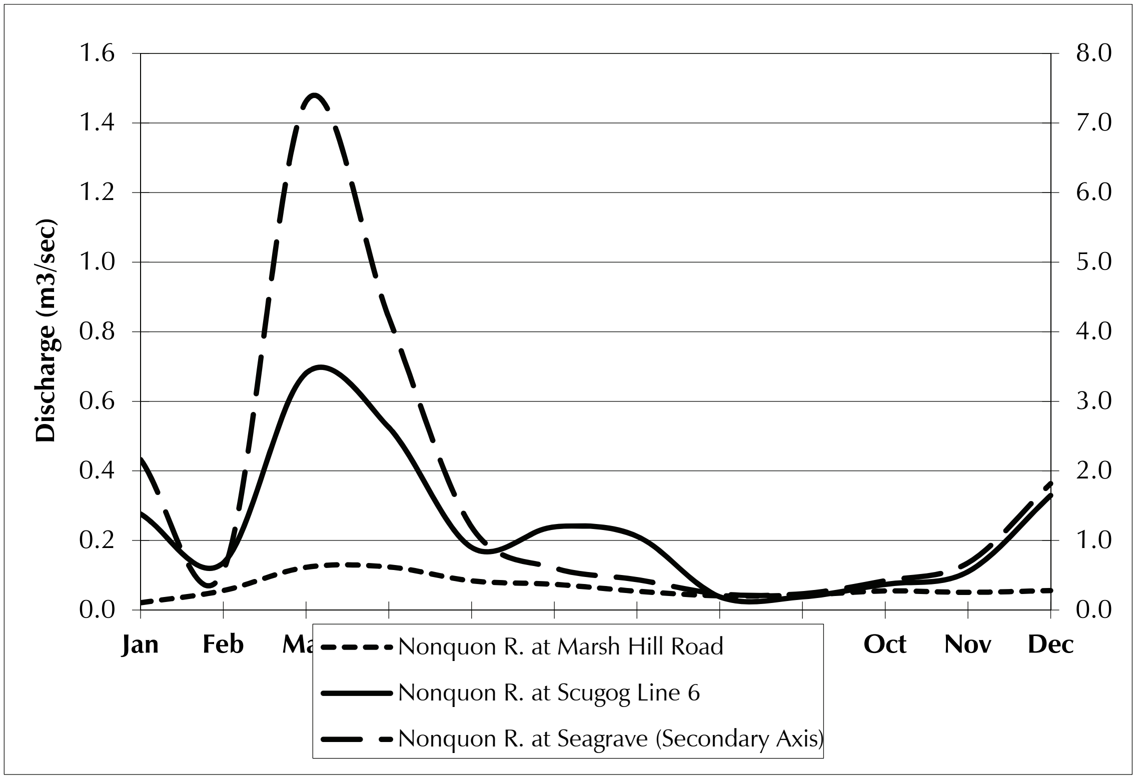


Figure 6.3: Monthly discharge, Nonquon River at gauging locations, 2007.

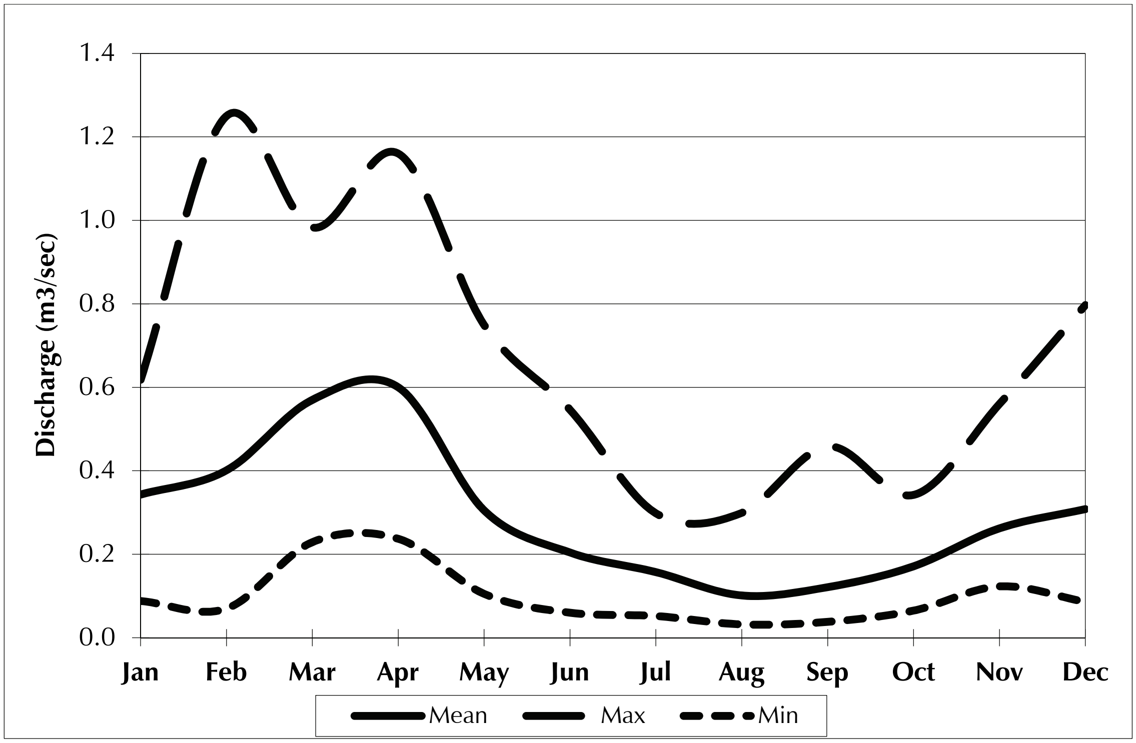


Figure 6. 4: Monthly mean, maximum and minimum discharge, Nonquon River at Scugog Line 6.

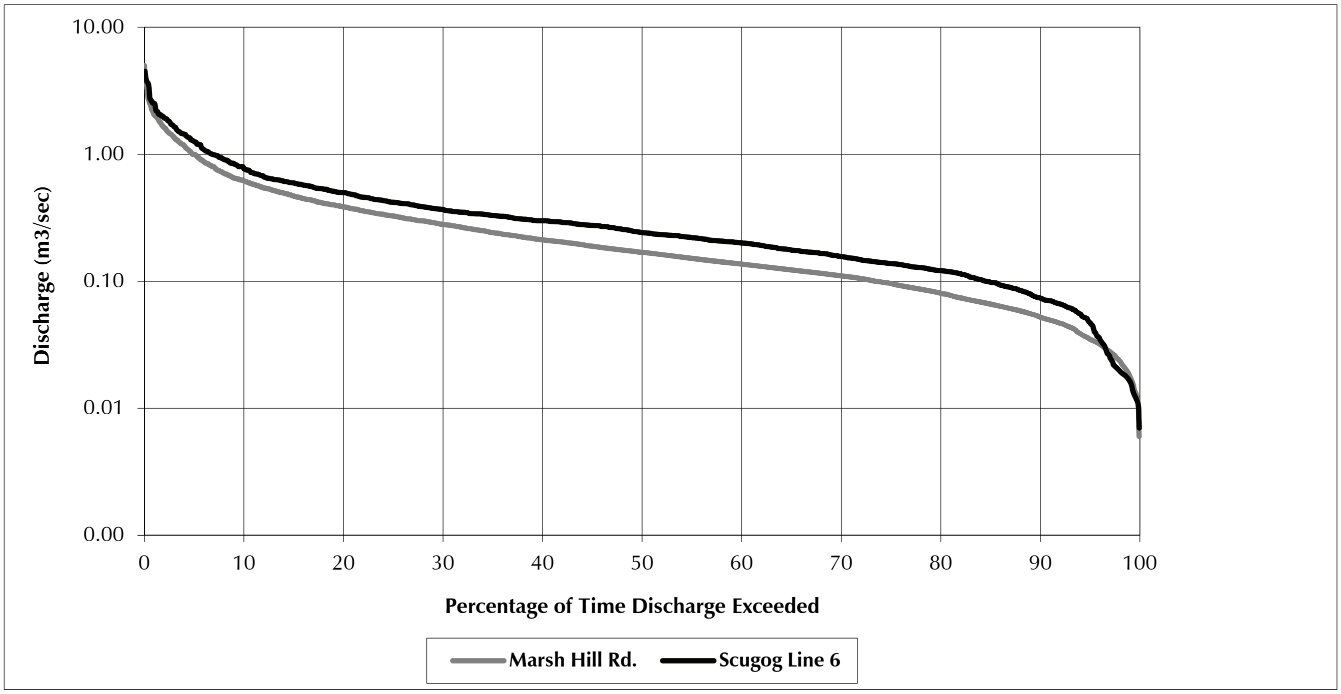


Figure 6.5: Semi-log plot of normalized Flow Duration Curves, Nonquon River at Marsh Hill Road and Nonquon River at Scugog Line 6.

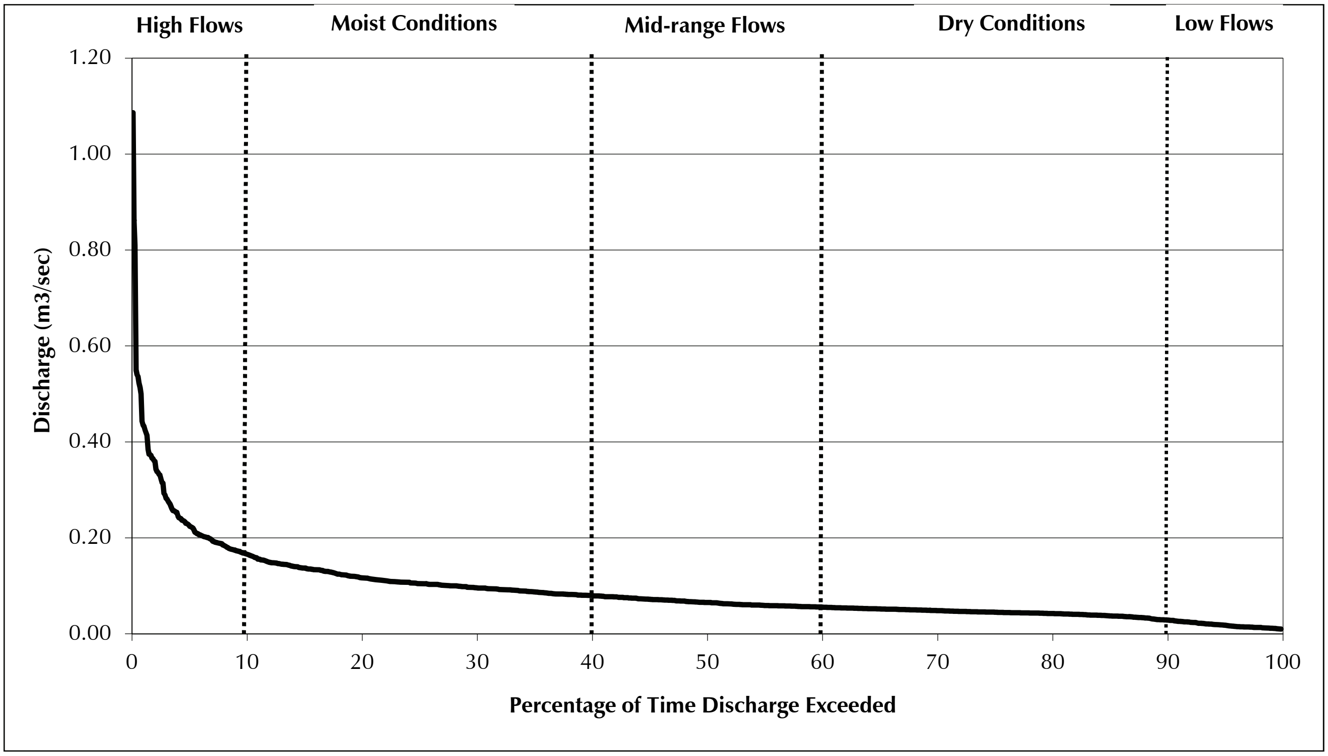


Figure 6.6: Flow Duration Curve, Nonquon River at Marsh Hill Road.

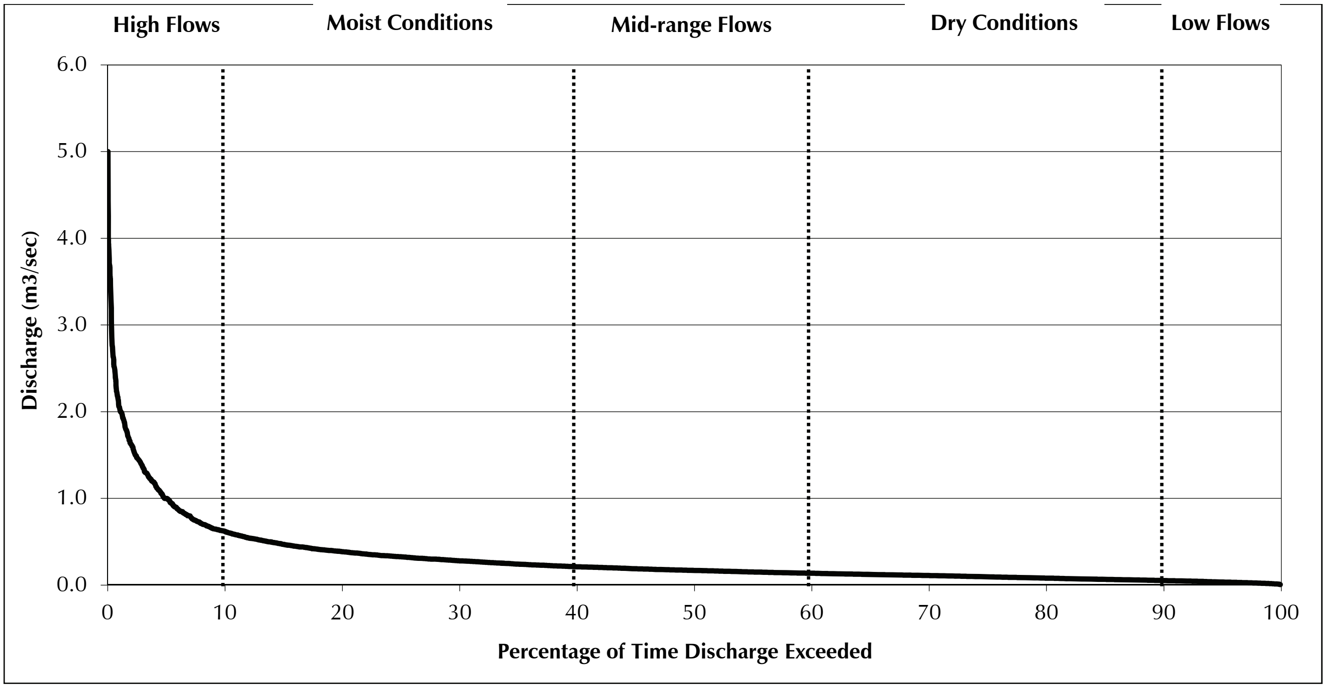


Figure 6.7: Flow duration curve, Nonquon River at Scugog Line 6.

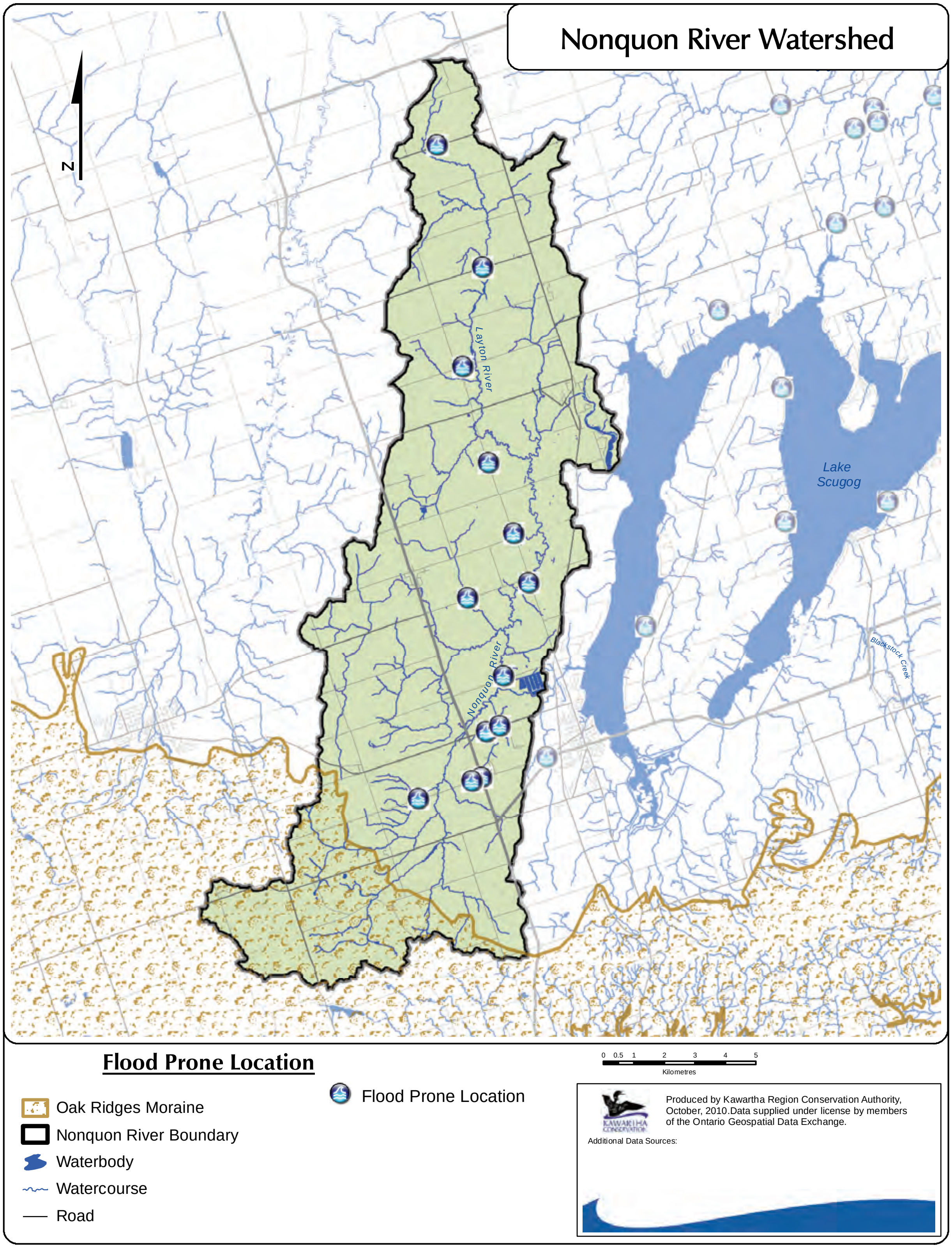


Figure 6.8: Flood vulnerable areas.

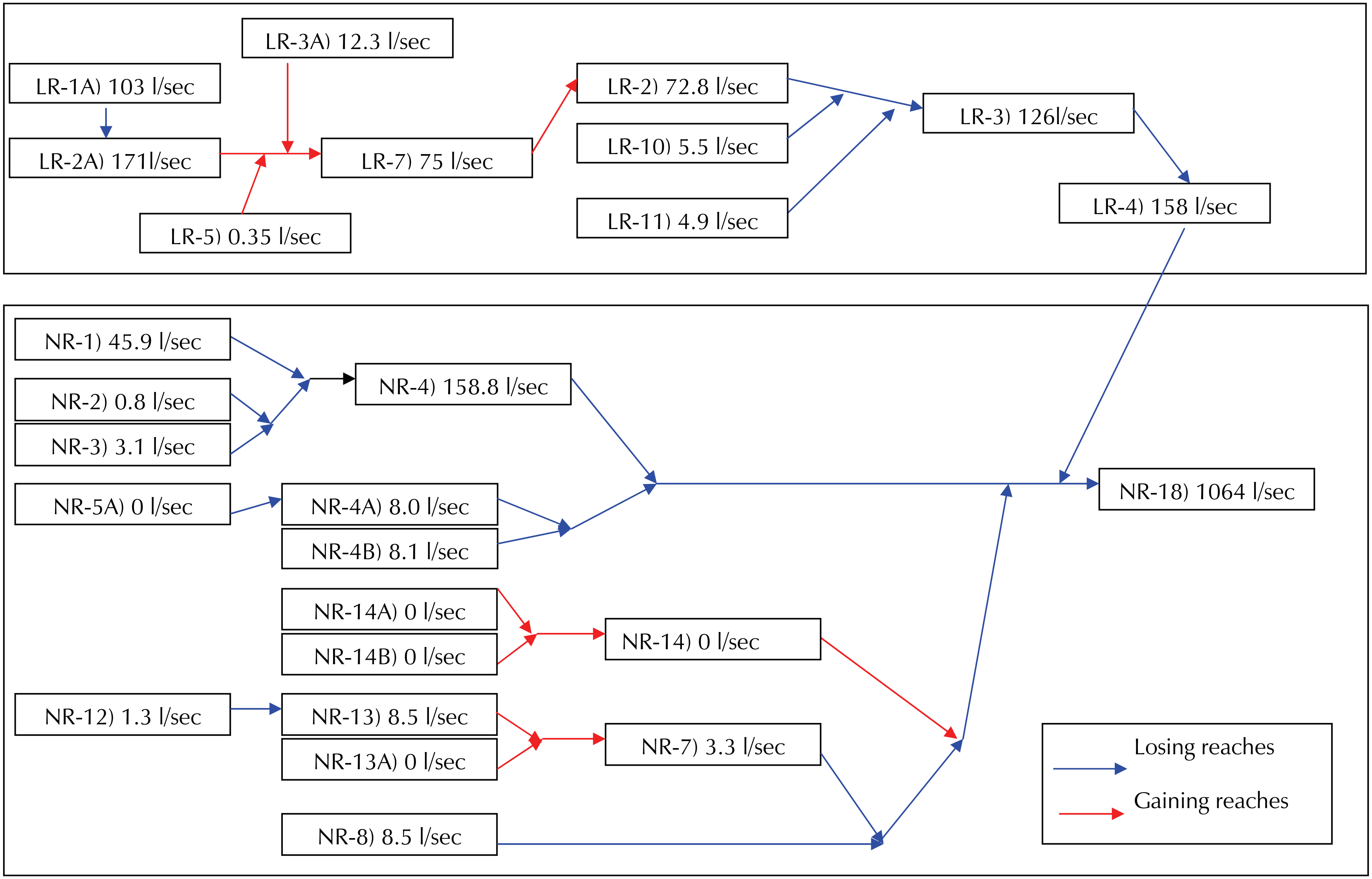


Figure 6.8: Site specific baseflow discharge.

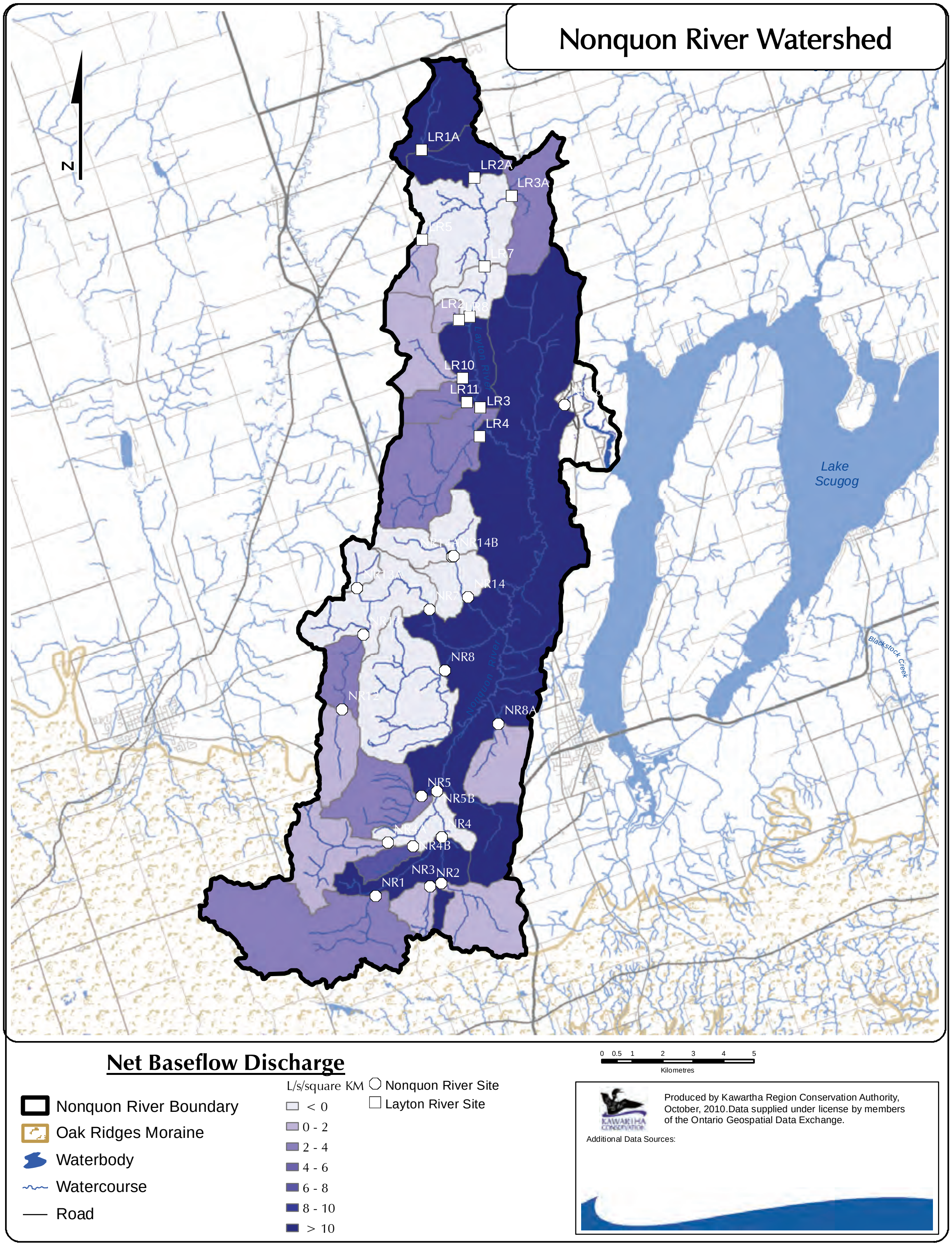


Figure 6.9: Net baseflow discharge per unit area.

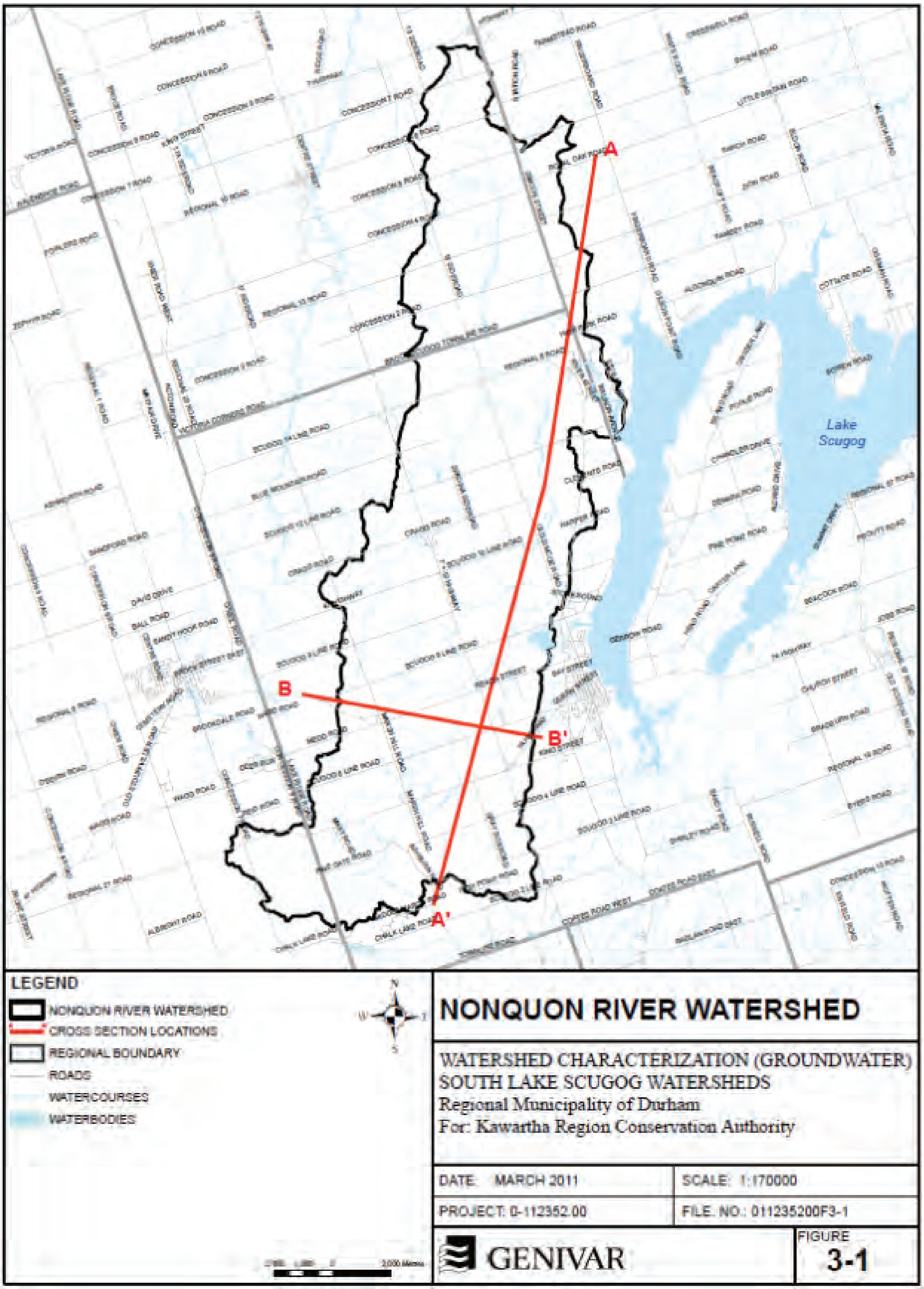


Figure 6.10: Locations of stratigraphic crosssections.

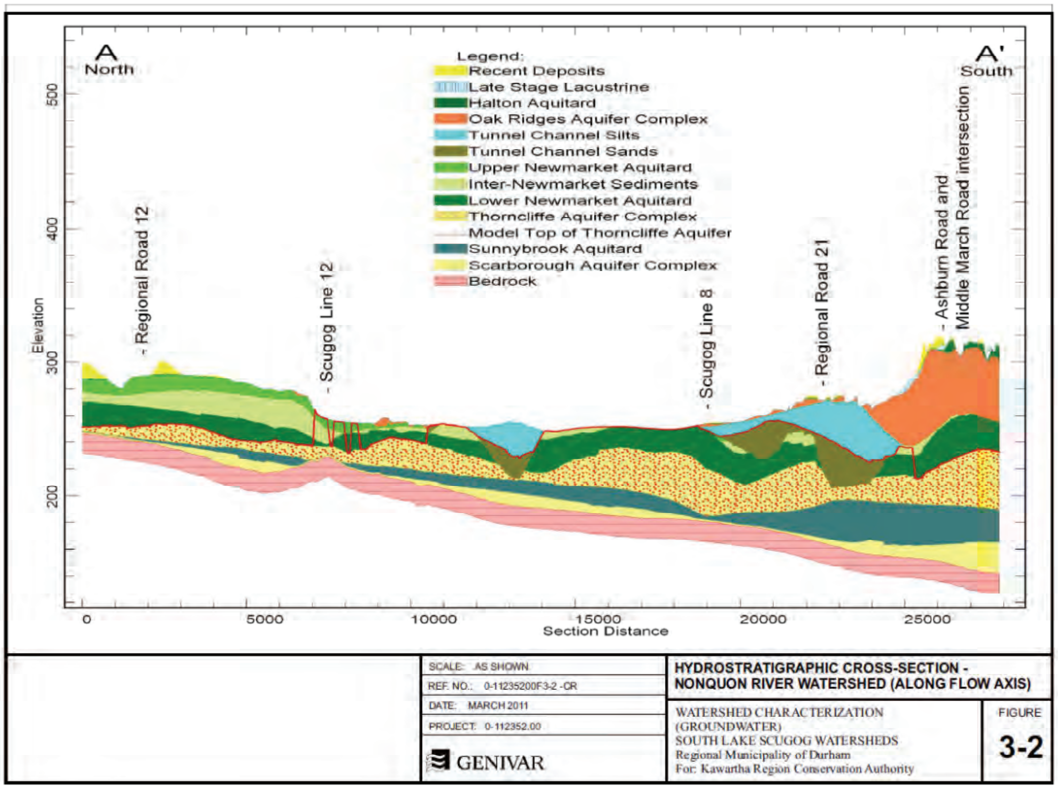


Figure 6.11: Crosssection A - A'.

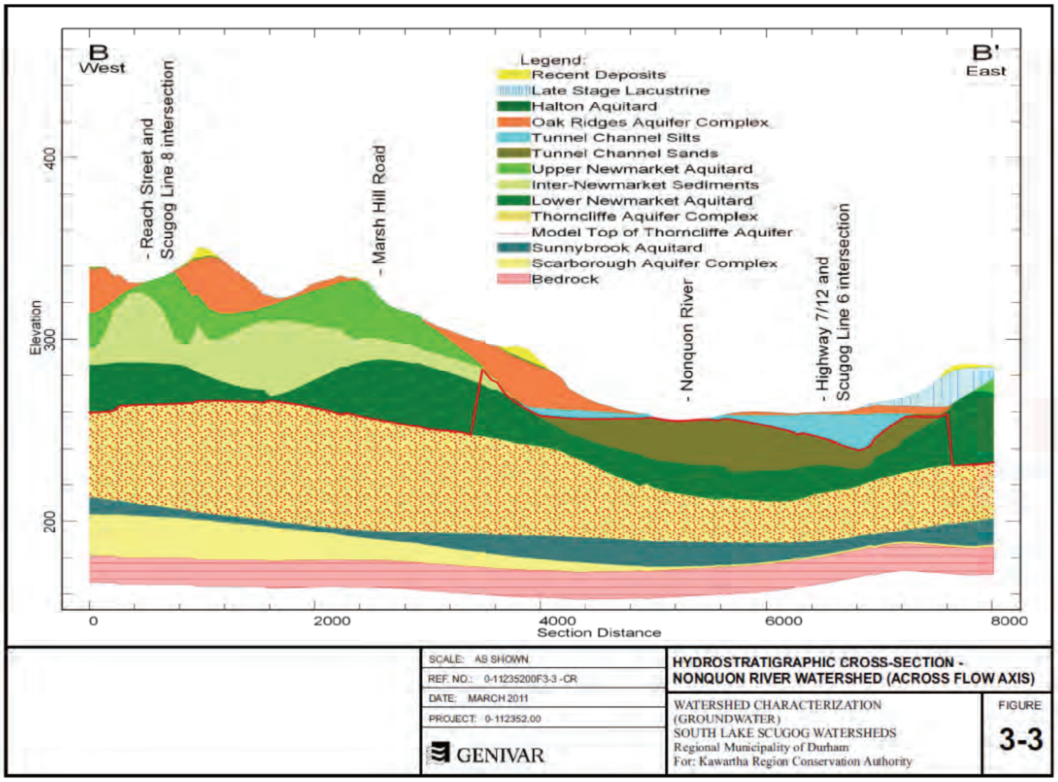
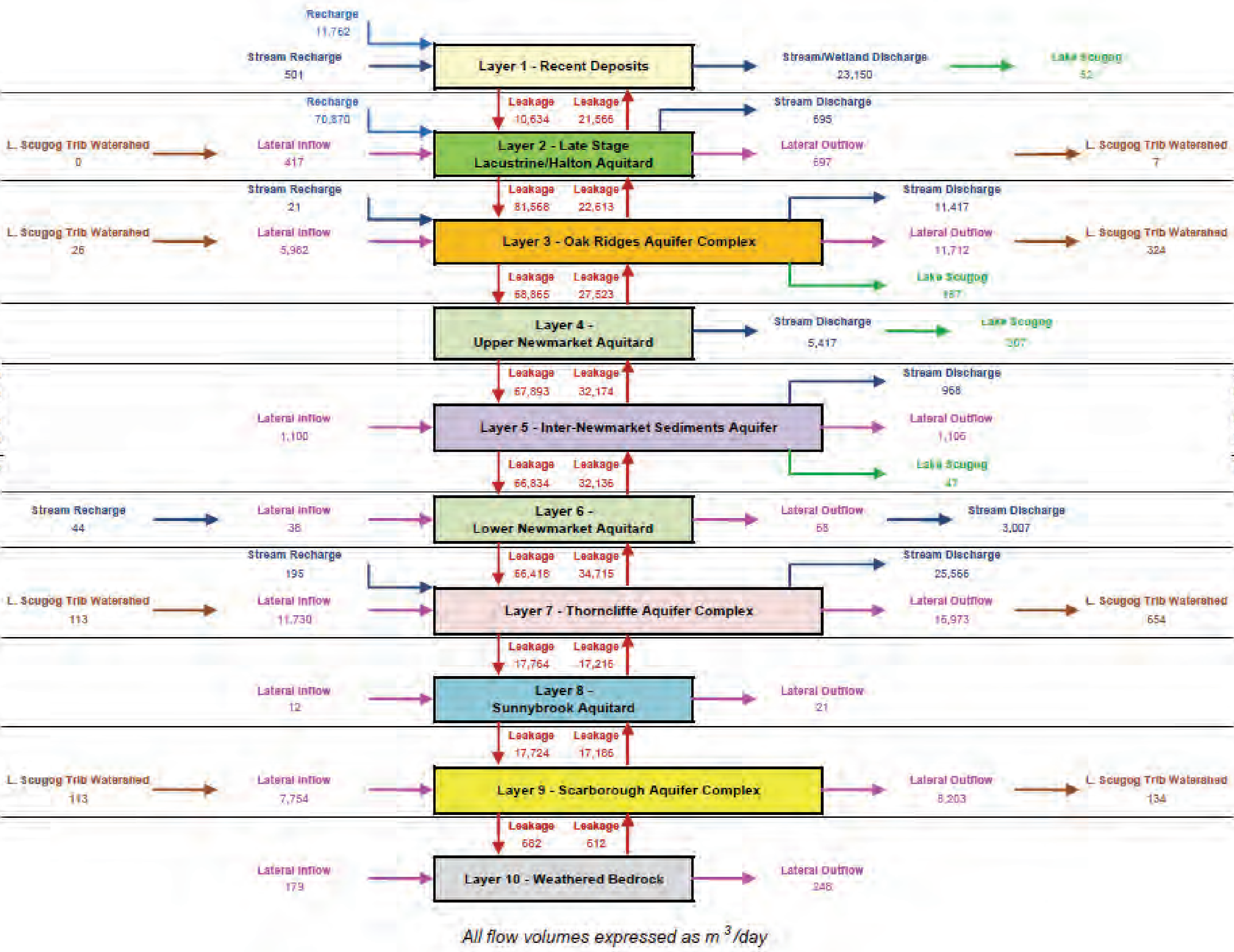


Figure 6.12: Crosssection B - B'.

Inputs	m³/day	%
Recharge	82,632	74.5%
Stream Recharge	761	0.7%
L.Scugog Trib	253	0.2%
Lateral Inflow	27,210	24.5%
Total Inputs	110,856	100.0%



All flow volumes expressed as m³/day

Outputs	m³/day	%
Stream	70,220	63.3%
Lake Scugog	492	0.4%
L. Scugog Trib	1,120	1.0%
Lateral Outflow	39,028	35.2%
Total Outputs	110,861	100.0%

Net Water Balance (In - Out) (%)
0.0%

From GENIVAR (2011)

Figure 6.13: Water budget for groundwater flow system

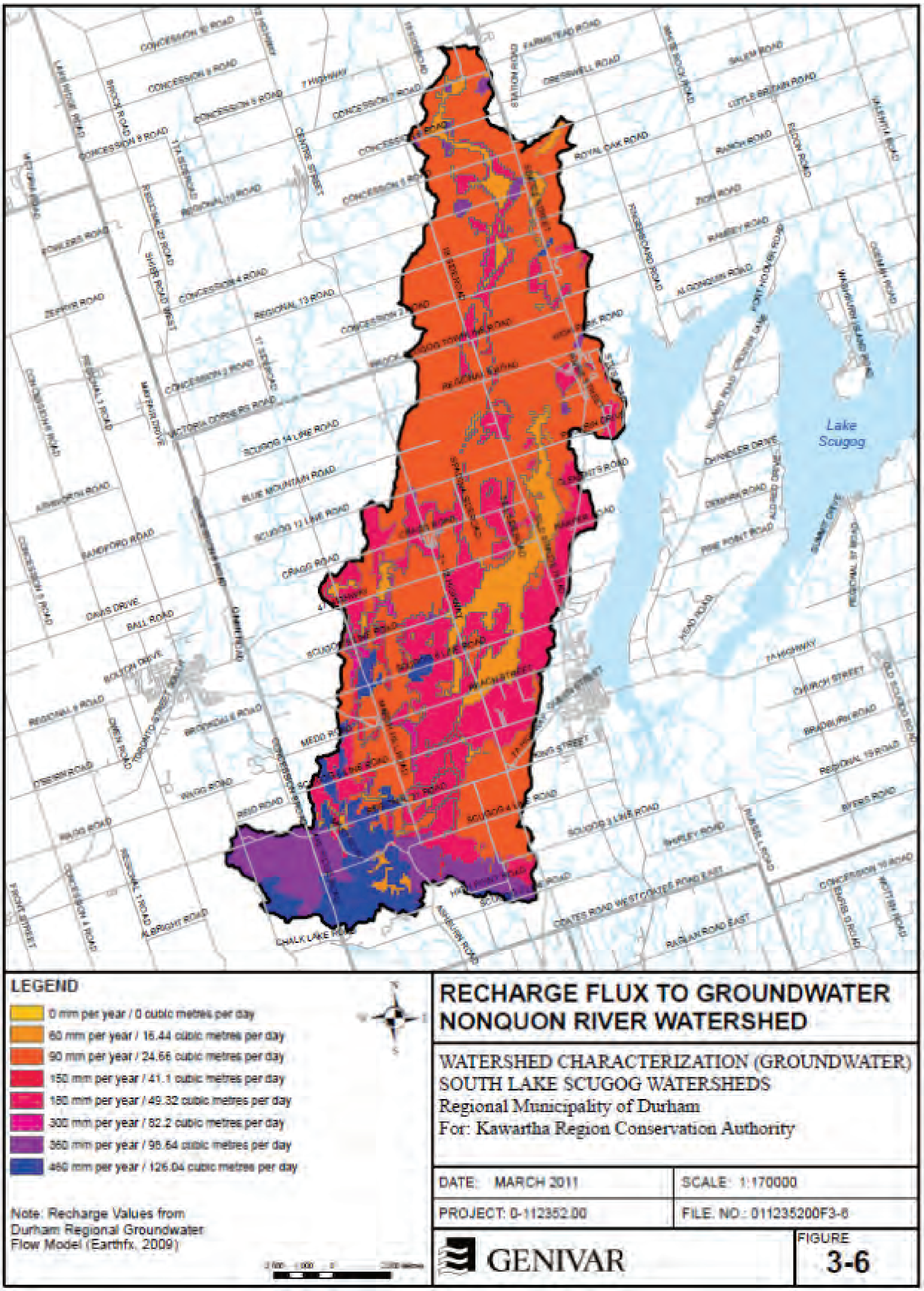


Figure 6.14: Recharge flux to groundwater.

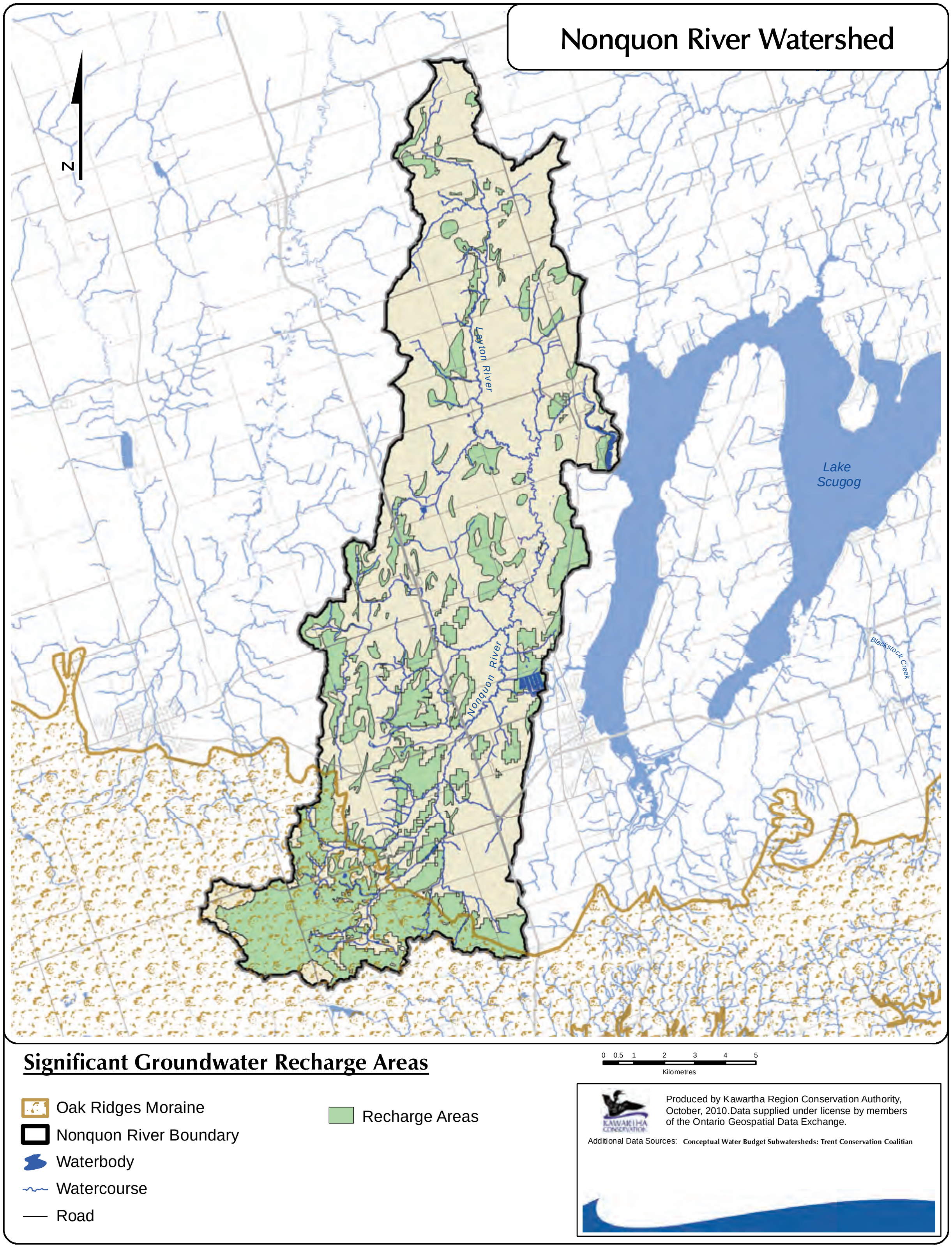


Figure 6.15: Significant groundwater recharge areas.

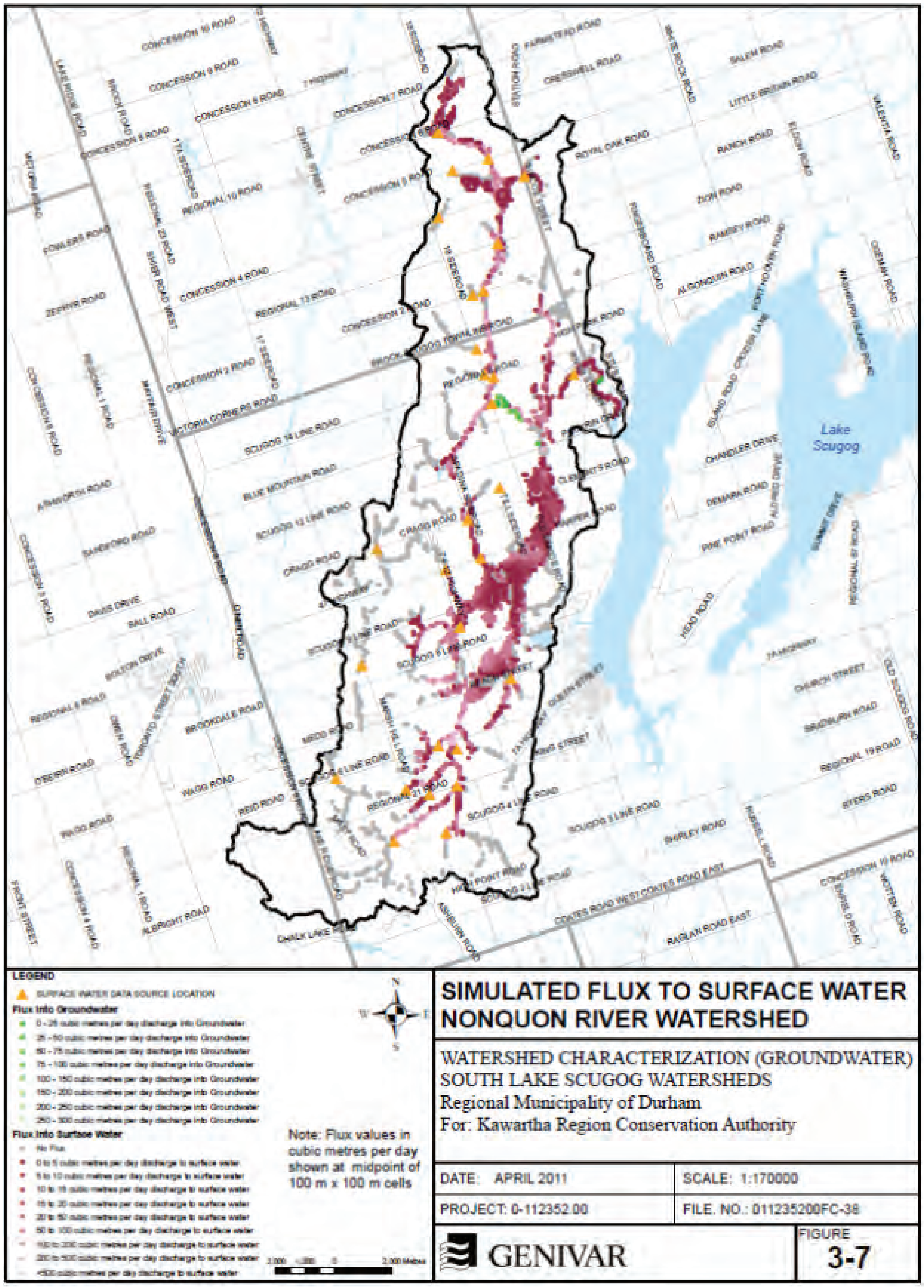


Figure 6.16: Simulated flux to surface water.

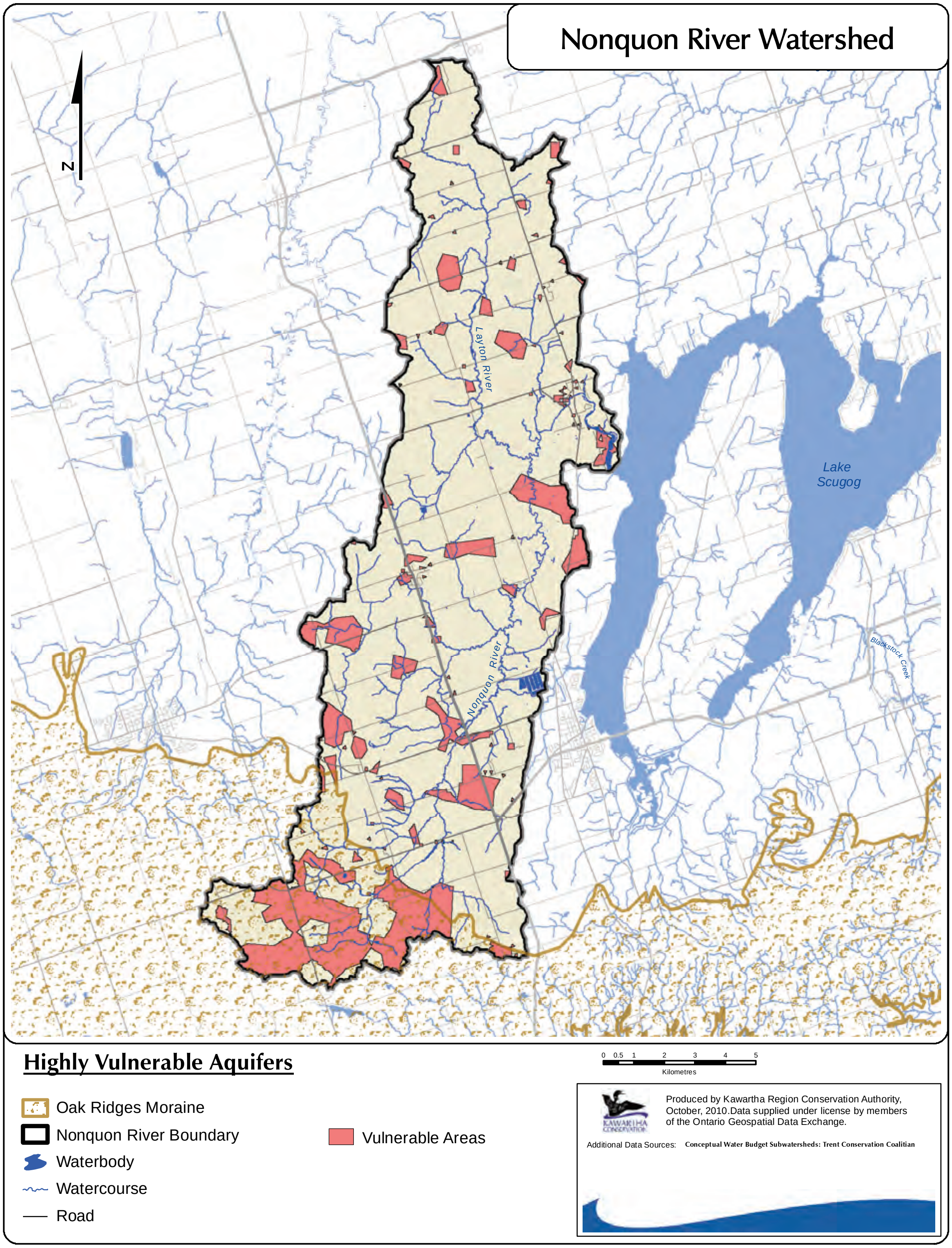


Figure 6.17: Highly vulnerable aquifers.

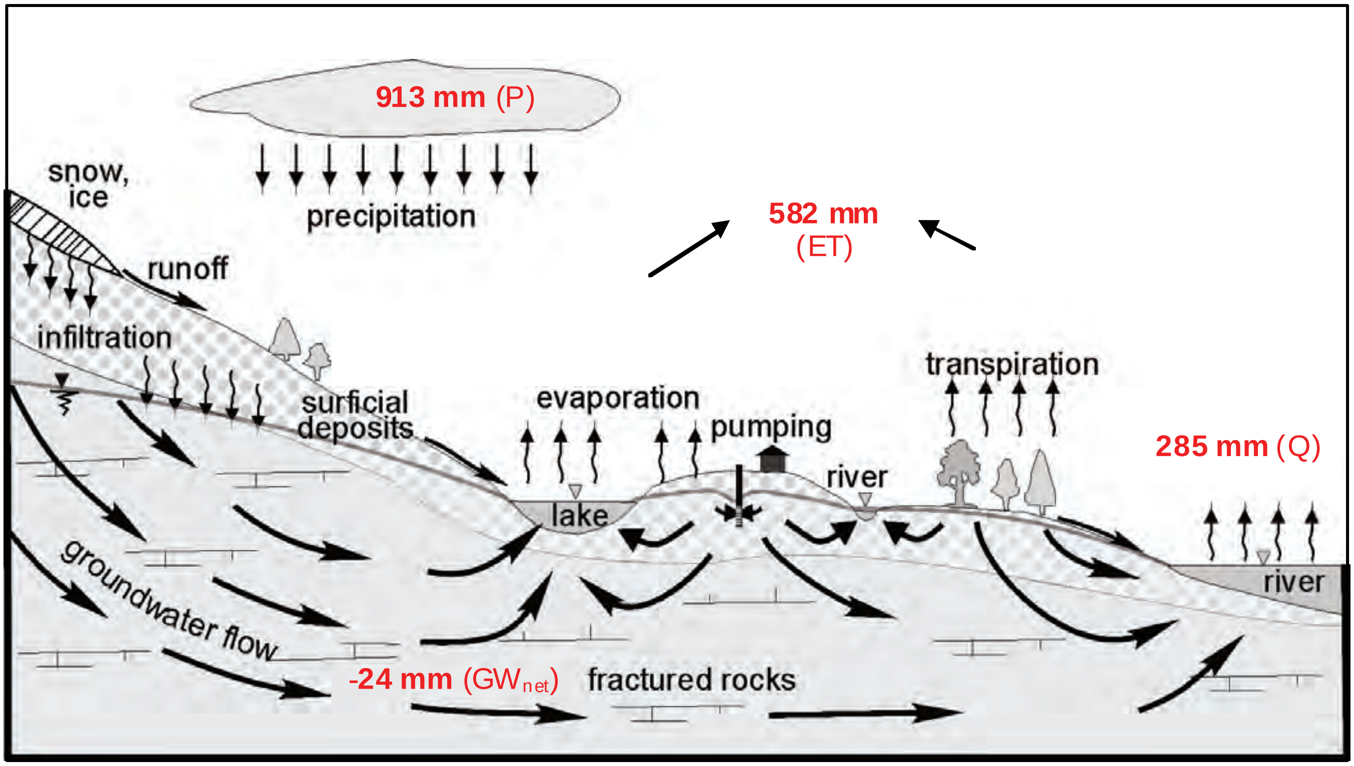


Figure 6.18: Hydrological cycle and water budget components.

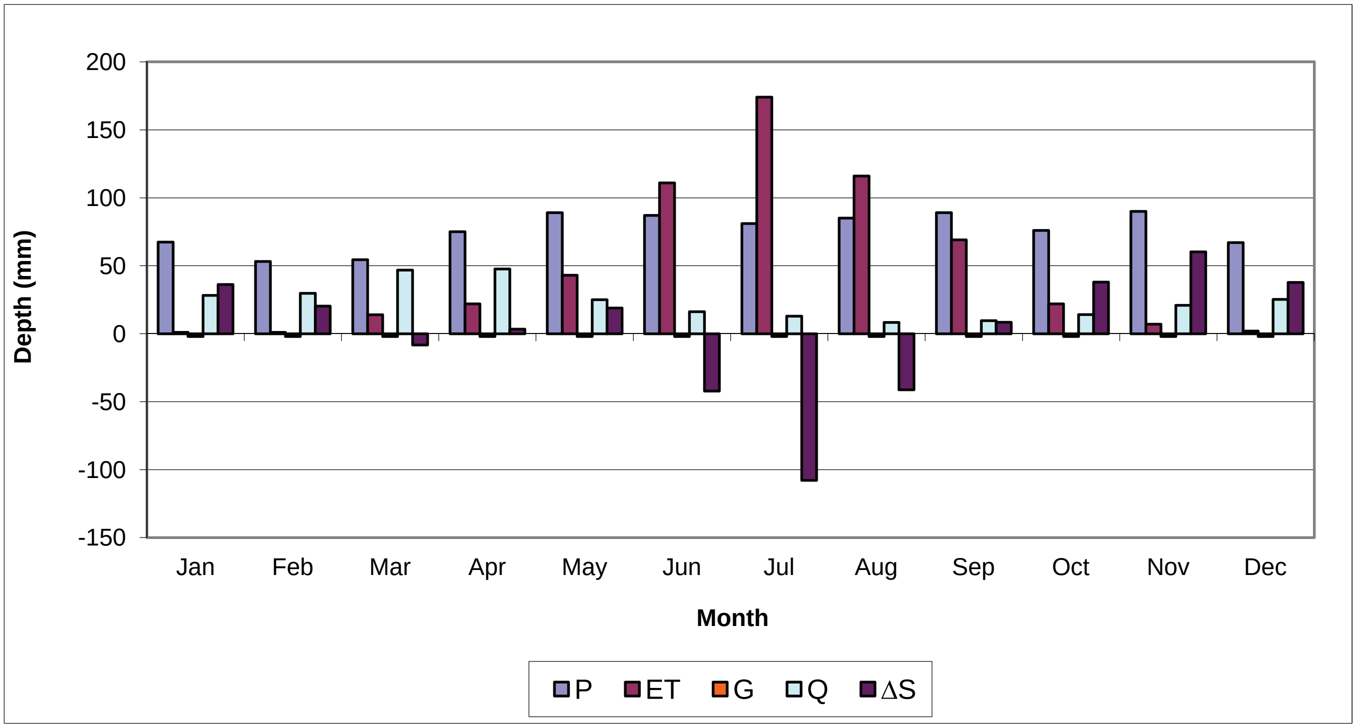


Figure 6.19: Monthly water budget components.

7.0 Water Quality

Nonquon River, south of Mast Road

.1 Introduction

Water quality can be defined as an integrated index of chemical, physical and microbiological characteristics of natural water. Water quality is a function of both natural processes and anthropogenic (of human origin) impacts. Natural processes such as weathering of minerals and erosion can affect the quality of ground and surface waters. Factors such as the type of bedrock and soil type can impact water quality as well. For instance, water samples from the central part of Ontario have naturally higher levels of metals than those in the south because of the Canadian Shield bedrock. Usually natural background concentrations of water quality parameters do not pose any threat to the health of aquatic ecosystems or humans.

Anthropogenic sources of pollution are generally classified as either point or non-point source pollution. Point sources may include municipal and industrial wastewater discharges, ruptured underground storage tanks, septic tanks and/or landfills. Point sources of pollution are typically more easily identified and managed. In contrast, non-point sources of pollution reflects land use and refers to diffuse sources such as agricultural drainage areas, urban runoff, land clearing and the application of manure and chemical fertilizers to fields. Non-point sources can be more difficult to identify and manage than point sources because they cover a large geographic area and are difficult to pinpoint to a specific site.

Water quality is a key element in achieving the objectives of any watershed management plan. By sampling a wide variety of parameters it is possible to get an accurate, overall assessment of the water quality at a given point in time. To broaden the perspective, numerous samples are taken at different locations and periods of time providing for variances such as air and water temperature, flow volume, precipitation and land uses that vary throughout the year. Obtained results are compared to the Provincial Water Quality Objectives (PWQOs) (OMOE 1994) and Canadian Water Quality Guidelines for the Protection of Aquatic Life (CWQGs) (CCME 2007). Some common water quality parametres and associated standards, are shown in listed in **Table 7.1**.

Table 7.1: Common water quality parametres and standards.

Parameter	Limits	Authority
Aluminum	0.100 mg/L	Canadian Water Quality Guideline for the Protection of Aquatic Life
Chlorides	128.0 mg/L	Canadian Water Quality Guideline for the Protection of Aquatic Life (Draft)
Iron	0.300 mg/L	Provincial Water Quality Objectives
Nitrate	2.930 mg/L	Canadian Water Quality Guideline for the Protection of Aquatic Life
Phosphorus	0.030 mg/L	Provincial Water Quality Objectives
Total Suspended Solids	Background+25.0 mg/L	Canadian Water Quality Guideline for the Protection of Aquatic Life

Methodology

Water quality data are obtained by the collecting water samples at monitoring sites throughout the entire Nonquon River watershed. As of 2010, the Nonquon River has three long-term monitoring sites (NR3, NR6 and SR3) sampled since 2004 through the monitoring program of the Lake Scugog Environmental Management Plan (LSEMP). Station SR3 is also part of the Provincial Water Quality Monitoring Network (PWQMN) and is sampled in the framework of this program since 2004. There are also nine new sites that were established and sampled in 2006 and 2008-2010 for the purposes of the Nonquon River Watershed Plan development (**Figure 7.1**).

The monitoring stations are dispersed across the watershed at twelve key locations covering all major tributaries and portions of the watershed. At each site water samples are collected by grab method according to the planned monitoring schedule and then sent to a certified private laboratory or to the Ontario Ministry of Environment's Laboratory Branch to be analyzed for alkalinity, total metals, hardness, suspended and dissolved solids, anions and nutrients including ammonia, nitrites, nitrates, total Kjeldahl nitrogen and total phosphorous. Furthermore, pH, dissolved oxygen, conductivity and temperature readings are taken at the time of sampling using an YSI hand held multi-meter. Samples for the PWQMN program (station SR3 at Seagrave) are collected during ice-free period eight times per year. Samples for the LSEMP monitoring program were collected bi-weekly year round. Samples were collected three or four times a year during both wet and dry conditions to account for all types of weather and different phases of the hydrograph. A complete list of parameters sampled are available in **Appendix A**.

Statistical analysis of data was completed for sites NR1, NR2, NR2A, NR3, NR4, NR6, NR6A and SR3 as they have the largest number of samples. **Table 7.2** shows the site ID, location, number of samples and date of the most recent sample.

Table 7.2: Water Quality Monitoring Stations in the Nonquon River Watershed.

Station ID	Location	Number of Samples	Most Recent Sample
NR1	Nonquon River at Mast Road	10	May-10
NR2	Western Nonquon tributary at Scugog Line 4	7	May-10
NR2A	Eastern Nonquon tributary at Scugog Line 4	7	May-10
NR3	Nonquon River at Scugog Line 6	108	May-10
NR3A	Nonquon tributary at Marsh Hill Road	4	May-10
NR4	Nonquon tributary at Scugog Line 10, east of Hwy 7&12	10	May-10
NR4A	Nonquon tributary at Hwy 7&12, north of Scugog Line 8	2	Aug-08
NR5	Nonquon River at Scugog Line 8	3	Oct-06
NR6	Layton River at Old Simcoe Road	111	May-10
NR6A	Layton River at Regional Road 13, east of Simcoe Rd. 4	7	May-10
NR7	Nonquon tributary at Saintfield Road	4	May-10
SR3	Nonquon River at River Road, Seagrave	168	June-10

Grey highlights indicate sites with enough samples to warrant statistical analysis.

7.2 Surface Water Quality Assessment

A major water quality concern in the Nonquon River watershed is elevated concentrations of nutrients; phosphorus in particular. Other parameters of concern include metals such as aluminum and iron, and total suspended sediments (TSS). In addition, a deficit of dissolved oxygen was often observed in the lower Nonquon River, particularly at station SR3.

Phosphorus

Phosphorus concentrations in the Nonquon River have historically exceeded the Provincial Water Quality Objectives (PWQO) set for total phosphorus (TP). Phosphorus data have been collected at the Seagrave monitoring station (SR3) near the river mouth since 1970, providing the long-term trend data (**Figure 7.3**). Phosphorus is not considered toxic to plants and animals, but elevated levels of this nutrient in water can result in the process of eutrophication and excessive algae and aquatic plant growth. The PWQO for total phosphorus is set at 0.030 mg/L, in order to prevent nuisance algae and aquatic plant growth. Total phosphorus is a measure of both soluble and insoluble phosphorus within a water sample. The insoluble component is primarily decaying plant and animal matter or soil particles, which either settles to the bottom or remains suspended in the water column. This form of phosphorus is not readily available to plants, and does not instantly change biological productivity of a water body. In contrast, soluble phosphorus (e.g., orthophosphates) can be readily taken up by aquatic plants, causing increased biological productivity and plant growth. Soluble phosphorus has primarily anthropogenic origin and poses a greater threat to the ecosystem than insoluble forms.

Figure 7.2 illustrates that total phosphorus levels in the Nonquon River, from a long-term perspective, have been in decline but are still in excess of the PWQO. Results of sampling in recent years have shown that most sites within the Nonquon River watershed, with the exception of sites NR1 and NR6A, have average total phosphorous concentrations over the PWQO of 0.030 mg/L (**Figure 7.4**). Average TP concentrations in the Nonquon River and its tributaries range from 0.025 to 0.058 mg/L. Phosphorus levels exceeded the PWQO the most often at station NR2A (100%) and the least at station NR6A (14%) (**Table 7.3**). The highest average concentration of 0.058 mg/L is observed at site NR3. At this site one of the maximum recorded values (0.327 mg/L) was also observed. Maximum TP concentration of 0.383 mg/L was observed in August of 2009 in the Nonquon River near Seagrave. On that date, along with phosphorus, elevated concentrations of other elements (Co, Fe, Mn, Zn) were detected as a result of processes of desorption from bottom sediments caused by high temperature, very low dissolved oxygen concentrations and low pH values in water of the lower Nonquon River.

Stations NR1 and NR6A, which meet the PWQO, are both located in the headwater sections of the Nonquon River and the Layton River correspondingly. Monitoring site NR1 is located on the Oak Ridges Moraine and has significantly lower phosphorus levels compared to the other sites. The average phosphorus concentration for NR1 was 0.025 mg/L with a range of 0.007 to 0.049 mg/L (**Table 7.4**). TP concentration exceeded the PWQO only on two occasions: after heavy rain in September of 2009 and during spring freshet in 2010. Good water quality at station NR1 is due to its location away from major sources of phosphorus such as agricultural fields and urban areas, and in relatively undisturbed area of the Oak Ridges Moraine with a significant groundwater inputs into the stream. Monitoring site NR6A is located in the upper portion of the Layton River subwatershed. Phosphorus levels at this station varied from 0.023 to 0.037 mg/L, with an average of 0.029 mg/L.

In contrast, stations NR2 and NR2A (western and eastern tributaries at Scugog Line 4) despite their location in the headwaters, both have elevated concentrations of phosphorus, with averages of 0.052 and 0.056 mg/L correspondingly. It can be explained by their locations downstream of agricultural lands. Station NR6 (Layton River at Old Scugog Road) is also situated among agricultural lands. As a result, there is a considerable increase in phosphorus concentrations between stations NR6A and NR6 and the river has quite high phosphorus levels near its mouth. Average annual TP concentrations at NR6 location fluctuated from 0.028 mg/L in 2004 to 0.061 mg/L in 2009 (Figure 6.4). The Layton River phosphorus levels show a noticeable increasing trend in recent years. Maximum phosphorus readings throughout the period of observation increased as well. For example, the highest detected TP value was 0.039 mg/L in 2004, 0.148 mg/L in 2005, 0.175 mg/L in 2006, 0.184 mg/L in 2007 and 0.303 mg/L in 2008. It seems that considerable deterioration of water quality happens in the area immediately upstream from the NR6 monitoring station at Old Scugog

Road. On both sides of the river intensive bank erosion is noticeable along with free access of livestock to the river.

Across the watershed, phosphorus levels ranged from 0.007 to 0.117 mg/L in headwaters of the streams (NR1, NR2, NR2A, NR6A), from 0.010 to 0.327 mg/L at midstream stations (NR3, NR4) and from 0.006 to 0.383 mg/L at downstream locations (NR6, SR3) (**Table 6.3**). While phosphorus levels generally increase midway down the river, there is a quite considerable decrease in TP levels near the river mouth at Seagrave. For example, throughout the period of observation the average TP value at Scugog Line 6 location (NR3) was 0.058 mg/L and much lower at the Seagrave location (SR3) – only 0.040 mg/L (**Table 7.3**, **Figure 7.4**). This is a 30% reduction in amount of phosphorus in the water. This considerable decrease in total phosphorus levels along the river, towards its mouth, despite additional influx of phosphorus from the Nonquon Water Pollution Control Plant and from the Layton River is an obvious indicator of the natural cleansing processes and phosphorus assimilation that occurs in the extensive wetlands in the central, lowing portion of the watershed.

Seasonal distribution of total phosphorus in the Nonquon River and its tributaries is characterized by the highest readings in springtime during intensive snowmelt and corresponding freshet. The lowest concentrations are usually observed throughout late autumn and early spring.

Based on data from three main water quality monitoring stations (NR3, NR6 and SR3) and flow data from the gauge stations at the same locations, phosphorus export per unit area was calculated for three consecutive hydrologic years. TP export varied from 19.27 kg/km^2/yr in 2005 – 2006 hydrologic year to 29.04 kg/km^2/yr in 2007 – 2008 for the headwater area upstream from Scugog Line 6 and from 11.68 kg/km^2/yr in 2007 – 2008 to 15.08 kg/km^2/yr in 2006 – 2007 for the entire watershed including the Layton River. Among three main monitoring locations within the Nonquon River watershed, area upstream from Scugog Line 6 has the highest TP export per unit area despite high percentage of forests and wetlands in that particular part of the watershed.

Table 7.3: Average and percent of exceedences of Total Phosphorus, Total Suspended Solids, Aluminum and Iron concentrations in the Nonquon River during 2006 - 2010.

Monitoring station	TP			TSS			Al			Fe		
	Mean, mg/L	Exceedences, %	Number of Samples	Mean, mg/L	Exceedences, %	Number of Samples	Mean, ug/L	Exceedences, %	Number of Samples	Mean, ug/L	Exceedences, %	Number of Samples
NR1	0.025	20	10	7.1	0	10	35	0	8	138	0	8
NR2	0.052	57	7	27.9	43	7	116	40	5	334	40	5
NR2A	0.056	100	7	8.0	0	7	42	0	5	270	40	5
NR3	0.058	68	108	11.7	20	10	103	20	10	278	30	10
NR4	0.039	40	10	10.3	20	10	63	13	8	232	13	8
NR6	0.048	61	111	12.3	25	8	284	89	8	534	63	8
NR6A	0.029	14	7	1.9	0	7	15	0	5	190	0	5
SR3	0.040	53	168	4.5	2	45	36	7	46	362	24	46

Table 7.4: Total Phosphorus concentrations at Nonquon River water quality monitoring stations during 2004 - 2010

	NR1	NR2	NR2A	NR3	NR4	NR6	NR6A	SR3
max	0.049	0.113	0.117	0.327	0.104	0.303	0.037	0.383
75-%	0.027	0.072	0.062	0.070	0.040	0.056	0.030	0.048
25-%	0.017	0.022	0.037	0.027	0.022	0.025	0.027	0.024
min	0.007	0.014	0.033	0.010	0.015	0.010	0.023	0.006
median	0.024	0.047	0.041	0.042	0.028	0.035	0.029	0.033
mean	0.025	0.052	0.056	0.058	0.039	0.048	0.029	0.040

Nitrogen

Nitrogen is present in surface water in several chemical forms such as ammonia, nitrite, nitrate and total Kjeldahl nitrogen (TKN). The nitrite values are usually combined with the nitrate concentrations, as a nitrite-ion is the transitional form of nitrogen from ammonia to nitrate-ion that is present in surface water in very low concentrations. Eventually all nitrites in lake or river water will be transformed into nitrates in a very short time. The combined concentrations of nitrate and nitrite are usually called total nitrate and consist typically of 98.0-99.9% of nitrates and 0.1 – 2.0% of nitrites. Throughout the Nonquon River watershed the total nitrate levels tend to be high in wintertime, late autumn and early spring. In general, the highest levels of total nitrate in all streams were detected during January and February when groundwater contributes the majority of flow in the watercourse. Total Kjeldahl nitrogen is a measure of total organic nitrogen plus total ammonia and in some cases can show presence of fresh organic pollution in a water body or level of the phytoplankton development in the lake water. Usually, TKN concentrations across the watershed are below 0.7 mg/L except the monitoring station at Seagrave, where TKN levels often exceed 1.0 mg/L.

Nitrates often constitute most of the total nitrogen amount in streams, which comprises all the above-mentioned chemical forms of nitrogen in water. Nitrates are essential for plant growth in both terrestrial and aquatic ecosystems because they are highly soluble and mobile in water solutions and are the most available for plant consumption. Anthropogenic sources of nitrates include inorganic fertilizers, septic systems and wastewater treatment plants. Concentration of total nitrates in surface water reflects general land use and an anthropogenic pressure within the various parts of the watershed. In the Nonquon River watershed nitrates periodically exceed the limit set by the Canadian Water Quality Guidelines for the Protection of Aquatic Life (CWQGs) at 2.93 mg/L (**Table 7.5**). At the same time the average nitrate levels in the Nonquon River and its tributaries are well below the limit (**Figure 7.5**).

The highest levels of nitrates are found at station NR6 on the Layton River at Old Simcoe Road, with an average of 1.011 mg/L and a range of 0.133 to 4.127 mg/L and at station NR3 on the Nonquon River at Scugog Line 6, with an average of 0.866 mg/L and a range of 0.013 to 3.969 mg/L (**Table 6.4**). It is important to note that data sets for these two stations are from year-round monitoring while other stations (excluding SR3) are represented by data collected only during summer and fall. Therefore, it can be assumed that other monitoring stations also have high nitrate concentrations during winter, late autumn and early spring as was observed at stations NR3 and SR6. The highest levels of nitrates in the Nonquon and Layton Rivers have been detected in the middle of winter (January – February), when the groundwater discharges contribute the most to the flow in watercourses, and natural processes of nitrate assimilation are very slow.

The highest summer nitrate concentration (2.52 mg/L) was detected in headwaters of the river at station NR2A on Scugog Line 4. This site has also high average nitrate concentration of 1.046 mg/L (**Table 7.5**). Another headwaters site, NR1 at Mast Road, had the lowest level of nitrates with an average of 0.091 mg/L and a range of 0.004 to 0.269 mg/L. Overall, average and maximum nitrate concentrations decrease towards the mouth of the river with the lowest readings at station SR3 near Seagrave. Usually the highest nitrate levels are detected in small streams or in upper sections of the main channel close to groundwater discharge points. Taking into consideration available monitoring data, it is possible to conclude that the main source of inorganic nitrogen in the Nonquon River watershed is groundwater discharge. In turn, high levels of nitrates in groundwater are likely caused by agricultural activities in the watershed.

Table 7.5: Nitrate concentrations at Nonquon River water quality monitoring stations during 2004 - 2010.

	NR1	NR2	NR2A	NR3	NR4	NR6	NR6A	SR3
75-%	0.143	0.770	1.505	1.312	0.725	1.241	0.440	0.654
max	0.269	1.310	2.520	3.969	1.160	4.127	1.073	2.649
min	0.004	0.280	0.120	0.013	0.020	0.133	0.020	0.003
25-%	0.050	0.345	0.385	0.243	0.448	0.632	0.040	0.067
median	0.110	0.532	0.900	0.535	0.500	0.821	0.370	0.255
mean	0.104	0.622	1.046	0.866	0.560	1.011	0.346	0.436

Aluminum

Aluminum can be toxic to various aquatic organisms, fish in particular, in concentrations above 0.100 mg/L (CCME 2003). Toxicity of aluminum increases in water with a pH below 6.5 and above 8.5 resulting in high mortality of aquatic organisms.

Elevated aluminum concentrations are observed at several locations across the Nonquon River watershed. At three monitoring stations average aluminum concentrations are above the CWQGs limit of 0.100 mg/L. Station NR6 on the Layton River has the highest levels of aluminum recorded during the observation period: a maximum of 0.989 mg/L and an average of 0.284 mg/L (**Table 7.6**). Two other stations with average aluminum concentrations above the CWQG are NR2 and NR3 with values of 0.116 and 0.103 mg/L correspondingly (**Figure 7.6**). Aluminum concentrations exceeded the CWQG in water of five stations out of eight. The most often aluminum levels above the guideline were observed at station NR6 (89%) and the least at station SR3 (7%) (**Table 7.3**). No exceedences were detected in water of stations NR1, NR2A and NR6A. Station NR6A in the headwaters of the Layton River has the lowest aluminum levels with an average concentration of 0.015 mg/L and the range of 0.002 to 0.035 mg/L (**Table 7.6**).

High aluminum concentrations in water of the Layton River at station NR6 can be explained by the intensive erosion processes upstream of the monitoring site. Local soils, which are probably rich in aluminum, seems are the major source of this element, as no anthropogenic sources of aluminum are known in the watershed.

Table 7.6: Aluminum concentrations at Nonquon River water quality monitoring stations during 2004 - 2010.

	NR1	NR2	NR2A	NR3	NR4	NR6	NR6A	SR3
75-%	0.045	0.216	0.051	0.077	0.053	0.295	0.022	0.054
max	0.066	0.252	0.059	0.323	0.251	0.989	0.035	0.106
min	0.015	0.029	0.027	0.027	0.018	0.060	0.002	0.003
25-%	0.019	0.032	0.034	0.039	0.041	0.142	0.007	0.017
mean	0.035	0.116	0.042	0.103	0.068	0.284	0.015	0.036
median	0.029	0.052	0.040	0.062	0.046	0.169	0.011	0.028

Iron

A numerical limit for total iron, which is 0.3 mg/L, was set by the Ontario Ministry of the Environment in 1984. Later it was adopted by the CWQGs. Iron in concentrations above 0.3 mg/L can be toxic to invertebrates and aquatic insects (CCME 1999).

Throughout the period of observation the majority of the monitoring stations had average iron concentrations well below the PWQOs and CWQGs limits of 0.30 mg/L, with the exception of site NR6 that has an average of 0.534 mg/L (**Table 7.7**). At this station 63% of samples exceeded the PWQO while ranging from 0.14 to 1.66 mg/L. Stations NR2 and SR3 also have average iron concentrations above the PWQO (**Figure 7.6**). NR2 only includes five samples, with two of them exceeding the limit. This considerably affects an average value. Station SR3, while having only 24% of samples exceeding the PWQO (46 samples in total), had extremely high iron concentration of 5.51 mg/L in August of 2009 that also significantly influenced an average value. Median and 75th percentile values at this station are still below the PWQO. The lowest iron levels have been detected at stations NR1 and NR6A with average concentrations of 0.138 and 0.190 mg/L correspondingly and no exceedences above the PWQO (**Table 7.3**, **Table 7.7**).

While the average concentrations of the most metals in water of the Nonquon River and its tributaries are generally below the PWQOs and CWQGs, some metals, such as aluminum, cobalt, iron, zinc and manganese all had readings that exceeded the corresponding limits at some point throughout the monitoring period. These elevated levels are likely the result of natural processes in the river. For example, elevated levels of iron and manganese can be related to the acute deficit of dissolved oxygen in combination with low pH values as it happened in August of 2009 at station SR3 and have been also quite frequently observed during the summer time throughout the entire observation period. As a result, low DO and pH values create a reducing environment in bottom sediments and at the water-sediment interface that can cause an intensive process of desorption of previously adsorbed metals from sediments. As well, reducing conditions can lead to mineral dissolution of iron-phosphorous, manganese-phosphorous and aluminum-iron-phosphorous minerals present in sediments. High concentrations of iron and manganese as well as phosphorus during summers in river water without known external sources of contamination are usually the indicators of the above-mentioned processes.

Table 7.7: Iron concentrations at Nonquon River water quality monitoring stations during 2004 - 2010.

	NR1	NR2	NR2A	NR3	NR4	NR6	NR6A	SR3
75-%	0.153	0.610	0.320	0.315	0.225	0.498	0.190	0.262
max	0.270	0.650	0.660	0.680	0.670	1.660	0.290	5.510
min	0.060	0.120	0.080	0.080	0.060	0.140	0.110	0.073
25-%	0.098	0.130	0.100	0.167	0.168	0.290	0.170	0.147
mean	0.138	0.334	0.270	0.278	0.240	0.534	0.190	0.353
median	0.125	0.160	0.190	0.215	0.200	0.403	0.190	0.205

Total Suspended Sediments

Total suspended sediments may have significant effects on aquatic organisms because of shading, abrasive action, habitat alteration and sedimentation. Suspended sediments have a significant effect on community dynamics when they interfere with light transmission. The role of sediments as a reservoir of toxic chemicals has been widely demonstrated. Most flowing waters have considerable variation in suspended sediments from day to day. Since this natural variation is so great, it is not desirable to establish fixed rigid guideline (CCME 2002). Therefore more flexible guidelines have been established: suspended sediment concentrations in stream water should not be increased by more than 25 mg/L over background levels during any short-term exposure period and no more than 5 mg/L over background levels for longer term exposure (30 days and more) (CCME 2002).

Background concentrations of total suspended sediments in streams of the Nonquon River watershed are usually 1-2 mg/L. Sometimes after rain events, TSS concentrations increase substantially in water of some tributaries (**Table 7.8**). Quite often high TSS levels have been observed in water of western tributary at Scugog Line 4 (station NR2). Maximum TSS concentration detected in water of this tributary was 100 mg/L. As well, 43% of samples from this station had TSS concentrations in excess of 25 mg/L above the background level (**Table 7.3**). Three stations had no exceedences (NR1, NR2A and NR6A).

Table 7.8: Total Suspended Solids concentrations at Nonquon River water quality monitoring stations during 2004 - 2010.

	NR1	NR2	NR2A	NR3	NR4	NR6	NR6A	SR3
75-%	7.5	32.0	10.5	5.8	4.8	14.8	2.5	5.2
Max	20.0	100.0	21.0	59.0	53.0	30.0	3.0	28.0
Min	1.0	2.0	3.0	1.0	1.0	4.0	1.0	1.0
25-%	2.3	4.0	3.0	2.0	2.3	5.0	1.0	2.3
Mean	7.1	27.9	8.0	11.7	10.6	12.3	1.9	4.5
Median	5.5	21.0	5.0	4.0	3.5	8.5	2.0	3.1

Chloride

During the monitoring period no chloride concentrations in water of streams of the Nonquon River watershed exceeded the recently developed draft CWQG for Chloride for the Protection of Aquatic Life, which is set at 128 mg/L (CCME 2010).

Monitoring station NR4, which is located downstream of Greenbank has the highest chloride concentrations with an average of 36.9 mg/L and a range of 23 to 70 mg/L. Station NR2 has the lowest levels with an average of 6.9 mg/L and a range of 5.0 to 9.7 mg/L (**Table 7.9**, **Figure 7.7**).

The PWQMN long-term monitoring data from station SR3 at Seagrave indicate distinct increasing trend in chloride concentrations in water of the Nonquon River (**Figure 7.8**). This information indicates that in future water quality in the Nonquon River watershed can be affected by the elevated chloride concentrations in excess of the CWQGs limit if the current trend continues

Table 7.9: Chloride concentrations at Nonquon River water quality monitoring stations during 2004 - 2010.

	NR1	NR2	NR2A	NR3	NR4	NR6	NR6A	SR3
75-%	12.0	7.4	36.0	23.3	36.8	21.0	23.0	31.2
max	12.0	9.7	38.0	30.0	70.0	25.0	27.0	49.4
min	9.5	5.0	21.0	16.0	23.0	14.0	17.0	17.1
25-%	10.8	6.0	23.0	18.3	31.0	17.5	19.0	22.9
mean	11.1	6.9	28.2	20.8	36.9	19.4	21.8	28.3
median	11.0	6.5	23.0	19.5	33.5	19.0	23.0	26.3

7.3 Point and Non-point Sources of Contamination

The Nonquon River Water Pollution Control Plant (NRWPCP), which is located along Scugog Line 8 and releases its effluent into the river, is the only known point source of pollution within the Nonquon River watershed. The NRWPCP serves the communities of Port Perry and Prince Albert with a total serviced population of approximately 9,511 people (Region of Durham 2009).

The approved discharge period is from October 16 to May 31, with the time period May 15 to May 31 allowable for the discharge only if the water temperature in the Nonquon River is less than 10°C. The NRWPCP was designed and approved to treat wastewater at an annual average daily flow rate of 3,870 m^3/day (Region of Durham 2008). In recent years the plant operated at 90.8% of capacity in 2006, at 67.5% of capacity in 2007, and at 88.7% in 2008 (Region of Durham 2007; 2008b; 2009).

Annually, the plant releases 150 to 200 kg of phosphorus and 12 to 14 tonnes of nitrogen into the Nonquon River (Kawartha Conservation 2010a). The MOE Certificate of Approval objective for phosphorus loading is 0.9 kg/day or approximately 192 kg/year and the Certificate of Approval limit is 1.2 kg/day or about 213 kg/year. Monthly Certificate of Approval limits for total ammonia loading vary from 11.7 kg/day to 38.7 kg/day, but the total annual limit is approximately 5,600 kg.

A major concern with respect to the NRWPCP operation is that the plant's effluent has continuously elevated ammonia concentrations during winter and spring months, which considerably exceed the compliance limits set by the Ontario Ministry of Environment . In order to solve this issue, the Region of Durham is undertaking a Municipal Class Environmental Assessment (EA) to examine alternatives to address the elevated ammonia concentrations in the effluent and consider an additional water pollution control plant capacity for Port Perry.

Non-point sources include runoff from agricultural fields that occupy more than half of the total watershed area, urban runoff from several small hamlets scattered across the watershed, and runoff from the road network. Previous data obtained for the purposes of the Lake Scugog Environmental Management Plan (LSEMP) show that phosphorus is the major concern in the Nonquon River watershed (Kawartha Conservation 2010b). Average phosphorus loading rate from the watershed into Lake Scugog is 2,600 kg annually. Approximately 55% of this amount is generated from the non-point sources of pollution including urban areas (9.4%), rural road network (9%) and agricultural lands (36.4%). Approximately the same proportion of total nitrogen amount in the river flow is coming from non-point sources as well. On average, around 124,000 kg of nitrogen entering Lake Scugog every year from the Nonquon River and 54.3% of this amount is from non-point sources such as agriculture (52%) and urban runoff (2%).

7.4 Groundwater Quality Assessment

Groundwater is an important component of natural water resources and an essential source of drinking water within the Nonquon River watershed. All drinking water for the municipal water supply systems, farms and private rural dwellings comes from groundwater wells. Therefore, it is very important to have comprehensive information about groundwater quality and quantity as well as clear understanding of problems and issues related to groundwater.

Natural groundwater quality varies from place to place and is determined mainly by the types of sediments and rocks that water moves through. When water from rain or snow moves over the land and infiltrates into the ground, it may dissolve minerals 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 chemistry and potentially water use.

The groundwater quality assessment within the study area is based on data obtained from the Greenbank municipal water supply system situated north of Hamlet of Greenbank, Sonya municipal water supply system, which serves Hamlet of Sonya and data from the Provincial Groundwater Monitoring Network (PGMN) well W386 located south of Scugog Line 4 near the intersection with Mast Road (**Figure 7.1**). Unfortunately, there are limited groundwater quality data to allow for the comprehensive analysis on the entire watershed scale. The PGMN well was initially sampled in 2004 and then annually since 2006. To date, there have been six rounds of sampling. Municipal wells in Greenbank and Sonya have available data, which is mainly microbiological, since 2003.

The Hamlet of Greenbank located in the central portion of the watershed draws water from five municipal wells that range from 12.59 m to 34.14 m in depth. At this depth, the wells draw water from the intermediate overburden aquifer within the lower sediment hydrological unit, which is up to 17 m thick and consists of sand deposits. This aquifer is discontinuous and is artesian, meaning it flows upward without need for pumping.

The Hamlet of Sonya, which is located in the northern part of the watershed, obtains water from two municipal wells with depths 16.77 and 22.9 m completed in an overburden confined aquifer of approximately 7 m of thickness. A third well was drilled in 2006. The system serves population of about 130 people.

The PGMN well W386 is located in the southern portion of the Nonquon River watershed. The well extends 27.92 m into the overburden intermediate aquifer of the lower sediments. According to the Ontario Ministry of the Environment protocol, all PGMN monitoring wells are to be sampled at least once a year or, if possible, twice per year. The main purpose of this sampling is to monitor the ambient water quality and chemical composition of groundwater and evaluate long-term trends and changes. Samples collected and analyzed from this monitoring well consistently show very good water quality.

Analysis of water quality data was based on a various parameters, including: general chemistry, metals, nutrients, microbiology, pesticides and other organic artificial compounds. In municipal wells, raw water is tested most often for E. coli and total coliform in compliance with the *Safe Drinking Water Act*. For other chemical compounds raw water samples analyzed only annually or semi-annually. **Table 7.10** shows the number of samples analyzed for each group of parameters at the various sampling locations. Analytical results were compared with the Ontario Drinking Water Quality Standards (ODWQS). The primary purpose of the ODWQ Standards, Objectives and Guidelines is to protect public health through the provision of safe drinking water. Water intended for human consumption should not contain disease-causing organisms or unsafe concentrations of toxic chemicals or radioactive substances. Water should also be aesthetically acceptable and palatable. Taste, odour, turbidity and colour are parameters that shall be controlled; such that water is clear, colourless, and without objectionable or unpleasant taste or odour. Standards, objectives and guidelines are considered to be the minimum level of drinking-water quality, although it does not preclude a better quality of water be achieved, or that the degradation of a high quality water supply to the specified level or range is acceptable. The standards, objectives and guidelines described in ODWQS have been derived from the best information currently available (OMOE 2003).

Based on the available data, both the Greenbank municipal wells and the PGMN well W386 have excellent water quality. No chemical parameter have exceeded the ODWQSs in the recent years. Nevertheless, it is worth noting that local groundwater at Greenbank has slightly elevated concentrations of copper (51–120 μg/L) and zinc (21–40 μg/L).

The Greenbank municipal drinking water system has available microbiological data for its five wells for the period of 2003-2008. During this time, between 194 and 203 raw groundwater samples of each well were tested for E. coli and total coliform. No E. coli has been detected, however, total coliform has been found in all wells at some point over the course of sampling. The most often total coliform was present in water of well #1: 19 times within the range of 1 – 16 cts/100 mL. This constitutes 11% of all samples. Well #4 had 14 cases when total coliform was discovered in raw water in the range of 1 – 9 cts/100 mL. On one occasion, total coliform concentration of 66 cts/100 mL were detected in this well. Total coliform has been detected in 12 water samples from well #5 (1 – 37 cts/100 mL), which constitutes 7% of all samples. In water of well #3 coliform was detected only three times, in the range of 1 – 2 cts/100mL. Despite these low levels of total coliform bacteria, the Greenbank municipal system has relatively good microbiological water quality as total coliform does not indicate fecal contamination and can be easily treated before distribution.

Sonya municipal drinking water supply system has good water quality from a chemical perspective with no exceedences above the Ontario Drinking Water Quality Standards for any chemical parameter. For example, lead has concentrations within the range of 0.4 – 3.1 ug/L. Iron levels are usually below the guideline of 0.3 mg/L. On one occasion, a value of 0.306 mg/L was detected.

Two wells of this system have been tested for bacteriological contamination; 179 (well #1) and 166 (well # 2) times. E. coli was detected once in water of well #1 in 2005 and once in waters of well #2 in 2004. In both cases a single E. coli colony was discovered. Total coliform has been detected seven times in water of well # 1 within the range of 1 - 27 cts/100 mL and eleven times in water of well #2 within the range of 2 – 23 cts/100 mL. This constitutes 5% of all tested water samples. According to the available data this municipal system has a relatively good raw water quality.

Although the groundwater monitoring results show good water quality, it is important to recognize that sampled wells represent limited number of aquifers in only three locations of the watershed. In many locations, several aquifers may provide adequate volumes of water. For example, within the Greenbank well field, a deeper aquifer beneath the municipal intermediate aquifer, is capable of producing high yields of water. However, the quality of water from this lower aquifer is poorer with high concentrations of dissolved minerals.

The greatest immediate concern for drinking water quality is bacteriological contamination. To address this concern municipal drinking water supply wells are frequently tested on a government-regulated schedule to ensure compliance with public health standards.

Table 7.10: Number of groundwater samples since 2003.

Well ID	Metals	Nutrients	Pesticides	E.coli & Total Coliform
PGMN well W386	6	6	2	3
Greenbank well#1	13	48	4	194
Greenbank well#3	13	48	3	203
Greenbank well#4	13	48	4	200
Greenbank well#5	13	48	3	199
Greenbank well#6	11	47	3	199
Sonya well #1	10	48	2	179
Sonya well #2	10	48	2	176

7.5 Key Observations and Issues

- Surface water quality monitoring results indicate that the Nonquon River and many of its tributaries have elevated total phosphorus levels caused by human activities in the watershed. It can be considered as a major water quality threat across the entire watershed. Elevated phosphorous concentrations are responsible for the highly eutrophic state of the Nonquon River that, in turn, creates adverse living conditions for biota. Further, high amounts of phosphorus and nitrogen found in the river system have been identified as one of the main causes of eutrophication in Lake Scugog.

- High nitrate levels are often detected in small streams or in upper sections of the main channel close to groundwater discharge points. It is possible to conclude that the main source of inorganic nitrogen in the Nonquon River tributaries is groundwater discharge.

- Other parameters of concern include metals such as aluminum and iron, and total suspended sediments that were found in elevated concentrations in some locations. As well, deficit of dissolved oxygen was quite often observed in water of the lower Nonquon River.

- The Nonquon River Water Pollution Control Plan is almost at capacity, and is a source of nutrient contamination, particularly total ammonia, into the Nonquon River. However, the amounts of nutrient inputs from this source significantly less than those from urban stormwater runoff and agricultural operations.

- Long-term water quality monitoring near the watershed outlet indicates an increasing trend in chloride concentrations. However, existing concentrations remain below federal guidelines.

- Groundwater quality in the watershed is considered good. In many cases, groundwater quality is getting better as the depth of wells increases. Shallow wells tend to draw water from shallow unconfined aquifers, which can exhibit poorer water quality. There are indications of high nitrate levels in shallow groundwaters, which are likely caused by agricultural activities in the watershed. Characterizing groundwater quality is a complex and difficult task because of a number of aquifers are present within the watershed, and there is a wide variety of different geologic features.

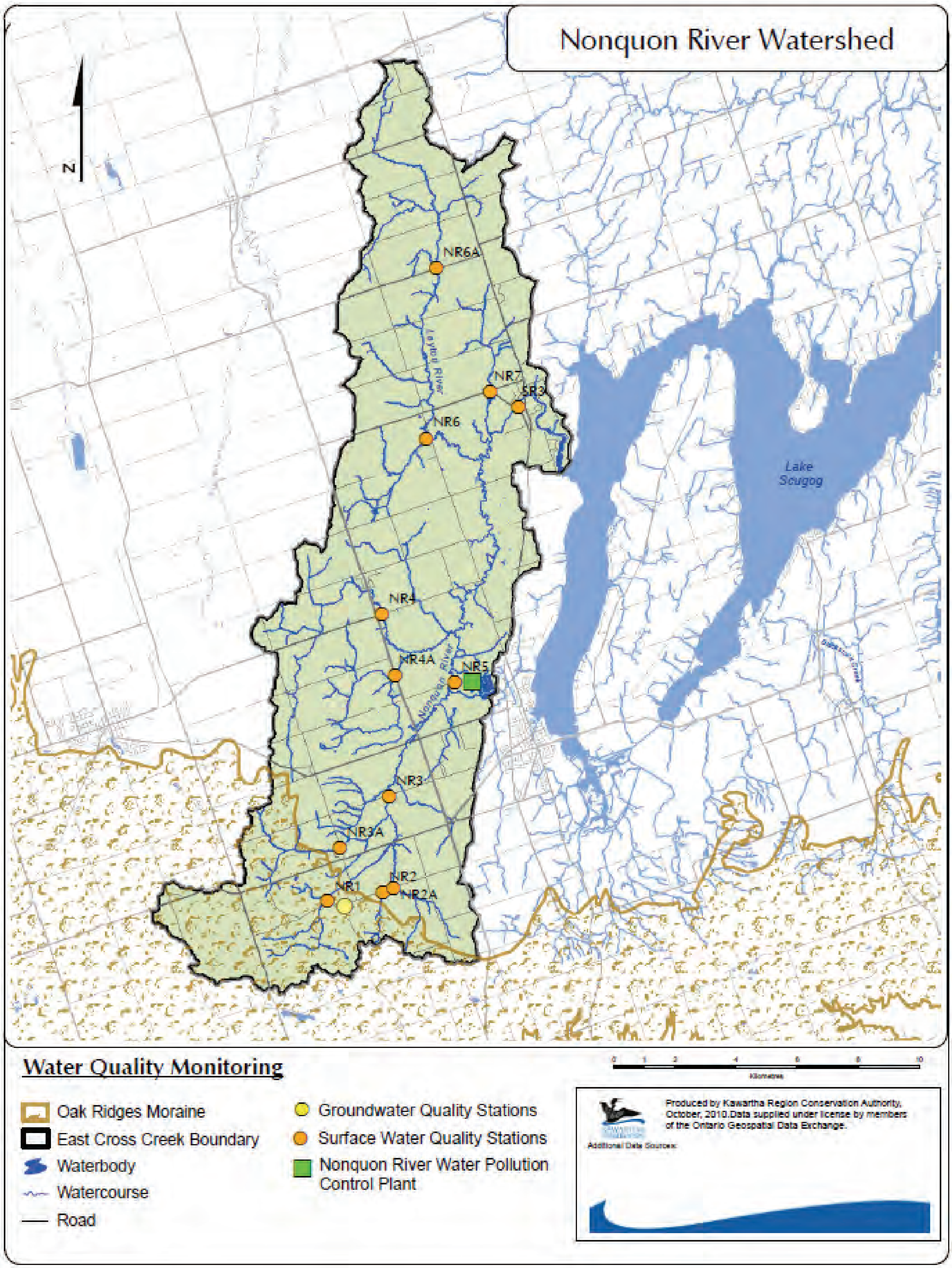


Figure 7.1: Water quality monitoring sites.

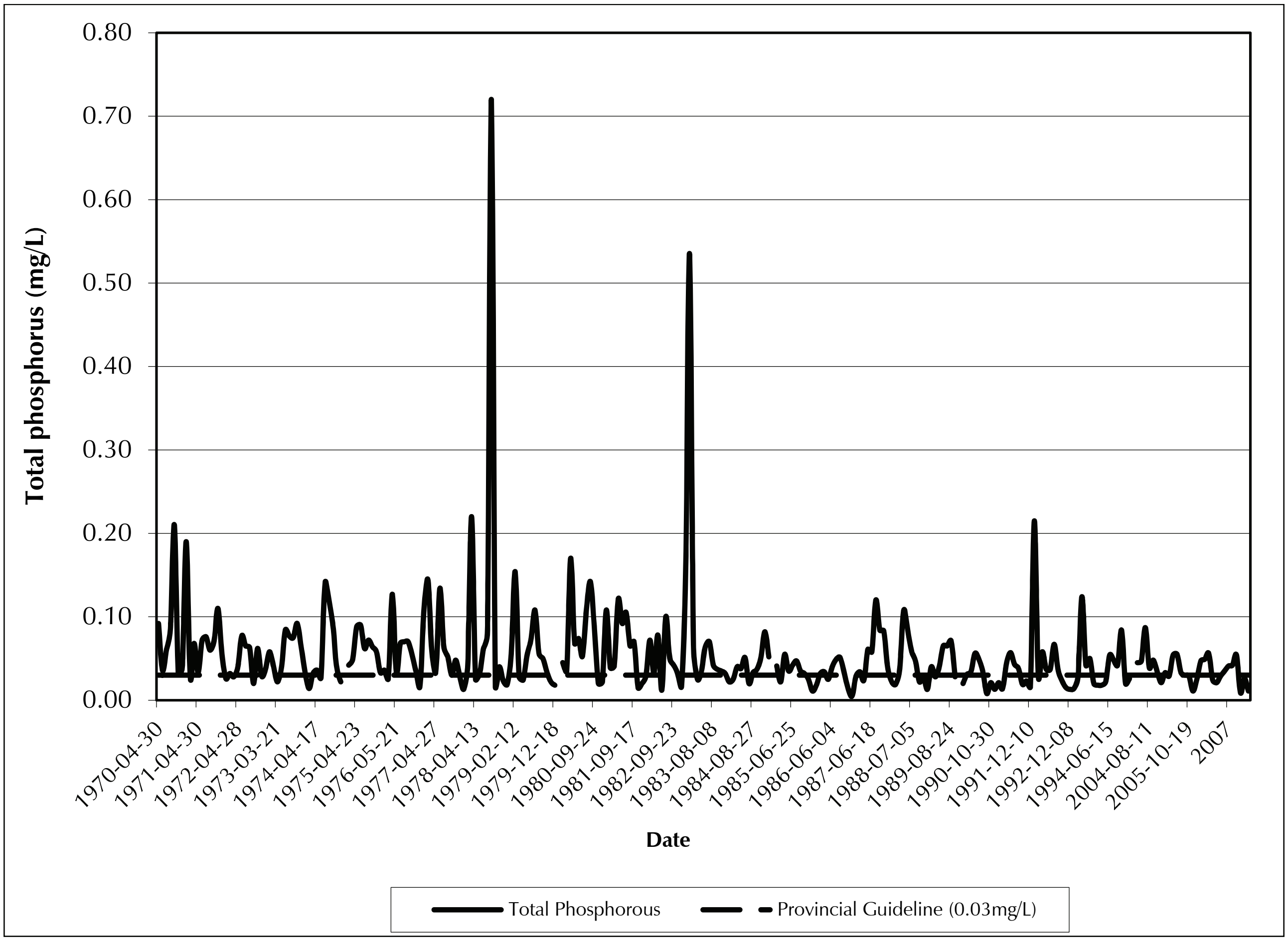


Figure 7.2: The long-term trends in Total Phosphorus levels in water of the Nonquon River near Seagrave (SR3).

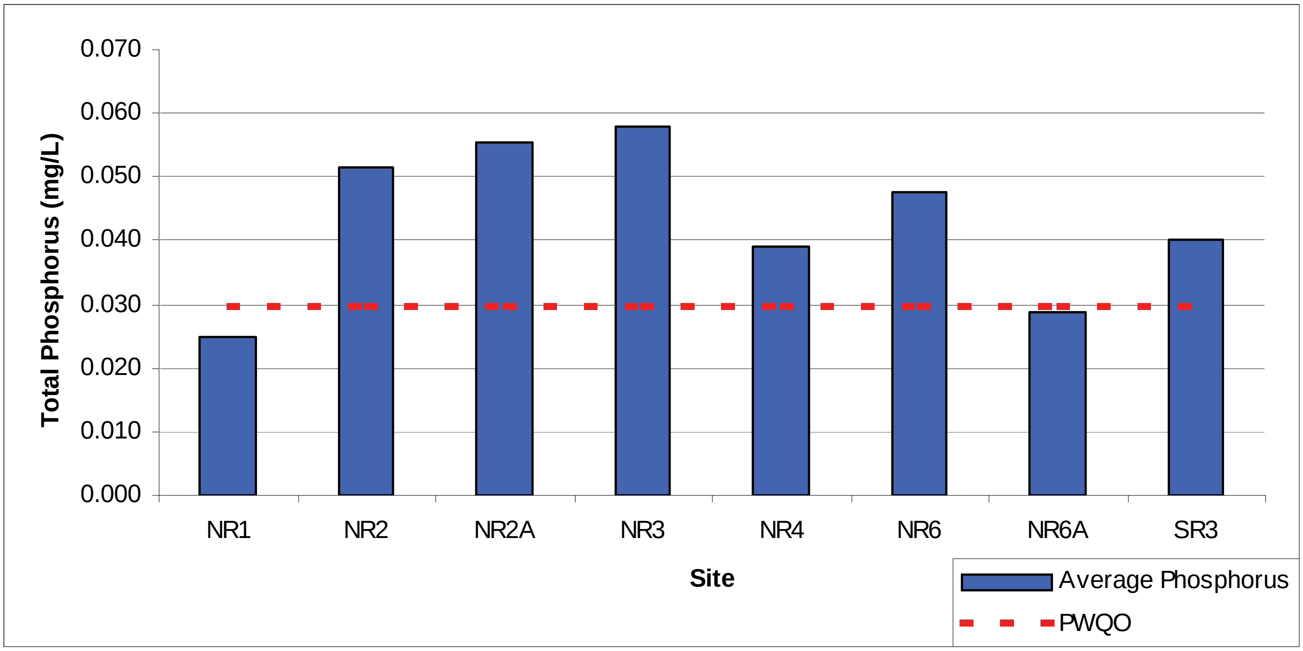


Figure 7.3: Average Total Phosphorus concentrations at Nonquon River monitoring stations in 2004 - 2010.

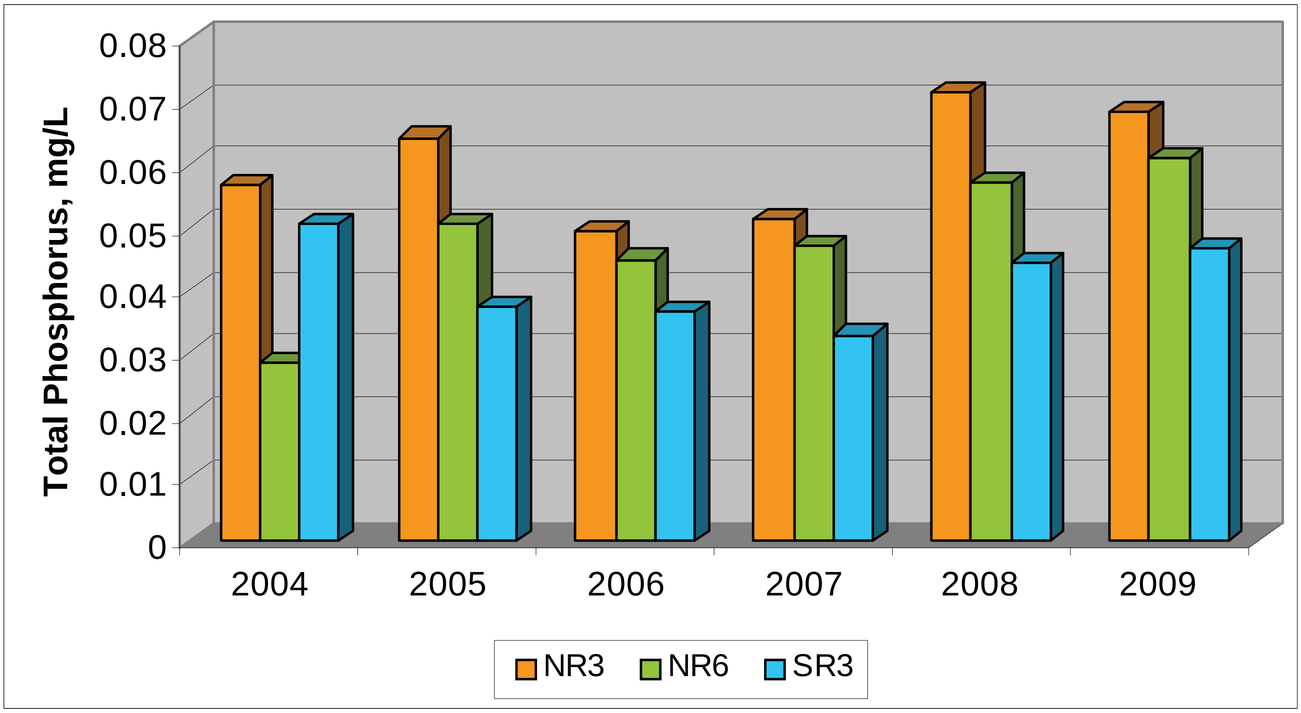


Figure 7.4: Annual average Phosphorus concentrations in water of three long-term monitoring stations in 2004 - 2009.

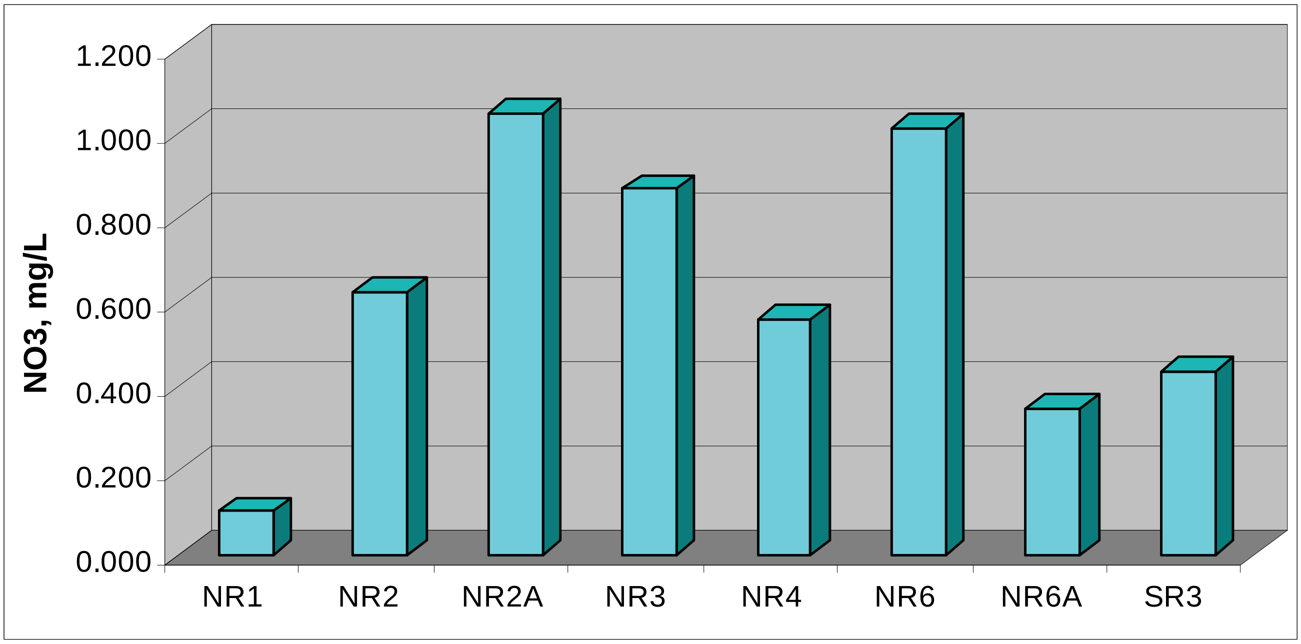


Figure 7.5: Average Nitrate concentrations at Nonquon River monitoring stations in 2004 - 2010.

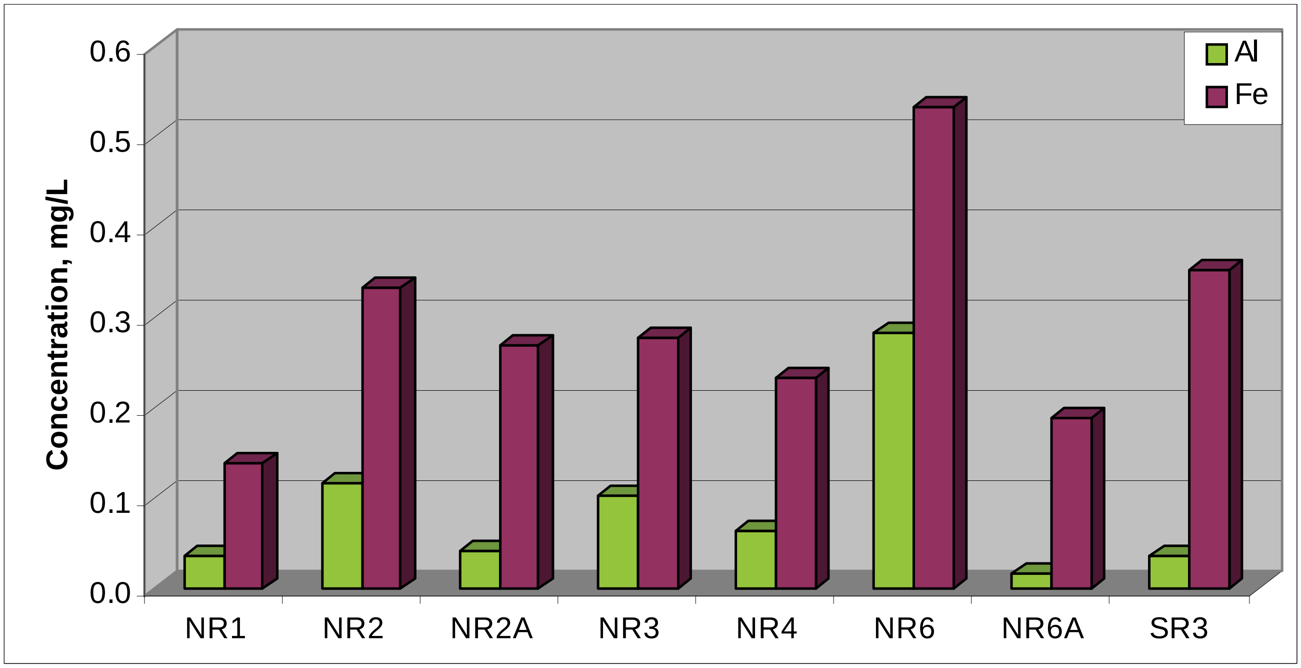


Figure 7.6: Average Aluminum and Iron concentrations at Nonquon River monitoring stations in 2006 - 2010.

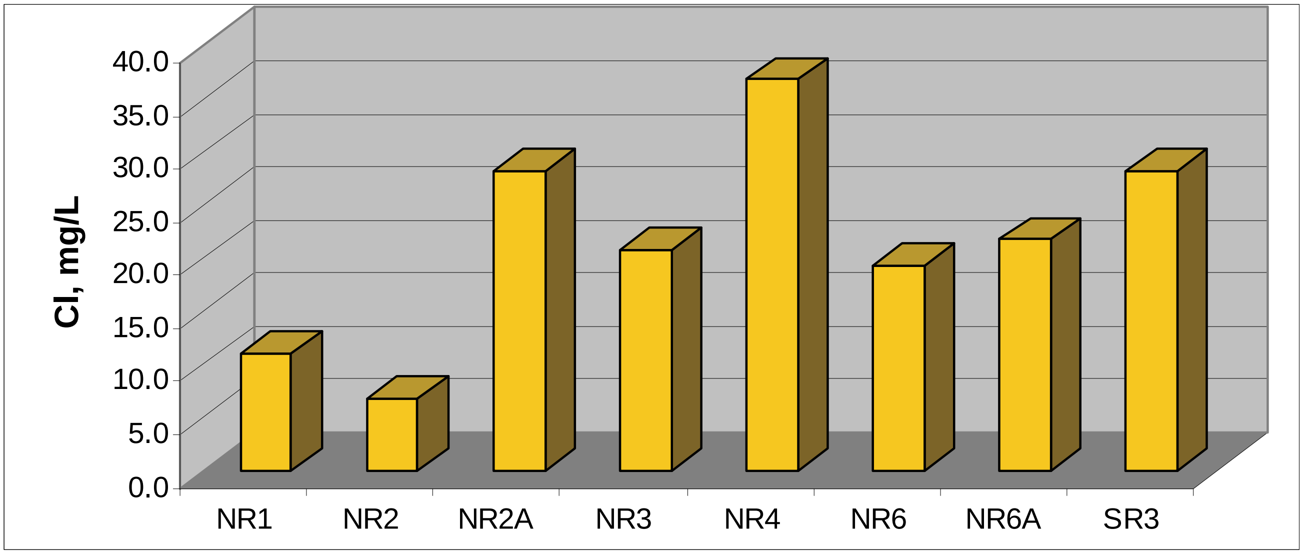


Figure 7.7: Average Chloride concentrations at Nonquon River monitoring stations in 2004 - 2010.

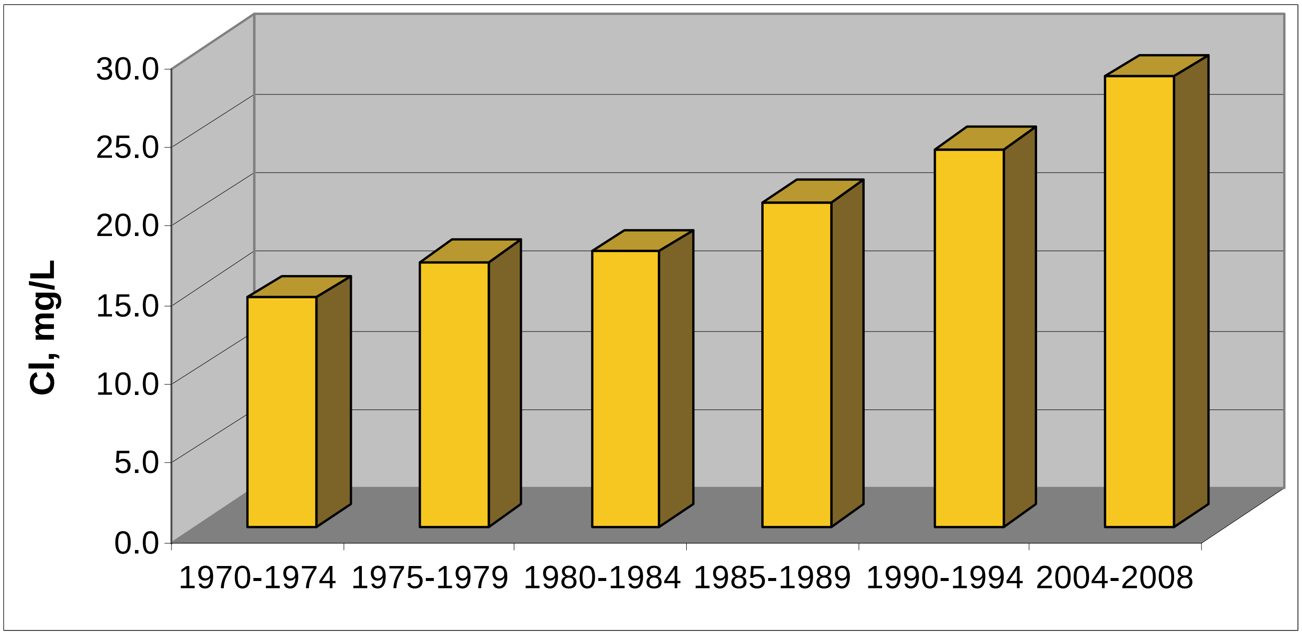


Figure 7.8: Long-term average Chloride concentrations in the Nonquon River near Seagrave during 1970 – 2008 monitoring period.

8.0 Aquatic Resources

Nonquon River, south of Scugog Line 12

8.1 Introduction

Aquatic resources include the aquatic species that occupy the watercourses flowing through the Nonquon River watershed as well as significant in-stream habitat features that support these species. The presence and distribution of these resources is largely a function of watershed geography (e.g., latitude, slope, and geology) and hydrological conditions (e.g., intensity, timing, and duration of flows), and land use (e.g., human influences). Due to these close linkages with the landscape, the presence and distribution of these resources within watercourses is often reflective of the ecological and hydrological conditions within their upstream catchments. This chapter characterizes existing (and historical where available) instream habitat, riparian areas, benthic macroinvertebrates and fish communities.

8.2 Instream Habitat

Instream habitat refers to the various components within the stream corridor that provide habitat for aquatic species such as benthic macroinvertebrates and fishes. Fish habitat, as defined in the *Fisheries Act*, includes spawning grounds and nursery, rearing, food supply, and migration areas on which fish depend directly or indirectly in order to carry out their life processes. This section provides an overview of some key instream habitat features that support aquatic resources within the watershed.

Stream Order

Stream ordering is a method of classifying the branching complexity of the stream network, which is largely influenced by the slope and geological characteristics of the stream valley. This can be a useful approach to assist in identifying watercourse reaches of similar biological, physical and chemical conditions as proposed by Vannote et al. (1980). First-order streams are watercourses with no tributaries; second-order streams begin when two first-order streams meet; third-order streams begin when two third-order streams meet; and so on (Strahler 1957). The term 'headwaters' is commonly used when referring to first-, second-, and third-order stream reaches.

The Nonquon River watershed supports a fifth order watercourse before emptying into Lake Scugog (**Figure 8.1**, **Table 8.1**). The Layton River, the only named tributary of the Nonquon River, is a fourth-order watercourse as it merges with the main channel of the Nonquon River. First-order streams account for the majority of individual stream sections and comprise the majority (42%) of the entire watercourse length. Many more first-order streams exist in the southern half of the watershed than in the northern half, which is likely due to the relatively steep topography and areas of groundwater discharge. Fifth-order streams include one distinct section that comprises the minority (8.1%) of the entire watercourse length. Headwater streams account for over 80% of the entire length.

Table 8.1: Watercourse length by stream order.

	1st order	2nd order	3rd order	4th order	5th order
Stream Length (km)	93.2	49.2	43.5	18.2	18.0
Stream Length (%)	42.0	22.2	19.6	8.2	8.1

Substrate

Substrate refers to materials (e.g., gravel, sand, silt, etc.) that exist on the streambed. These features can significantly influence the types of aquatic communities living within the watercourse. In a general sense, substrates tend to be dominated by coarse materials (e.g., gravel, cobble, boulder) in relatively high gradient (steep) streams and where water velocities tend to be high and dominated by fine materials (e.g., silt, sand) in relatively low gradient (flat) stream sections and where water tends to be slow moving (Mackie 2001). The dominant substrate type within a given reach can be indicative of the types of aquatic organisms that live nearby. Stoneflies, blackflies and caddisflies, for example, prefer stream reaches with coarse substrates, whereas aquatic worms prefer fine substrates. Certain fish species, such as Walleye and Brook Trout, have an affinity towards coarse substrate during reproduction stages, whereas Largemouth Bass and Yellow Perch tend to spawn amongst aquatic vegetation that are rooted in fine substrates.

To characterize substrate conditions within the Nonquon River watershed, methods outlined in the Rapid Assessment Module of the Ontario Stream Assessment Protocol (Stanfield 2007) were applied at sample sites between 2003 and 2006. Average particle size of the substrate materials was determined at each sample site and grouped into three categories: fines (<2 mm), gravel (2mm to 100mm), and cobble (<100 mm). Of the 23 sites sampled, 11 of these have substrates that fall within the gravel category and 12 have substrates that fall within the fines category (**Figure 8.2**). There were no sites with dominant cobble substrate. Both substrate types are quite evenly distributed among all sample sites, however, more sites exhibiting gravel substrates were found to exist in the southern portion of the watershed than in the north.

Instream barriers and ponds

Instream barriers include any man-made structure (e.g., dams, weirs, perched culverts) within a watercourse that obstructs or isolates aquatic species and habitats in either an upstream or downstream direction. These structures often alter the natural flow regime, and can negatively impact aquatic habitat and species by: fragmenting habitat, reducing the downstream movement of organic matter and habitat structure, impounding water thereby elevating temperatures, and genetic isolation (Bunn and Arthington 2002). In some cases, however, instream barriers have proven to be beneficial in protecting aquatic ecosystems by preventing the natural colonization of non-native species into a particular area within a watershed.

Perched culverts refer to culverts that are elevated from the stream bed. This often results from either improper installation (rare) or from high water velocities scouring the bed of the stream over time. The locations of perched culverts within the watershed were assessed in 2009 by volunteers during low-flow conditions following the Check Your Watershed Day protocol (Stanfield 2007). Of the 63 sites that were visited, 16 perched culverts were identified (**Figure 8.3**). The majority of these perched culverts were located in the southern portions of the watershed.

The locations of potential in-stream (directly connected to a watercourse) ponds were identified by highlighting areas of open water that exist along the watercourses. These are referred to as "potential" instream ponds because there was no detailed verification process. There are 60 potential ponds located within the watershed (**Figure 8.3**). The largest instream pond is located just south of Regional Road 21.

Water Temperature

Water temperature plays an important role in the overall health of aquatic ecosystems, affecting the rates of productivity, timing of reproduction, molting and movement of aquatic organisms (Caissie 2006). Fishes and other aquatic organisms often have specific temperature preferences, which can ultimately determine their distribution within streams. This 'thermal habitat' is influenced by a number of factors including: air temperature, precipitation, relative humidity, flow, geology, topography, land use, channel morphology, and riparian vegetation (Poole and Berman 2001).

To examine the existing thermal regime throughout the Nonquon River watershed, in the summer of 2007, temperature data loggers were installed at road-stream crossings and point-in-time spot-measurements were recorded following the protocols outlined in the Ontario Stream Assessment Protocol (Stanfield 2007). The data from these surveys were used to assigned a thermal regime status (cold, cool, or warm) to each sample site, based on the nonograms in Stoneman and Jones (1996), which were developed from relationships between air temperature and water temperatures observed in streams across southern Ontario (**Figure 8.4**).

Within the Nonquon River watershed, the thermal regime at 26 sites was determined. Of these sites, 8 (30.8%) were classified as warmwater, 13 (50.0%) as coolwater, and 5 (19.2%) as coldwater (**Figure 8.5**). The Layton River watershed has warmwater sites along the main channel, however, there are some coolwater sites along its tributaries. There are three warmwater sites within the southern tributaries, all of which tend to follow one particular reach. This warming is likely due to the extensive online ponds in the catchment, as well as a lack of dense riparian areas. According to Bowlby (2008), all sites within the coolwater and coldwater category are likely capable of supporting a coldwater (i.e., Brook Trout) fish community, whereas warmwater sites are not. Data show that there are elevated stream temperatures in the southern portion of the watershed, which could negatively impact native coldwater fishes populations in the area.

8.3 Riparian Areas

Riparian areas are the transitional zones between aquatic and terrestrial habitats. Natural riparian areas encompass a range of vegetation types (i.e., forest, wetland, meadow), and provide many benefits to the watershed system, including: stabilizing stream banks, reducing erosion, moderating water temperatures, filtering contaminants, providing cover and spawning habitat for fishes, and supplying nutrient and food sources into the watercourse (Gregory et al. 1991).

Various studies have investigated the minimum riparian buffer width that is necessary to maintain the ecological and hydrological integrity of watercourses. These often range from 5 metres to 300 metres depending on the functions they provide (**Figure 8.6**). For example, a larger width may be required in areas adjacent to pristine or highly valued wetlands or streams; in close proximity to high impact land use activities; or with steep bank slopes, highly erodible soils, or sparse vegetation (Fischer and Fischenich 2000). Appropriate lengths of riparian coverage along watercourses have been investigated as well. Studies in southern Ontario suggest that stream degradation occurs when riparian vegetation amounted to less than seventy-five percent of the total stream length (Environment Canada 2004).

To characterize riparian areas within the Nonquon River watershed, the extent and type of land cover along the watercourse was interpreted from aerial photography taken in 2008. Natural cover (e.g., forest, wetlands, etc.) within the riparian areas was classified according to Ecological Land Classification methodology (Lee et al. 1998), whereas non-natural land cover (e.g., agricultural lands, urban areas, aggregate pits, etc.) was classified according to methods developed to complement this protocol developed by Credit Valley Conservation (1998).

Table 8.2 shows the percentage of major land cover types that occupy the riparian areas for a variety of widths (5, 30, 50, 100 and 200 metres), along both sides of the watercourse. Natural lands account for the most riparian area coverage among all widths, and tend to decline as width increases. From a width of 50 metres and narrower, the Nonquon River watershed meets the minimum recommended length of natural coverage of 75%. Agricultural lands are the next prominent land cover type within all riparian widths, followed by areas of development. **Figure 8.7** shows the extent of these cover types within the 30 metre riparian area.

Table 8.3 shows the percentage of natural land cover that occupy the same riparian widths, based on stream order. Among all orders and widths, fourth- and fifth-order streams have extensive natural riparian coverage. In contrast, first-order watercourses have relatively low natural coverage (approximately 20% difference) when compared to the rest. The characteristics of these lower-order streams make them much more dependent upon riparian vegetation for protection of natural ecological functions.

Table 8.2: Riparian area coverage by land use type.

Land Cover Type	**Riparian Area Coverage (%)**				
	5 metre	**30 metre**	**50 metre**	**100 metre**	**200 metre**
Agriculture (intensive and non-intensive)	16.0	18.3	21.6	28.2	36.3
Aggregate	0.0	0.0	0.0	<0.1	<0.1
Natural	81.4	78.7	74.8	67.1	57.9
Development (rural and urban)	2.6	2.9	3.4	4.6	5.5
Manicured Open Space	0.1	0.2	0.2	0.2	0.3

Table 8.3: Natural riparian areas by stream order.

Stream Order	**Natural Riparian Area Coverage (%)**				
	5 metre	**30 metre**	**50 metre**	**100 metre**	**200 metre**
1st order	68.9	67.8	59.2	56.3	39.8
2nd order	91.5	87.4	83.1	74.6	64.9
3rd order	89.6	86.9	82.3	73.8	64.6
4th order	95.1	97.5	95.8	93.2	88.3
5th order	99.8	95.8	92.1	86.7	79.3

8.4 Benthic Macroinvertebrates

Benthic macroinvertebrates (benthos) are small, stream-dwelling organisms visible to the naked eye. They include taxa such as: crayfish, worms, spiders, beetles, mussels, snails, fly larvae and other organisms that live within or on the bottom substrates of watercourses for a significant portion of their life cycles.

Benthos have long-been utilized in biological assessments to characterize water quality and watercourse health. Sampling for benthos is advantageous because they are abundant in most streams, serve as primary food source for fishes, respond to ecosystem stress, and are relatively inexpensive to collect (Barbour et al. 1999). Also, an assessment of benthos condition within a watershed can complement traditional water chemistry sampling. A variety of indices are currently being used among conservation authorities to assess benthos data, including: number of taxa (richness); diversity; percent composition; Hilsenhoff Biotic Index; and, functional feeding groups (i.e., filters, grazers, shredders, etc.).

Historical benthos information within the Nonquon River watershed is limited; however, there are two known reports of significance. In 1983, IEC Beak Consultants Ltd. conducted a benthos survey at 15 sites, examining their functional feeding groups, diversity and physical habitat conditions. That study found that, in general, water quality and benthic habitat at these sites were of high quality (IEC Beak Consultants Ltd. 1983). Also, the Nonquon River and Layton River watersheds ranked 5th and 6th, respectively, when compared to sites within the Pigeon River, Fleetwood Creek, Blackstock Creek, and East Cross Creek.

In 1992, the OMOE conducted a water quality survey of 28 sites in relatively undisturbed headwater streams across the Oak Ridges Moraine using benthos. One of these minimally impacted sites was located within the Nonquon River watershed. From these regional data, a proposed set of reference values was derived for indicators of minimally-impacted benthos community composition: benthic taxa richness, >=20; EPT taxa richness >=8; and Hilsenhoff's Biotic Index, <=4.40 (Maude and Di Maio 1996). In addition, the authors utilized these data to develop a preliminary model of benthos community composition expected in minimally impacted sites across the Oak Ridges Moraine (**Figure 8.8**).

To examine the existing benthos community compositions within the Nonquon River watershed, Kawartha Conservation collected benthos at 24 sites, between 2003 and 2006, following methodology outlined in the Ontario Stream Assessment protocol (Stanfield 2007). Benthos were identified to a 27-taxa level, made up of classes, orders, and families. To characterize biological water quality at each site, benthos data are summarized using two indices: a modified version of Hilsenhoff Biotic Index and percent EPT.

Hilsenhoff's Biotic Index is commonly used to assess the degree of organic pollution at the site level. In this approach, taxa identified down to the species-level (Hilsenhoff 1982) or family-level (Hilsenhoff 1988) are rated on a scale of 0 (least tolerant to nutrient enrichment) to 10 (most tolerant). An index value is calculated by summarizing the number of benthos in a given taxa, multiplied by tolerance value, and divided by the number of total organisms in the sample. This value is then compared to a range of values that specify the degree of organic pollution. Since benthos collections within the Nonquon River watershed were not identified consistently to species or family level, a modified Hilsenhoff Biotic Index approach was utilized, that averages tolerance values found in Mandaville (2002) for the 27 course-taxonomic level. Kilgour (1998) applied a similar approach on southern Ontario streams, demonstrating that a modified biotic index can be used to distinguish nutrient-poor and nutrient-rich streams with about 70% accuracy.

Using this modified Hilsenhoff Biotic Index approach to determine water quality, the majority of sites (42%) are classified as having "fair" water quality, no sites were found to have "excellent" or "very good" water quality, only 3 sites (13%) were found to have "good" water quality, and 2 sites were found to have "very poor" water quality (**Table 8.3**, **Figure 8.9**).

Another commonly used index is Percent EPT. This index refers to the total percentage of taxa within the orders of Ephemeroptera (mayflies), Plecoptera (stone flies) and Tricoptera (caddis flies) within the sample. This index is considered one of many "best candidate benthos metrics" because taxa percentages have been shown to decrease in response to increasing perturbation (Barbour et al. 1999). **Figure 8.10** shows the relative benthos composition at each site, using the same seven taxa (EPT are lumped together) as used by Maude and Di Maio (1996) in the development of their benthos community composition model. Among all sample sites, percent EPT ranges from 0% to 53%. Within-and-around the Oak Ridges Moraine planning area, none of the sites matched the "reference composition" of 55% EPT, however, some were close. Sites within the western and southern portion of the watershed tend to be more dominated by EPT than sites in the northern portion.

Table 8.3: Hilsenhoff index values.

Index Value	Water Quality	Degree of Organic Pollution	Number and (%) of Samples Sites
0.00-3.75	Excellent	Organic pollution unlikely	0 (0)
3.76-4.25	Very Good	Possible slight organic pollution	0 (0)
4.26-5.00	Good	Some organic pollution probable	3 (13)
5.01-5.75	Fair	Fairly substantial organic pollution likely	10 (42)
5.76-6.50	Fairly Poor	Substantial organic pollution likely	5 (21)
6.51-7.25	Poor	Very substantial organic pollution likely	4 (17)
7.26 - 10.00	Very Poor	Severe organic pollution likely	2 (8)

8.5 Fisheries

Fish species are an important ecological link in the food web and are also important indicators of water quality and ecosystem health. In addition, they serve as food for other fish, birds, reptiles and mammals, including humans. Understanding the status of fisheries resources within a watercourse often provides insight into the ecological status of the entire watershed in which the watercourse flows. Fish, as do all aquatic life forms, serve as "sentinel" species, alerting people that water quality is changing.

Historical data on fish communities is limited within the Nonquon River watershed; however, there have been some inventory work. In 1975, the OMNR sampled seven sites (**Figure 8.11**) and documented the presence of seventeen species. All of these species are considered to be warmwater, native and common to streams in the area. In 2002, Stantec Consulting Ltd. surveyed six sites (**Figure 8.11**) and documented the presence of eleven species (Palmer 2005). All of these species were native and common to streams in the area, however, due to the headwater sampling locations, this was the first time that Brook Trout were formally documented within the Nonquon River watershed. Stocking records obtained from the OMNR indicate that small numbers of Muskellunge were released in the river in the 1980's.

To examine the existing fisheries communities within the Nonquon River watershed, Kawartha Conservation sampled 69 sites between 2003 and 2008 (**Figure 8.11**). Sites and sampling techniques were selected to reflect the influence of landscape features that are known to influence aquatic community composition, and other variables such as: physiographic regions, land use, above-and-below significant barriers, site accessibility, depth and substrate, and above all, geographic coverage. In wadeable stream sections (24 sites), single-pass electrofishing method, as outlined in the Ontario Stream Assessment Protocol (Stanfield 2007), was used to determine fish species composition. In non-wadeable stream sections (45 sites) hoop-nets and, rarely, bag seines were used to determine fish species composition. These sites were located along the main channel of the Nonquon River, from the watershed outlet upstream to Highway 7/12, because the Ontario Stream Assessment Protocol methodology was not suitable (i.e., non-wadeable substrate) within this section of the watercourse. In addition, spring spawning surveys, targeting Walleye and Muskellunge, were conducted in the main channel of the Nonquon River watershed in 2006.

A total of 34 fish species, represented 12 families, were captured during these recent sampling efforts, including all of the historically-documented species (**Table 8.4**). Species richness per site ranged from 0 to 16 (average of 6.4) for wadeable sites and from 0 to 15 (average of 6.7) for nonwadeable sites. Most of these fishes are common throughout watercourses within south-central Ontario; there are no species of conservation concern. Bluegill and Black Crappie are considered the only non-native (not naturally occurring) species within the watershed. These species are native to the Great Lakes Basin, but have relatively-recently expanded their range throughout the Kawartha Lakes region (OMNR 2009) and, subsequently, the Nonquon River watershed.

The Nonquon River watershed contains both warmwater and coldwater fish communities. **Figure 8.12** shows the sites where coldwater fishes (Brook Trout) and where warmwater fishes (all other species) were captured, both during historical (OMNR) and recent (Stantec and Kawartha Conservation) sampling efforts. The distribution of warmwater fishes is widespread throughout the watershed, whereas Brook Trout were found at only 6 sites, restricted to the southern portion of the watershed south of Scugog Line 6. Brook Trout naturally occurs in cold, well-oxygenated waters with nearby groundwater-upwelling areas. They are particularly sensitive to ecosystem disturbance, thus their presence and continuing natural reproduction within a watercourse indicates healthy aquatic habitat conditions.

The ability for Brook Trout to persist within the upper reaches of the Nonquon River is largely due to continuous groundwater inputs, cold water temperatures, lack of development in the area, and absence of known competitors (i.e., Rainbow Trout and Brown Trout). The fact that Rainbow Trout were not documented within the headwaters of the Nonquon River is extremely significant, as they have been introduced to many Oak Ridges Moraine tributaries.

Walleye and Muskellunge are two of the most sought-after game fishes within Lake Scugog. Due to their migrating tendencies during spawning stages, surveys were conducted in the spring of 2006 to assess the extent that they would be utilizing the Nonquon River as spawning habitat.

Walleye spawning surveys were conducted mainly at night, in April, commencing in Seagrave. Two persons per boat would work their way slowly upstream along one shoreline and downstream along the other, scanning the water with a spotlight. In total, 13 walleye were observed; however, no spawning activity was witnessed. Due to the fact that walleye were captured during recent hoopnet surveys in the main channel, coupled with anecdotal evidence from fishermen observing spawning activity, it is assumed that Walleye do in fact utilize the lower reaches as spawning habitat. The ice was out early that year, so it is likely that the peak spawn was missed. Areas of suitable spawning habitat are shown in **Figure 8.13**.

Muskellunge spawning surveys were conducted during the day between April and May, from Scugog Line 8 downstream to Seagrave out of a canoe, paddling upstream to the start location and recording fish observed upon returning downstream. Muskellunge were only observed on April 20, and not observed upstream of Scugog Line 10. Only one observation was made in which spawning behaviour was actually witnessed, but many areas of suitable spawning habitat exist, which are shown in **Figure 8.13**.

The data from the spawning surveys not only illustrates that many fishes migrate great distances to carry out life processes that are essential to their survival (e.g., reproduction), but also demonstrates the important biological linkages between the Nonquon River watershed and Lake Scugog.

Table 8.4: List of fish species.

Common Name	Scientific Name	Recent Catch (2003-2008)	Historical Catch (1975)
Rock Bass	Ambloplites rupestris	√	√
Brown Bullhead	Ameiurus nebulosus	√	
Central Stoneroller	Campostoma anomalum	√	
White Sucker	Catostomus commersonii	√	√
Brook Stickleback	Culaea inconstans	√	
Iowa Darter	Etheostoma exile	√	
Johnny Darter	Etheostoma nigrum	√	
Banded Killifish	Fundulus diaphanus	√	√
Brassy Minnow	Hybognathus hankinsoni	√	√
Brook Silverside	Labidesthes sicculus	√	
Pumpkinseed	Lepomis gibbosus	√	√
Bluegill	Lepomis macrochirus	√	
Common Shiner	Luxilus cornutus	√	√
Northern Pearl Dace	Margariscus nachtriebi	√	
Smallmouth Bass	Micropterus dolomieu	√	√
Largemouth Bass	Micropterus salmoides	√	√
Hornyhead Chub	Nocomis biguttatus	√	
Golden Shiner	Notemigonus crysoleucas	√	√
Blackchin Shiner	Notropis heterodon	√	
Yellow Perch	Perca flavescens	√	√
Logperch	Percina caprodes	√	
Trout-perch	Percopsis omiscomaycus	√	
Northern Redbelly Dace	Chrosomus eos	√	√
Finescale Dace	Chrosomus neogaeus	√	
Bluntnose Minnow	Pimephales notatus	√	√
Fathead Minnow	Pimephales promelas	√	√
Black Crappie	Pomoxis nigromaculatus	√	
Blacknose Dace	Rhinichthys atratulus	√	√
Longnose Dace	Rhinichthys cataractae	√	√
Brook Trout	Salvelinus fontinalis	√	
Walleye	Sander vitreus	√	
Creek Chub	Semotilus atromaculatus	√	√
Central Mudminnow	Umbra limi	√	√
Muskellunge	Esox masquinongy	√	
Total number of documented species		**34**	**17**

8.6 Key Observations and Issues

- The watershed supports diverse fish communities that are dominated by native species. Thirty-four species of fish have been documented within the watershed.

- No aquatic species of conservation concern (e.g., Species at Risk) have been documented.

- No aquatic invasive species have been documented. Bluegill, and Black Crappie are not native to the watershed, but are now widespread throughout the Kawartha Lakes and as such, are considered naturalized.

- Fish communities within the watershed are linked with Lake Scugog, as supported by evidence that suggests Walleye and Muskellunge migrate up the main channel to reproduce.

- Brook Trout, a sensitive coldwater species, exist within the southern sections of the watershed. However, elevated water temperatures caused by on-line ponds and lack of riparian areas are likely limiting suitable habitat for this and other coldwater species. Climate change has the potential to exasperate the effects of stream temperature warming.

- Small headwater streams (i.e., 1st, 2nd and 3rd order streams) account for over 80% of the total watercourse length within the watershed.

- The watercourses have extensive natural vegetation along their length, at approximately 79%, that meet minimum ecological requirements with respect to total riparian area coverage (i.e., 75% of the total watercourse length being naturally vegetated to a width of 30 metres on both sides). However, riparian areas are lacking along the smaller tributaries (e.g., 1st and 2nd order streams).

- Benthic macroinvertebrate communities tend to be dominated by pollution tolerant organisms. Community composition indicates that there is likely substantial organic pollution occurring throughout the watershed.

- The fragmentation of aquatic habitat, caused by in-stream barriers, has the potential to negatively impact the integrity of existing populations of fishes.

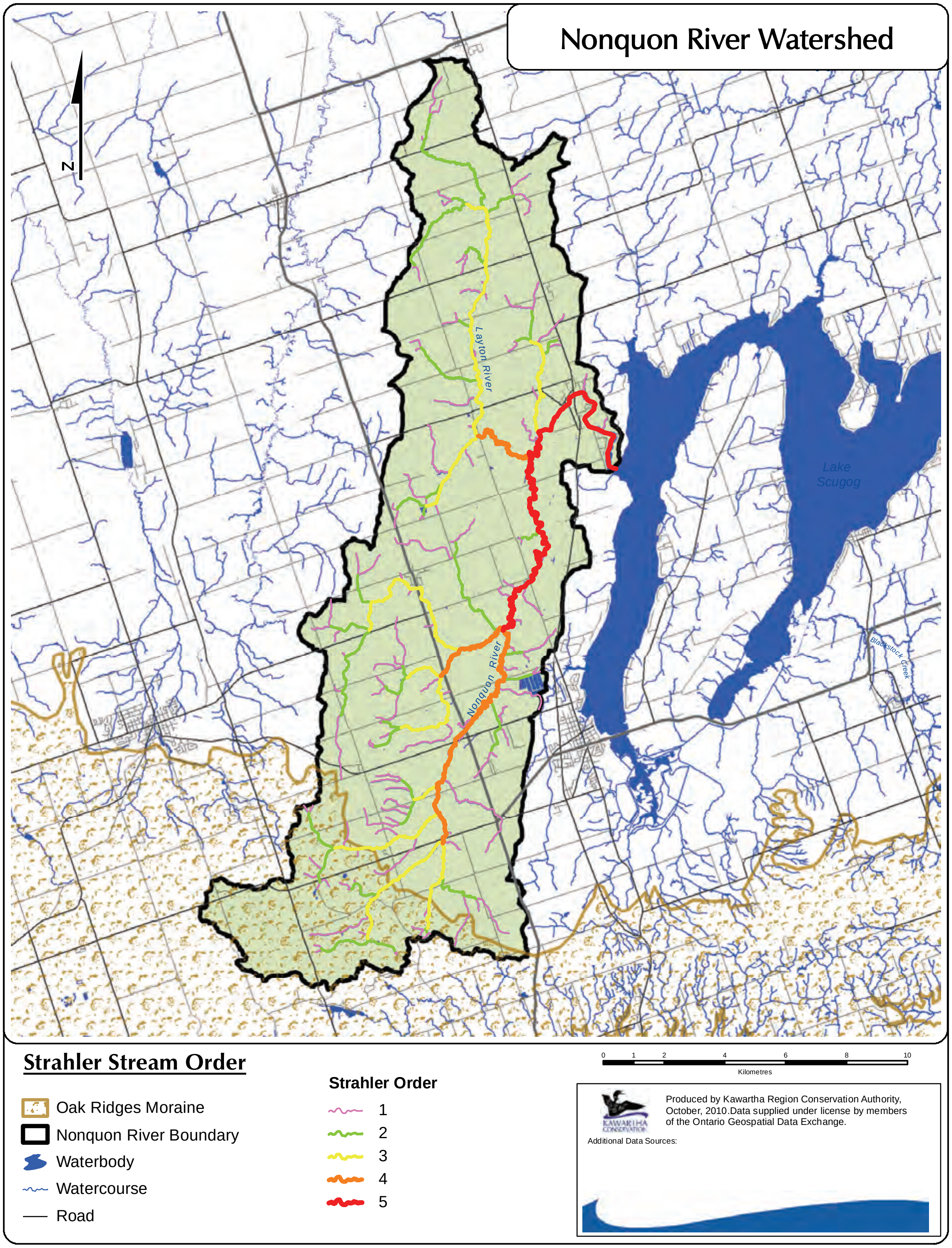


Figure 8.1: Stream order.

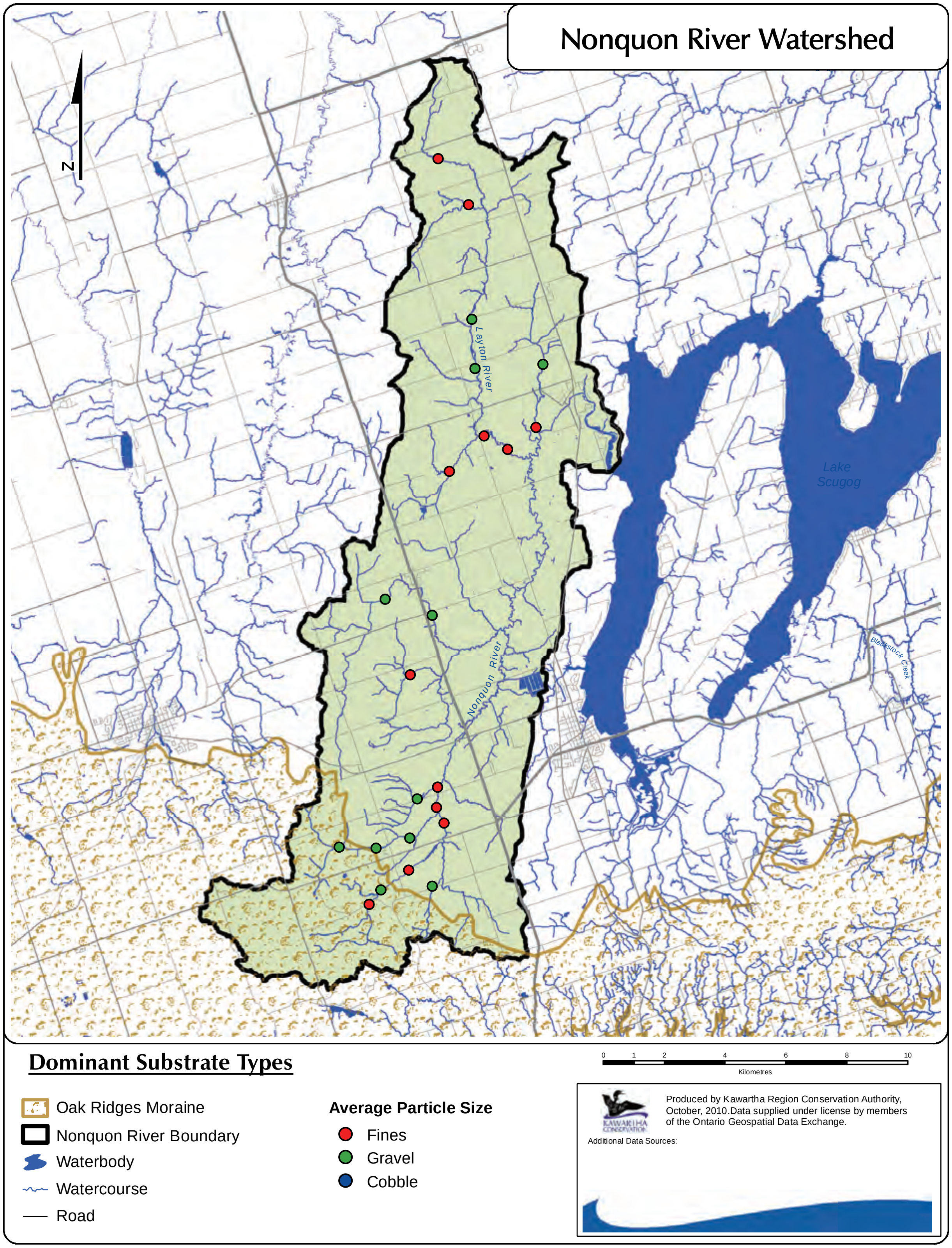


Figure 8.2: Dominant substrate types.

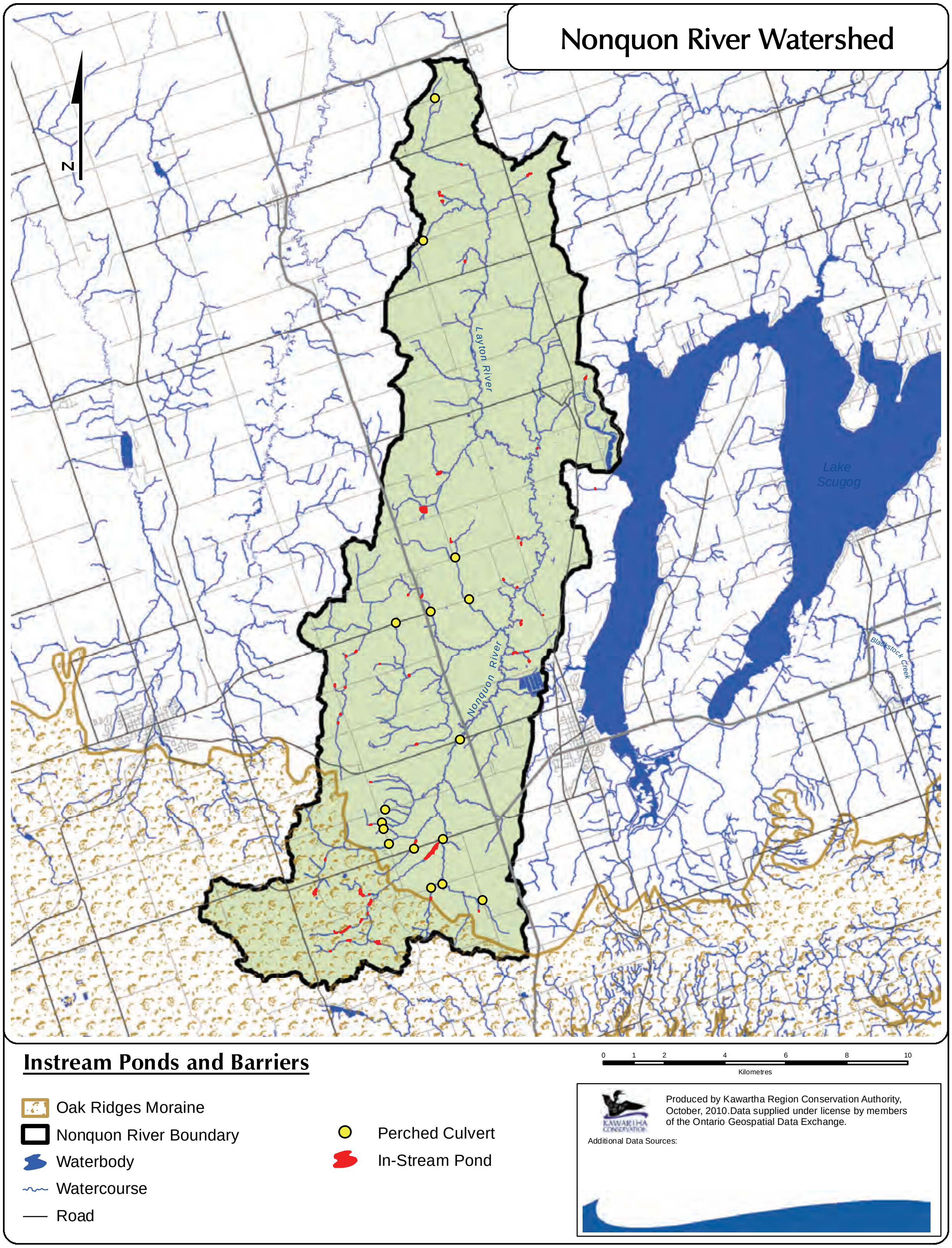
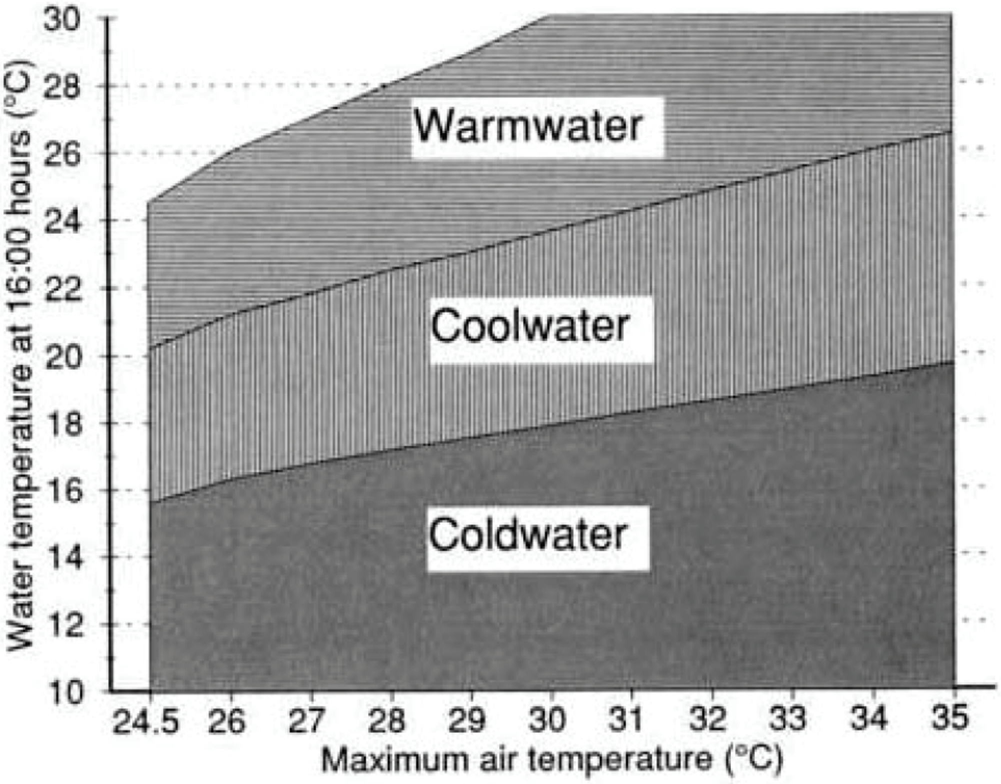


Figure 8.3: Instream barriers and ponds.



From Stoneman and Jones (1996)

Figure 8.4: Thermal regime classifications, based on relationships between maximum air temperatures and water temperatures.

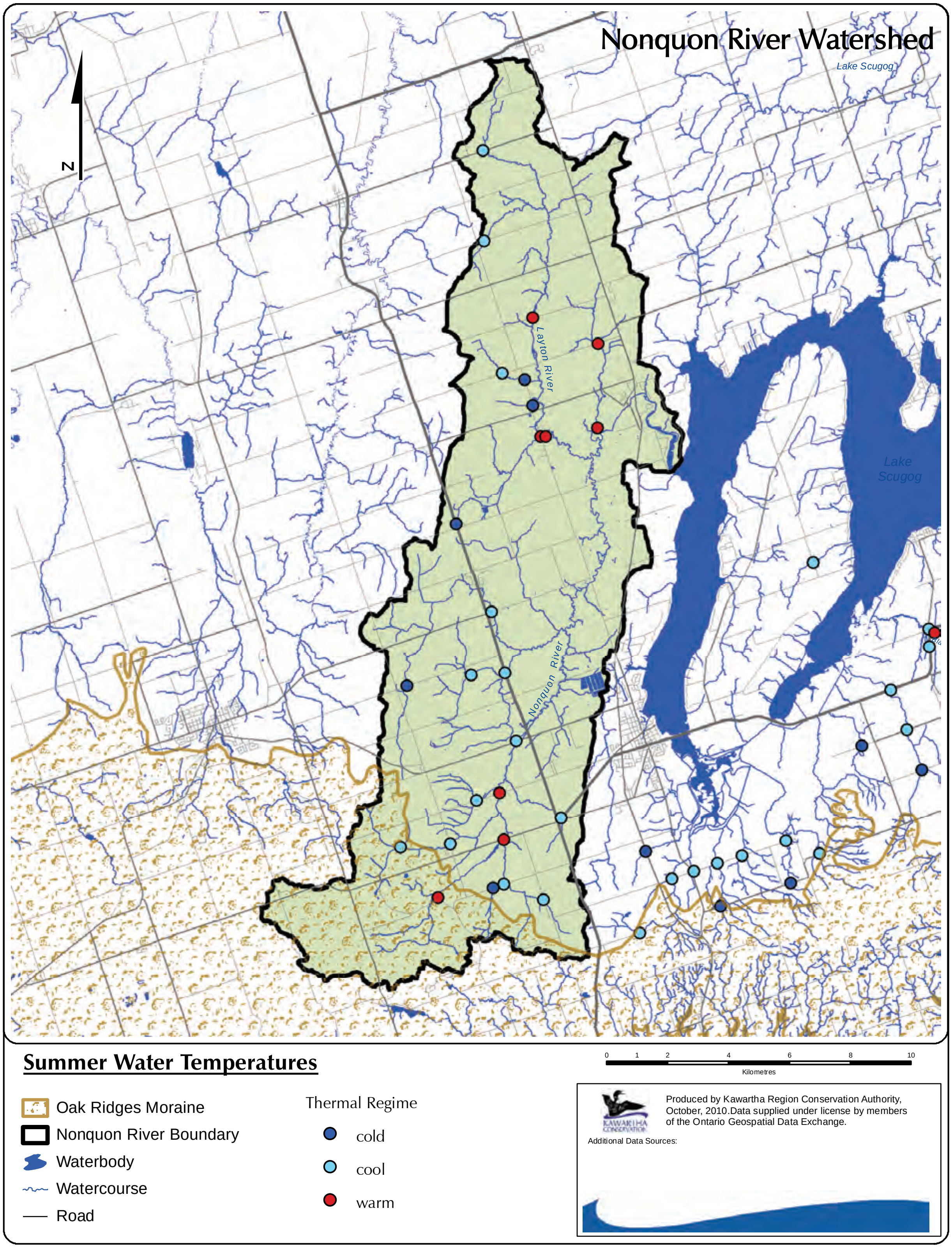
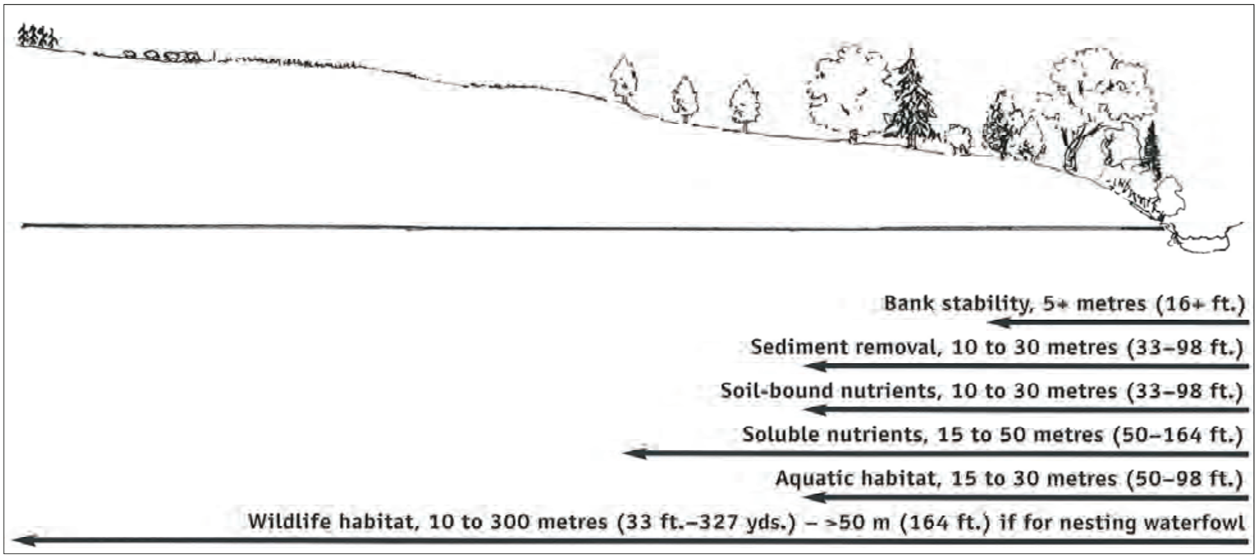


Figure 8.5: Thermal regime based on summer water temperatures.



From OMAFRA (2003)

Figure 8.6: Length of naturally vegetated buffers necessary to maintain functions.

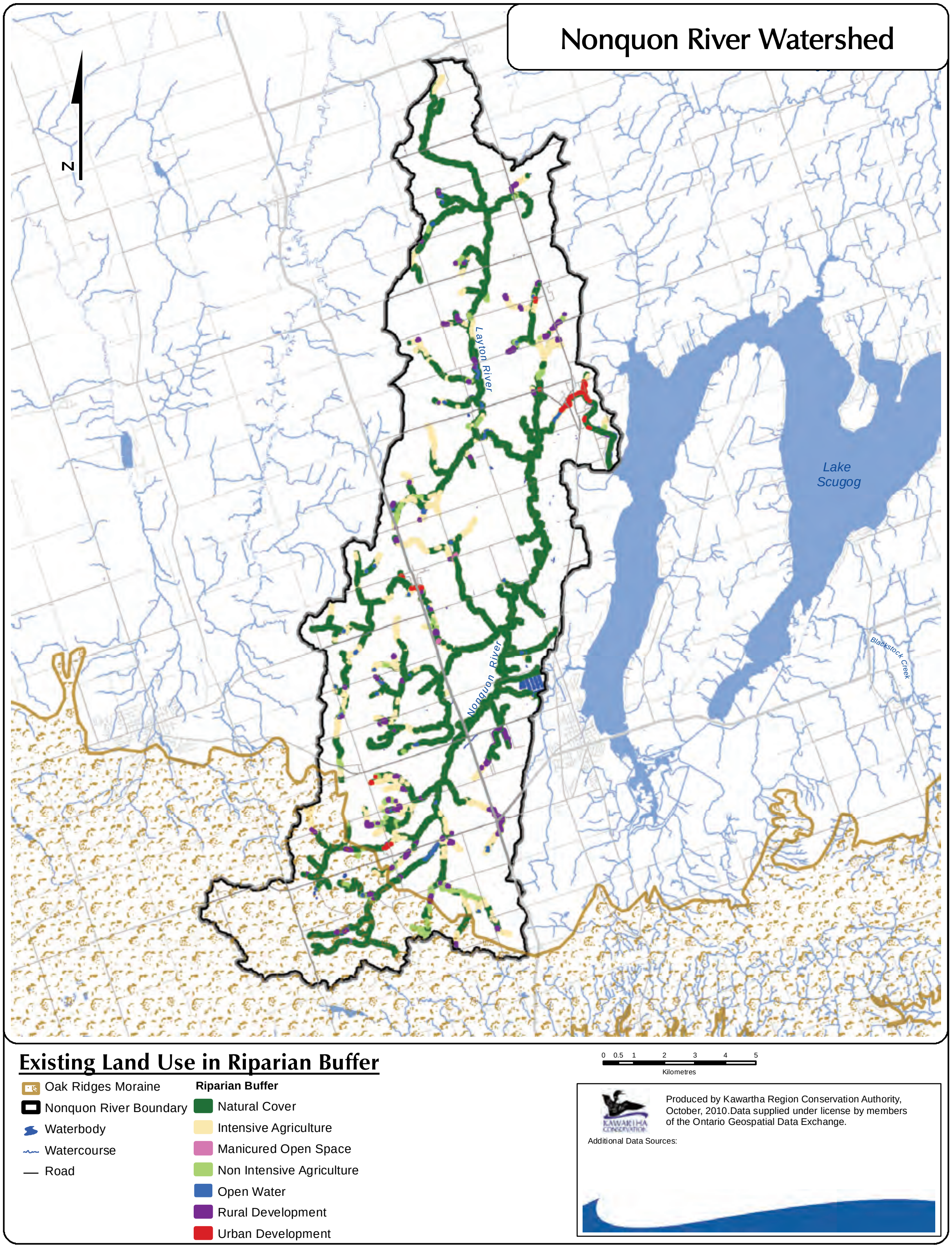
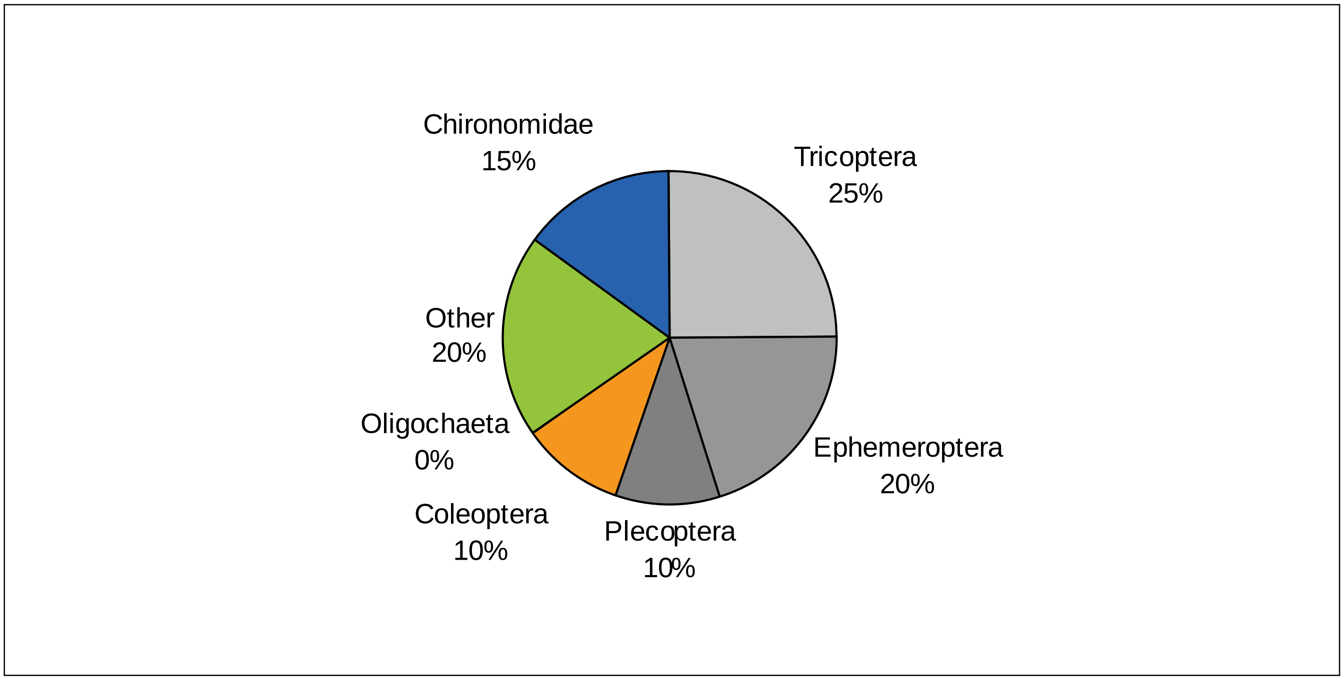


Figure 8.7: Existing riparian cover.



From Maude and Di Maio (1996)

Figure 8.8: Benthos community composition model.

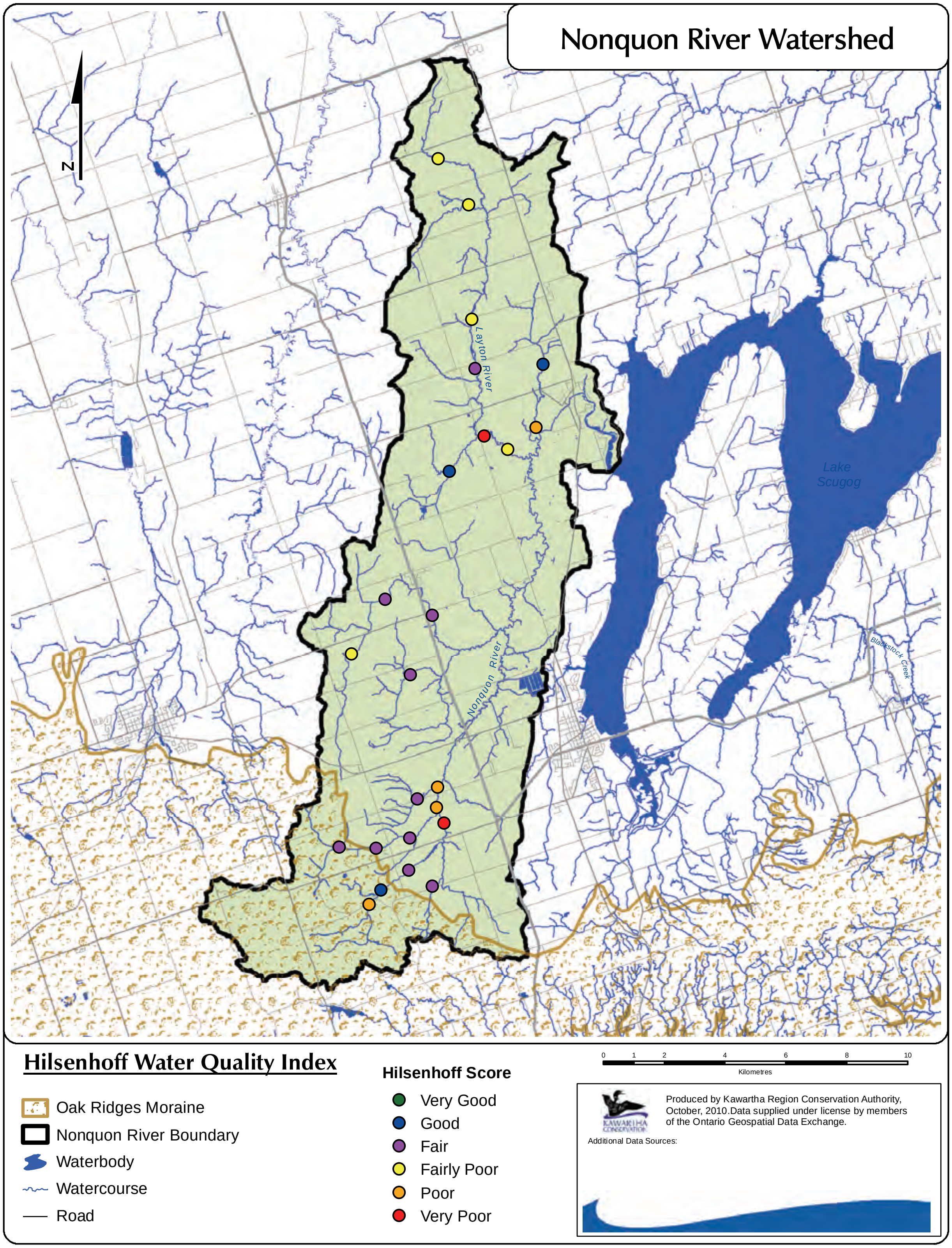


Figure 8.9: Hilsenhoff Index values.

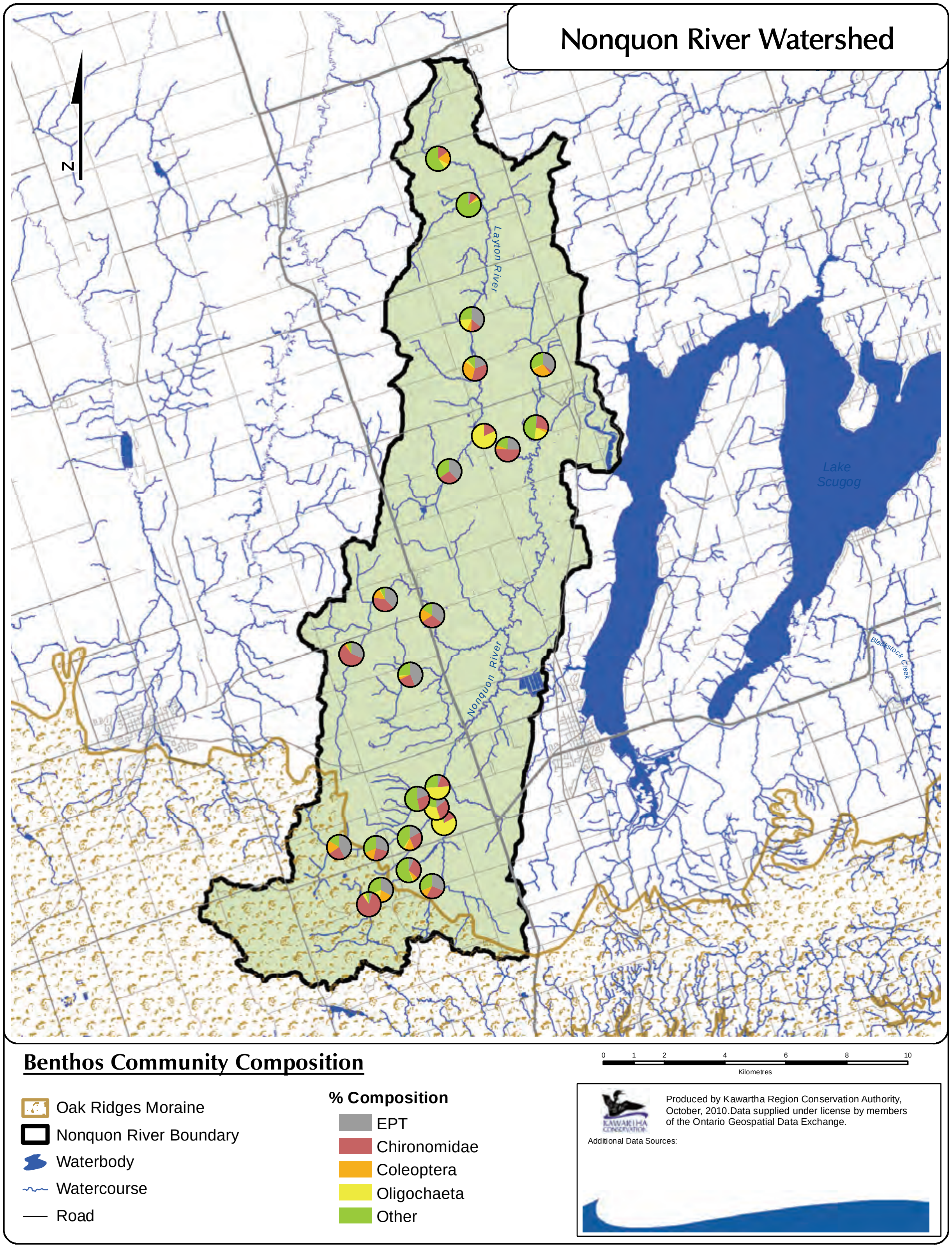


Figure 8.10: Benthos community composition.

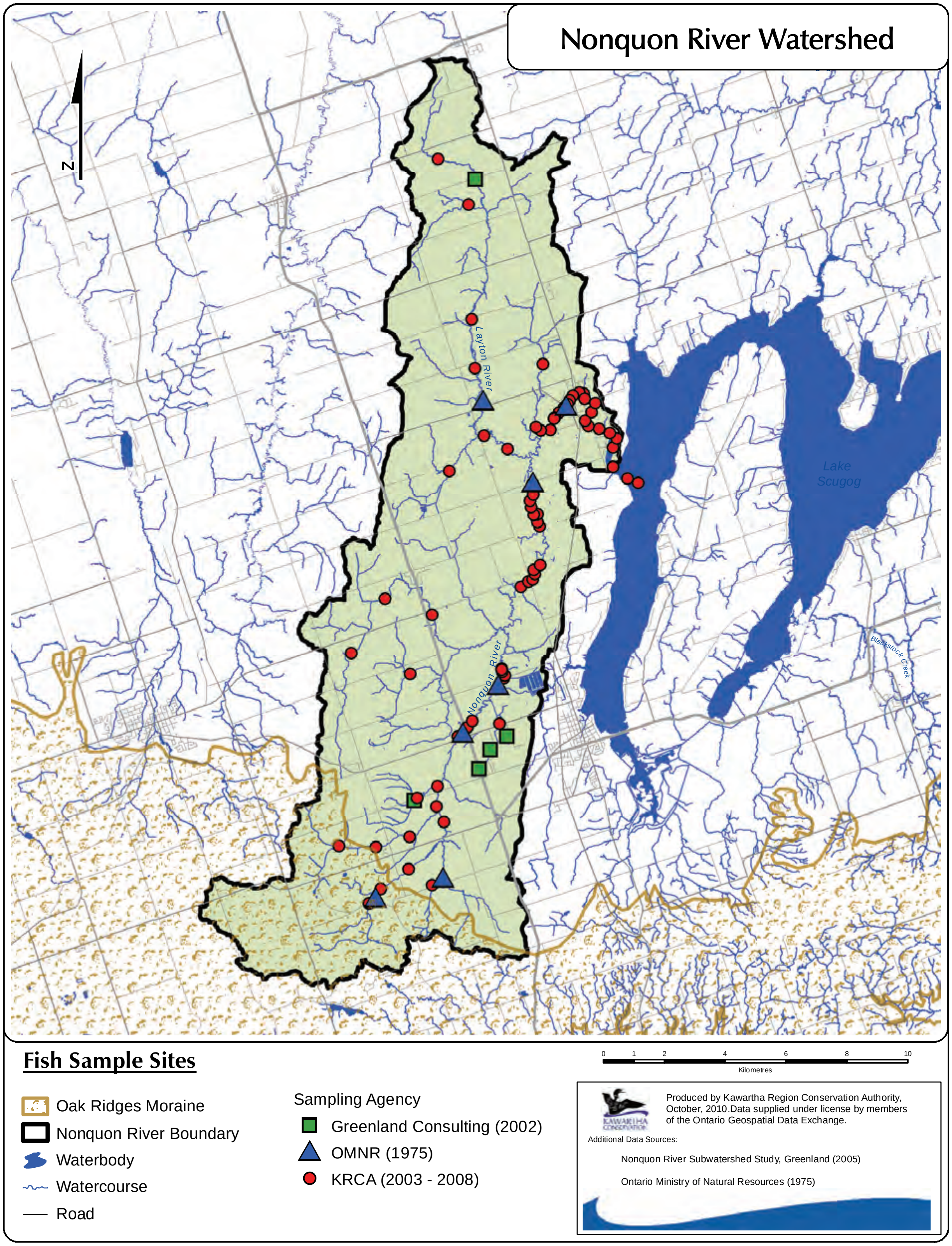
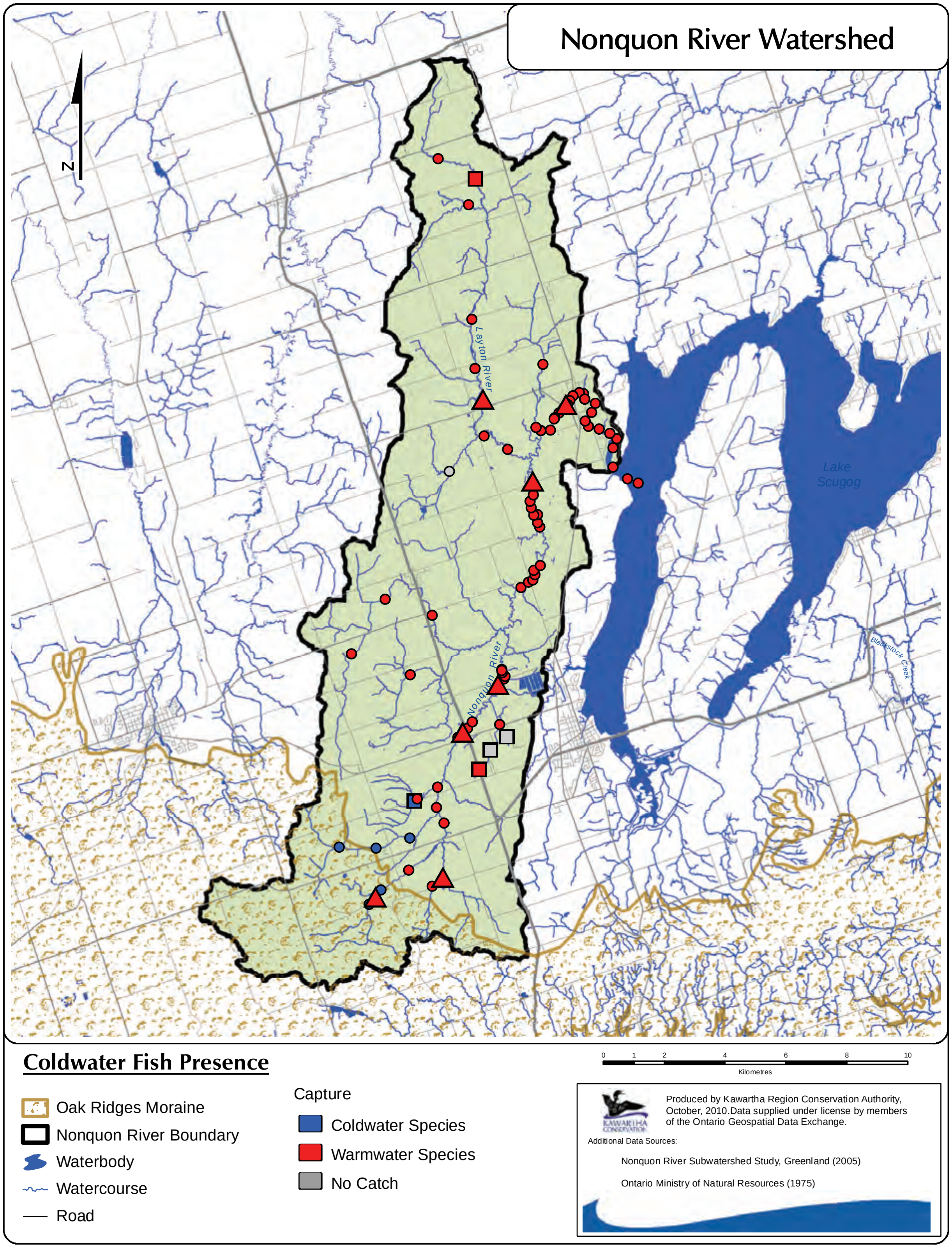


Figure 8.11: Fish samples sites.



Produced by Kawartha Region Conservation Authority, October, 2010.Data supplied under license by members of the Ontario Geospatial Data Exchange.

Additional Data Sources:

Nonquon River Subwatershed Study, Greenland (2005)

Ontario Ministry of Natural Resources (1975)

Figure 8.12: Coldwater fish captures.

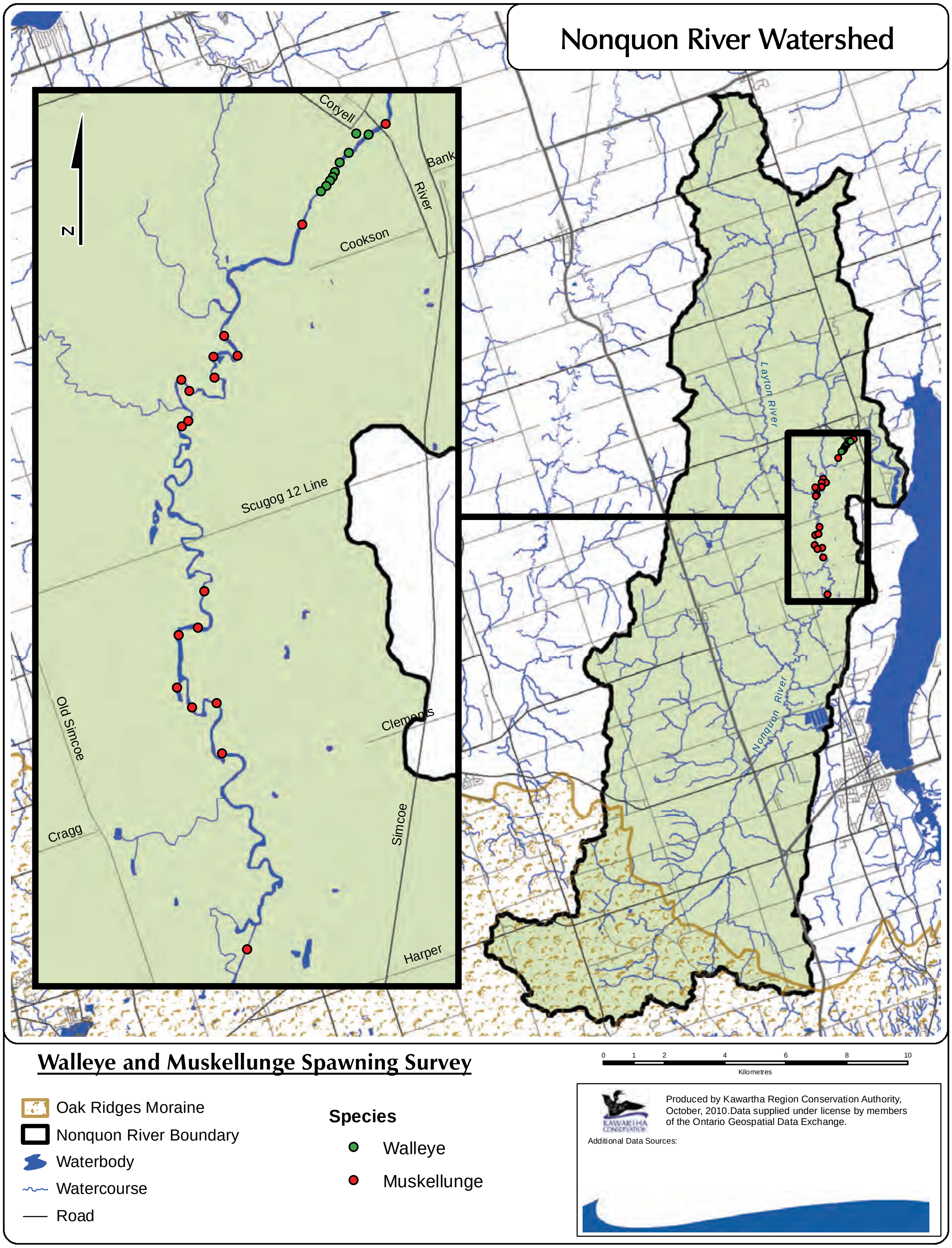


Figure 8.13: Walleye and Muskellunge spawning areas.

9.0 Terrestrial Natural Heritage

Nonquon River, north of Nonquon Industrial Tributary Area

9.1 Introduction

This section reports on the terrestrial natural heritage system within the Nonquon River watershed through an analysis of natural cover, vegetation communities, wildlife habitat, biodiversity, significant natural heritage features and forest cover. Principles of conservation biology and landscape ecology are used to evaluate terrestrial natural heritage resources and to predict the impact of alterations to natural cover, vegetation communities, wildlife habitat, biodiversity or significant natural heritage features.

9.2 The Watershed Within the Surrounding Landscape

The Nonquon River watershed lies within the Huron-Ontario section of the Great-Lakes St. Lawrence Forest Region. This region is characterized by its glacial-derived irregular topography that is often plain-like. The area is well-settled with few extensive forest tracts. The dominant forest canopy species of the region historically included Sugar Maple, American Beech, Basswood, Ash, Birch, Oak, White Pine and occasionally Eastern Hemlock, White Cedar and Balsam Fir, with softwood plantations being more common in the headwater regions. The species composition of the Nonquon River watershed forests are typical of this forest region, supporting nearly equal amounts of deciduous, mixed and coniferous forests.

The Nonquon River watershed is located within the Scugog Tertiary Watershed, 2HG, as classified by the "Great Lakes Conservation Blueprint for Aquatic Biodiversity" (Phair et al. 2005). 2HG is an inland watershed wherein the land use is predominantly agriculture with some relatively small residential communities. 12.6% of the 2HG watershed consists of lands under conservation protection, the majority of these being provincially significant wetlands. Natural cover in 2HG consists of mixed forest, coniferous and deciduous forest; deciduous and coniferous swamp; and marsh. The north east portion of the Nonquon River watershed has been designated as a priority stewardship area within the 2HG watershed.

The Nonquon River watershed is situated over two ecodistricts including the Peterborough Ecodistrict (6E-8) and the Uxbridge Ecodistrict (6E-7). The majority of the Nonquon River watershed is located within ecodistrict 6E-8. This ecodistrict is underlain for the most part by a drumlinized till plain referred to as the Peterborough Drumlin Field but its southern portion, to the west of the watershed, is situated over scattered sands and the Schomberg Clay Plains, to the west of the watershed. Within the watershed, the physiography is mainly sand plain with one area of clay plain and scattered drumlins. One percent of ecodistrict 6E-8 is residential settlement and approximately 60% of the lands are agriculture related. The ecodistrict contains over 49 000 ha of provincially significant wetland, and 96% of the target conservation areas for the ecodistrict are provincially-significant wetlands.

A relatively small area of the southern portion of the Nonquon River watershed is located in ecodistrict 6E-7. Ecodistrict 6E-7 encompasses the majority of the Oak Ridges Moraine and features kame moraines, drumlinized till plains and sand plains. Over half of the ecodistrict is currently in agriculture including crops, pasture and abandoned fields. Approximately 30% of the ecodistrict remains in natural cover and is primarily deciduous forest with some wetland. Seven percent of the ecodistrict is conservation land, with one-third of this being owned by Conservation Authorities.

Wetlands in these ecodistricts are primarily swamp with some marsh with small amounts of fen and bog. Significant remnants of globally rare vegetation communities including tallgrass prairie, savannah and alvar have been identified as high priority conservation targets for ecodistricts 6E-7 and 6E-8, however there are no such known remnants within this watershed.

The Oak Ridges Moraine, extending along the southern portion of the Nonquon River watershed, is an environmentally-sensitive geological feature that extends across the landscape of south central Ontario. The deep deposits of sand and gravel substrates that make up the Oak Ridges Moraine support an ecological system that is unique within the surrounding landscape. Due to its complex hydrogeologic functions, the terrestrial system of the Oak Ridges Moraine has great influence on water systems within the Nonquon River watershed and all of south central Ontario.

9.3 Natural Cover

An area of natural cover refers generally to land that has not been significantly influenced by anthropogenic activity. Areas of natural cover provide many benefits and perform a variety of functions that are essential to overall watershed health including:

- filtering nutrients, sediments and pollutants from surface water run off;
- improving air quality through filtration and oxygen release;
- improving the natural aesthetic of communities thus contributing to the well being of local citizens;
- maintaining aquatic and terrestrial wildlife habitat;
- performing flood attenuation;
- providing opportunities for recreation and for people to connect with the natural world through activities such as hiking, nature viewing, biking, fishing, and hunting;
- providing wildlife habitat & preserving biodiversity;
- reducing shoreline erosion by slowing and reducing surface water run off;
- sequestering carbon to reduce atmospheric carbon dioxide levels, thus contributing to the mitigation of the effects of climate change; and,
- moderating summer temperature extremes through transpiration.

Alteration of natural cover within the watershed, particularly within riparian buffer areas, may affect any or all of the above functions.

The watershed contains 79.7km^2 of natural cover, representing 41.8% of the total watershed area. This includes all areas classified as forest, wetland or meadow. **Figure 9.1** details the areas of each of these natural cover types existing within the watershed and **Table 9.1** illustrates the percentage of each land use type within the watershed.

The watershed, with 41.2% natural cover, exceeds related targets set by the Great Lakes Conservation Blueprint for Biodiversity for percent natural cover including: 30% natural cover for Ecodistrict 6E-8, and 22% natural cover for Ecodistrict 6E-7.

A subset of natural cover, forest cover, was also assessed in relation to percent cover targets. To determine the total forest cover area, forested wetlands (swamps) are included in the total forest area. Forested wetlands are also included in the total wetland area. When determining the total natural cover for the watershed, forested wetlands cannot be double counted as part of both forests and wetlands, therefore forests, forested wetlands and wetlands are counted separately to determine the total natural cover area. The watershed contains 29% forest cover, falling just below target levels of 30% forest cover for the Regional Municipality of Durham (Region of Durham 2008a) and Areas of Concern watersheds within the great lakes basin (Environment Canada 2004), and within the target of 25% - 35% forest cover for watersheds in Ontario (Conservation Ontario 2001).

Comparison of the amount of forest cover with target levels suggests that restoration efforts to increase forest cover would be beneficial for overall watershed health. The unique characteristics of the watershed suggest that such restoration efforts would be focused on lands currently in use for agriculture. This determination was made based on an assessment of the amounts of each vegetation community type and land use type existing in the watershed. The areas of the watershed available for forest restoration include all those areas not already under natural cover. This includes lands currently being used for agriculture, inactive landfill, manicured open space, urban areas, aggregate extraction areas, and rural development (please refer to Chapter 4: Land Use). Areas that are inappropriate for forest restoration include roads, active landfill sites and active aggregate extraction areas. If forest restoration was completed in urban areas and rural development areas it would be possible only in small patches and would not increase percent forest cover to meet target levels. Thus meeting targets for percent forest cover would require restoration efforts in areas that are currently in agriculture, manicured open space, or inactive aggregate extraction areas. Additionally, restoration efforts will have the highest benefit if they are focused on areas where habitat connectivity can be simultaneously improved.

Table 9.1: Percentage of natural cover.

Land Use	Watershed Area (km^2)	Watershed Area (%)
Forest	35.6	18.6
Forested Wetland	20.3	10.7
Non-Forested Wetland	14.8	7.7
Meadow	8.0	4.2

9.4 Ecological Land Classification

Ecological Land Classification (ELC) is a method to further classify natural cover types into vegetation community types within the Nonquon River watershed. Vegetation communities for the watershed were classified and mapped in 2008-2010 based on the ELC System for Southern Ontario (Lee et al. 1998). All areas of the watershed were classified through interpretation of 2008 aerial photography. In total, 12 unique types of cultural areas and 13 unique types of natural areas, based on the community series level of detail, were identified for the watershed. Cultural areas refer to natural cover that has resulted from, or is maintained by human-based disturbances and often have a large proportion of non-native plant species. Natural areas refer to natural cover have not been subject to severe human-based disturbance, and hence offer higher quality habitat value watershed resource. Vegetation community types are described in **Table 9.2**, and mapped in **Figure 9.2**.

The ELC assessment shows that the watershed contains 9.3 % cultural vegetation community types, and 32.5% natural vegetation community types. Deciduous forests encompass the greatest area of the natural forest community types, accounting for 5.2%, and coniferous and mixed forest amounts are fairly equal at 4.4% and 3.6% respectively. Nine different wetland types have been identified within the watershed and account for 18.7% of the watershed with mixed swamp, thicket swamp and coniferous swamp making up the majority of wetland area. There are nearly equal amounts of deciduous swamp, meadow marsh and shallow marsh. There are only minimal areas of shallow aquatic and open aquatic vegetation communities within the watershed.

Table 9.2: Community series description.

Community Series (Code -Descriptive Name) [1]	Description of Community Series	Watershed Area (km^2)	Watershed Area (%)
Cultural Areas			
CUM – Cultural Meadow	Areas that have resulted from or are maintained by cultural or anthropogenic-based disturbances and often have a large proportion of non-native plant species. These areas are characterized by a tree and shrub cover each of less than 25%.	6.1	3.2
CUP – Cultural Plantation	Areas that have resulted from or are maintained by cultural or anthropogenic-based disturbances and often have a large proportion of non-native plant species. These areas are characterized by tree cover > 60%.	7.8	4.0
CUS – Cultural Savanna	Areas that have resulted from or are maintained by cultural or anthropogenic-based disturbances and often have a large proportion of non-native plant species. These areas are characterized by 25%< tree cover ≤ 35%.	0.8	0.4
CUT – Cultural Thicket	Areas that have resulted from or are maintained by cultural or anthropogenic-based disturbances and often have a large proportion of non-native plant species. These areas are characterized by tree cover ≤ 25%; shrub cover >25%.	1.1	0.6
CUW – Cultural Woodland	Areas that have resulted from or are maintained by cultural or anthropogenic-based disturbances and often have a large proportion of non-native plant species. These areas are characterized by tree cover between 35% and 60%,	2.3	1.2
Natural Areas			
FOC – Coniferous Forest	Areas where tree cover is greater than 60%,	8.6	4.4

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[1] Community series' refer to those described in the Ecological Land Classification for Southern Ontario manual, first approximation (Lee et. al. 1998), unless marked with a * which indicates a land use code that has been created by practitioners and accepted by the South Central Ontario Conservation Authorities terrestrial natural heritage discussion group (SCOCA), but which are not explicitly included in Lee et. al. (1998).

Community Series (Code -Descriptive Name) [1]	Description of Community Series	Watershed Area (km^2)	Watershed Area (%)
	and the canopy is comprised of greater than 75% coniferous tree species		
FOD – Deciduous Forest	Areas where tree cover is greater than 60%, and the canopy is comprised of greater than 75% deciduous tree species	10.0	5.2
FOM – Mixed Forest	Areas where tree cover is greater than 60%, and the canopy is comprised of greater than 25% deciduous tree species and greater than 25% coniferous tree species	7.0	3.6
MAM – Meadow Marsh	Areas with <2m of water over substrates. Often seasonally flooded with soils drying out by mid-summer. Tree and shrub cover is less than or equal to 25% and area is dominated by emergent hydrophytic macrophytes. Represents the wetland-terrestrial interface.	2.9	1.5
MAS – Shallow Marsh	Areas with <2m of water over substrates. Often with standing or flowing water for much or all of the growing season. Tree and shrub cover is less than or equal to 25% and cover of emergent hydrophytic macrophytes is greater than or equal to 25%.	3.1	1.6
OAO – Open Aquatic	Areas with water >2m deep. Plankton dominated with no macrophyte vegetation and no tree or shrub cover.	1.1	0.6
SAF – Floating-leaved Shallow Aquatic	Area with standing water <2m deep. No tree or shrub cover, and if emergent vegetation is present is not dominant. Greater than 25% cover of floating-leaved macrophytes. Often influenced by shoreline energy.	<0.1	0.0
SAM – Mixed Shallow Aquatic	Area with standing water <2m deep. No tree or shrub cover, and if emergent vegetation is present is not dominant. Greater than 25% cover of submerged and floating-leaved macrophytes. Often influenced by shoreline energy.	1.3	0.7
SAS – Submerged Shallow Aquatic	Area with standing water <2m deep. No tree or shrub cover, and if emergent vegetation is present is not dominant. Greater than 25% cover of submerged macrophytes. Often influenced by shoreline energy.	<0.1	0.0
SWC – Coniferous Swamp	Areas with variable flooding where water depth is <2m and standing water or vernal pooling makes up >20% of the ground coverage. Tree cover is >25%, canopy height is greater than 5m, and conifer tree species make up >75% of the canopy. Hydrophytic shrubs and herbs present.	7.9	4.1
SWD – Deciduous Swamp	Areas with variable flooding where water depth is <2m and standing water or vernal pooling makes up >20% of the ground coverage. Tree cover is >25%, canopy height	3.2	1.7

Community Series (Code -Descriptive Name) [1]	Description of Community Series	Watershed Area (km^2)	Watershed Area (%)
	is greater than 5m, and deciduous tree species make up >75% of the canopy. Hydrophytic shrubs and herbs present.		
SWM – Mixed Swamp	Areas with variable flooding where water depth is <2m and standing water or vernal pooling makes up >20% of the ground coverage. Tree cover is >25%, canopy height is greater than 5m, deciduous tree species make up >25% of the canopy, and coniferous tree species make up >25% of the canopy. Hydrophytic shrubs and herbs present.	9.5	4.9
SWT – Thicket Swamp	Areas with variable flooding where water depth is <2m and standing water or vernal pooling makes up >20% of the ground coverage. Tree cover is less than or equal to 25% and hydrophytic shrub cover is >25%.	8.6	4.4
Cultural Areas		**18.0**	**9.5**
Natural Areas		**61.7**	**32.3**
Total Natural Cover		**79.7**	**41.8**

9.5 Terrestrial Biodiversity

The diversity of terrestrial flora and fauna species that are supported by the available habitat within the watershed can provide an insight into the overall ecological health and condition of the watershed. The existence of significant species, such as designated species at risk or species populations known to be in decline, can assist with prioritization of conservation work within the watershed.

Full flora and fauna lists have not been compiled for the watershed, however significant species existing in the watershed or with high potential to exist within the watershed have been determined. 22 species at risk have been identified as conservation targets within ecodistricts 6E-7 and 6E-8. Of those species, 2 have been confirmed within the watershed, including the Green-striped Darner and the Least Bittern. An additional 7 fauna and 2 flora species are recognized as having high potential to exist within the watershed (**Table 9.3**, **Table 9.4**).

Table 9.3: Significant Fauna Species with High Potential to Exist within the Watershed.

Scientific Name	Common Name	Species Target for Ecodistrict 6E-7	Species Target for Ecodistrict 6E-8	Species Target for Tertiary Watershed 2HG	EO[2] in Nonquon River Watershed	Comments
Aeshna verticalis	Green-striped Darner				√	
Buteo lineatus	Red-shouldered Hawk	√				Requires relatively large undisturbed forests. Observations relatively close to the watershed in forests similar to those existing in the watershed.
Childonias niger	Black Tern		√	√		
Dendroica cerulea	Cerulean Warbler	√	√			This migratory species has been observed elsewhere in the Regional Municipality of Durham. It is more likely to pass through the watershed than to breed there.
Ixobrychus exilis	Least Bittern	√	√	√	√	
Lanius ludovicianus	Loggerhead Shrike		√			Found in only 6 core locations in Ontario including the Carden Plain just 45km north of the watershed.
Rallus elegans	King Rail		√	√		Observed in wetlands just east of the watershed. Suitable habitat available in the watershed.

Table 9.4: Significant Flora Species with High Potential to Exist Within the Watershed.

Scientific Name	Common Name	Species Target for Ecodistrict 6E-7	Species Target for Ecodistrict 6E-8	Species Target for Tertiary Watershed 2HG	EO in Nonquon River Watershed	Comments
Juglans cinerea	Butternut	√	√			Mature deciduous forests. Species common, Ontario populations undergoing rapid decline due to Butternut canker.
Panax quinquefolius	American Ginseng	√				Observed in relatively close proximity to the watershed.

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[2] EO (Element Occurrence): species observation recorded in the Natural Heritage Information Center (NHIC) database

Forests

Woodlands in the Oak Ridges Moraine have been impacted by nearly 200 years of human settlement activities. When Europeans first settled the Oak Ridges Moraine the value of timber was not recognized and the forest was viewed as an impediment to settlement and travel. Woodlands that were not cleared for settlement were used to meet the demand for rapid growth and construction of towns.

All of this has resulted in a landscape very different than the one encountered by the first settlers. Most southern Ontario woodlands are now small, fragmented forests. These forests include: plantations on private land and Conservation Areas or large municipal properties (e.g., the Durham Regional Forest); abandoned Christmas tree plantations (often referred to as Scots pine jungles); immature mixed forests that are regenerating abandoned agricultural lands; or the fairly extensive lowland woodlands along the middle and lower reaches of the Nonquon River watershed.

Woodlands and the Hydrological Cycle

The hydrological cycle is a complex web of interacting events and features that move water within our atmosphere and on or under the land. The cycle includes processes such as evaporation, transpiration, rainfall, and features such as streams, rivers, geology and the water table.

Woodlands affect the hydrology of watersheds in many ways, including: retaining snow melt and storm runoff (thereby increasing infiltration and groundwater recharge); reducing the nutrient load of runoff; and, providing balanced groundwater discharge during periods of drought. Excessive forest clearing leads to erosion, increased sedimentation in streams, warming of surface waters, and seasonal extremes in high and low stream flow.

Tree cover creates and maintains a mat of decomposing leaf and twig litter which protects the soil surface, slows runoff, reduces erosion, and increases infiltration. The older, most decomposed materials near the bottom of this layer become the organic matter in the soil, tending to be rich in nutrients, with improved soil structure. Infiltration may also be improved by the development of root channels as trees grow.

Woodland Streams

Woodlands play an important role in stream health and hydrology. By retaining and discharging ground water throughout the year, forests help maintain the base flow of the smaller headwater tributaries that often originate in woodlands or small wetlands. Overhead shade helps to maintain cool water temperatures. These small streams can provide essential habitat for the native Brook Trout; as they require excellent water quality, cool water temperatures and high oxygen levels. The presence of Brook Trout is considered an indicator of healthy streams and watersheds.

Forest Types

The forests within the Oak Ridges Moraine and south-central Ontario are considered to be part of the Great Lakes – St. Lawrence Forest Region, located north of the Deciduous Forest Region (generally running along and south of the 401) and south of the Boreal Forest Region. Some forest types are unique to this area but others resemble forests in the Regions to the north and south (Farrar 1995).

The primary forest types of the Oak Ridges Moraine and area are variations of upland woodlands, lowland woodlands, and early successional forests (commonly referred to as pioneer forests). One other major southern Ontario woodland type is the plantation, with various species and many planting arrangements, which are generally established on eroded valleylands, riparian areas, and abandoned or marginal farmlands.

Pioneer Forests

Pioneer forests are the first stage in succession, naturally regenerating after a significant disturbance, e.g. fire, wind damage, clear cutting, large scale mortality from insects or diseases, or abandonment from agricultural use. These forests are usually comprised of fast growing, relatively short-lived hardwoods requiring full sunlight for germination and growth. Within several decades, many of these pioneer species die off, having created the more suitable conditions (cooler, moister, greater organic materials) for natural 'succession' to longer-lived species that grow more successfully in shade. Pioneer species vary from site to site, most commonly including:

- Trembling (Populus tremuloides) and large toothed aspens (Populus grandidentata), balsam poplar (Populus balsamifera), silver (Acer saccharinum) and red maples (Acer rubrum), white ash (Fraxinus americana), red (Prunus) and black (serotina) cherries, and white birch (Betula papyrifera).

- With the appropriate soil and a ready seed source, red oak (Quercus rubra), white pine (Pinus strobus), spruce (Picea spp.) and white cedar (Thuja occidentalis) can occasionally be considered pioneer species.

- Pioneer conifers include white pine, white cedar, balsam fir (Abies balsamea), and white spruce (Picea glauca). However, these species can usually tolerate slightly more shade and follow a few years after the pioneer hardwoods.

- Shrub species include hawthorn (Crataegus spp.), beaked hazel, dogwood (Cornus spp.), elderberry (Sambucus spp.), choke cherry (Prunus virginiana) and wild raspberries (Rubus ideaus).

- Exotic species such as Scots pine (Pinus sylvestris) and the very invasive European buckthorn (Rhamnus cathartica), also thrive in these conditions. These two species are becoming increasingly common in many areas of the Nonquon watershed, replacing native trees and shrubs as pioneer species.

Upland Forests

There are basically two types of upland forests in the Nonquon River watershed, depending on soil types, drainage patterns, stages of succession, and land-use history. These forest types and their variations can be found growing side by side, often signaling a change in the site or stand history. These woodlands, once the most common in the Nonquon River watershed uplands, now exist only as remnant features.

Upland Oak-Pine Forests are found on drier sites, with red oak and occasionally white oak being the major hardwood species, in conjunction with white pine, hemlock, white spruce, and occasionally red pine. They can grow on shallow or drought prone soils, e.g. the higher slope, coarse sandy – gravel soils of the Oak Ridges Moraine. Oaks are not extremely tolerant of shade, and usually follow shortly after the pioneer forests that become established after major disturbances - fire, heavy logging, or perhaps clearing for agriculture – or may in fact be elements of pioneer forests. Associated species include: Red maple (Acer rubrum), Sugar maple (Acer saccharum), White Ash (Fraxinus americana), American beech (Fagus grandifolia),and Basswood (Tilia Americana).

Upland Hardwood Forests are comprised primarily of deciduous trees with high tolerance to shade, and growing most successfully in deep soils which are moister and typical of the mid-range slopes and well drained flat lands. Hard (sugar) maple (Acer saccharum), American beech (Fagus grandifolia), Ironwood (Ostrya virginiana), hemlock (Tsuga canadensis), and occasionally balsam fir are all very tolerant of shady conditions and tend to dominate this forest type. These species can successfully regenerate in small openings (i.e. where 1-2 mature trees die or blow over). This forest type is the final step of the “succession” process, and is often referred to as the climax forest (i.e., it will sustain itself for centuries until there is a major forest disturbance).

Lowland Forests

Lowland forests can be very different in species composition and history, with distinct types often growing side by side, in mixtures, or in adjacent pockets. These woodlands are the most common of all forest types growing in the watershed, especially in the middle and lower reaches of the river, as it meanders to Lake Scugog.

Cedar swamps are dense woodlands in low areas, higher moisture soils, and valley lands adjacent to streams and small rivers. White cedar can also quickly colonize abandoned fields adjacent to established cedar woodlands, and could then be referred to as a ‘pioneer forest’. Other species commonly associated with white cedar include white spruce, white pine, balsam fir, hemlock, poplar, yellow and white birch, black ash, white elm (Ulmus americana) and poplar. Tamarack (Larix laricina) frequently grows on sites with higher water levels, where wetland shrubs such as red osier dogwood, alder, willow (Salix spp.) shrubs become more common. Black spruce is a common lowland conifer species in the boreal forest, but is very rare this far south.

Plantations

With the extensive land clearing following settlement in the 1800’s, large areas became unsuitable for farming in the long term due to poor soils or topography. With faster snowmelt and downstream flooding, erosion, dust storms and the subsequent abandonment of thousands of acres of cleared land resulted. Tree planting was the most obvious option to effectively reduce further site degradation. Plantations have become a major southern Ontario forest type. These “man-made” woodlands now provide the same benefits as natural woodlands, usually much quicker than natural regeneration. This cultural forest, primarily red pine and other conifers, now the most common forest type on the Oak Ridges Moraine portion of the Nonquon watershed. Reforestation was accomplished in several ways, as summarized below.

Much of the most severely degraded land was taken over by municipalities or Conservation Authorities, then reforested and managed by the Provincial Government until the late 1990’s. Local examples include the Ganaraska, the Northumberland, the York and Durham Regional Forests – the main block of the Durham Forest is located in the western portion of the Nonquon watershed, visible from Durham Road 21. Some of the finest examples of reforestation in North America are exhibited within these forests.

The Ontario Ministry of Natural Resources and conservation authorities undertook an ambitious private land tree planting program from the late 1960’s. Although much reduced at the present time, several thousand acres were planted annually throughout Ontario to the early 1990’s.

Private landowners undertook reforestation on their own properties, largely through the purchase and planting of trees from the Provincial Nurseries in Orono and Midhurst, now closed. These projects were generally one of two types:

i.) Large areas of unsuitable farm land were planted to Christmas trees, with the main species being Scots pine. Other species include white and blue spruce or western fir. The Scots pine planted for Christmas trees often were left unharvested as the market collapsed with the appearance of artificial trees. This species tends to regenerate easily, perpetuating itself and invading into adjacent fields as they become abandoned to agriculture.

ii.) Small areas were reforested by the landowner, friends and family, often only a few hundred trees each spring. Thousands of acres have been reforested over the decades, including field corners, stream banks, windbreaks and pockets of wildlife habitat.

Forest Conservation By-Laws

Commercial forest operations in many southern Ontario municipalities are now regulated by Forest Conservation By-Laws. These municipal acts of legislation are enacted for the purpose of achieving the objectives of the Official Plans by sustaining a healthy natural environment, while regulating forest harvests so they comply with good forestry practices. They encourage sustainable forest harvest and provide a certain measure of protection to the landowner.

The current Durham Region Forest Conservation By-Law applies to all Woodlands one (1) hectare or more in size. Individuals who are considering the harvest or removal of trees in any way are strongly encouraged to contact the Regional Planning Department. They may be required to submit a Good Forestry Practices Permit Application form, or be within one of a number of exemptions which may be applicable to individual circumstances.

Forest Health

Over the last century, forest pests (insects and diseases) imported from other continents have resulted in the decimation of several significant tree species – American chestnut (Castanea dentate), American (or white) elm, American beech, and butternut. All ashes are now at risk from the Emerald Ash Borer at the time this report is being produced. The impact of these species all but disappearing is incredibly significant.

For example, American beech, one of the three most common and important species within the upland hardwood forest, has over the last 12-15 years become a remnant species, the result affects the entire eco-system. Not only was this tree excellent at self regenerating after any disturbance, but it had the potential to provide high quality lumber. In addition, it was formerly a valuable nut producing species for a wide range of forest wildlife, while almost certainly providing less obvious roles within the forest eco-system.

The ash family seems to be the next species threatened as the Emerald Ash Borer has expanded its territory into North America. In the last 4-5 years, the Ash Borer's range has rapidly expanded from the Windsor – eastern Michigan area (its point of first discovery) well into the central states, to Sault Ste. Marie in the north and the Regional Municipality of Durham at the time of this report (spring of 2009). Significantly, white ash is the second of the three most common species within the upland hardwood forest.

At this very time, over the last several years, federal, provincial and municipal governments are working to contain the Asian Long-Horned Beetle in the Vaughan – Black Creek area. This insect is fatally destructive of several species, including sugar maple – the most common species within our upland hardwood forest. Fortunately, this insect is slow moving, reasonably detectible, and seemingly possible to be contained.

Invasive Plants and Shrubs

In our southern Ontario forest ecosystems and natural areas, invasive plants are now well established and altering our natural ecosystem communities. An invasive species is one that has been moved from its native habitat – usually from another continent - to a new area, often for a landscaping or other domestic use. Occasionally, a plant escapes and reproduces so aggressively in its new environment (without the natural controls of its native environment) that it displaces species within our native communities. Some very common species we have all become familiar include: starlings, zebra mussels, purple loosestrife and gypsy moth.

Some particularly persistent plant species now well established in Ontario woodlands, to varying degrees, include common and glossy buckthorn, swallow wort / dog-strangling vine (Cynanchum louiseae, nigrum; Vincetoxicum nigrum), garlic mustard (Alliara petiolata), and Norway maple (Acer plantaoides) and its many cultivars. These plants are capable of displacing native plants such as Trilliums and ferns, as well as smothering the natural regeneration of forest trees. Some of these plants also have the alleliopathic qualities, i.e. capable of discouraging other plants from growing nearby. Garlic mustard, for example, is thought to produce chemicals that may interfere with the function of the soil fungi / plant root relationship necessary for the long-term survival and health of our native plants.

Woodlands and Bio-Diversity

Forests were the dominant terrestrial vegetation community throughout Ontario prior to European settlement. In today's southern and central Ontario landscape, our remaining forest cover is mostly small, fragmented woodlands separated by agricultural land, urban / residential areas, and expansive transportation networks. These 'island' woodlands provide habitat for species that benefit from both the forest and the adjacent land uses – e.g. deer, wild turkeys, raccoons, squirrels - however larger woodlands, or woodlands connected by corridors of natural vegetation are healthier and provide the varied habitat required by many native woodland species.

Large woodlands contain an increasingly rare, high quality wildlife habitat referred to as the "forest interior". As a rule, forest interior habitat is that portion of a woodland greater than 100 metres from any edge – a field, road or hydro corridor. To put this into perspective, a square 4 hectare (10 acre) woodlot measures 200 metres by 200 metres, and will contain only a fraction of 1 hectare of forest interior habitat. Some bird species require up to 2 ha of home range, and will not tolerate other nesting pairs of that same species within their range. In fact, some species require an area of interior habitat sufficiently large for social interaction of several nesting pairs. **Table 9.5** lists the general response of species to varying sizes of forest patches.

Like many natural heritage features, guidelines for the minimum amount of forest interior have been developed. Environment Canada recommends that the proportion of the watershed that is forest cover 100 meters or further from the forest edge should be greater than 10 %. The proportion of the watershed that is forest cover 200 meters or further from the forest edge should be greater than 5%. The Nonquon River watershed has only 7.4% forest coverage that is >100 meter from edge and 2.9% forest coverage that is > 200 meter form edge. Therefore the Nonquon river watershed is lacking in interior forest and deep interior forest due to the fragmented nature of forest cover in this area. **Figure 9.3** shows the distribution of interior forest areas within the watershed.

Table 9.5: Anticipated response by forest birds to size of largest forest patch (EC 2004).

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

From Environment Canada (2004)

9.6 Significant Natural Heritage Features

The assessment of significant natural heritage features for the watershed is primarily based on key natural heritage features (KNHFs) as defined by Section **22** of the Oak Ridges Moraine Conservation Plan, but also includes other features determined to have particular ecological importance at any scale within the watershed.

Identifying significant natural heritage features provides an understanding of the unique conservation values associated with the watershed. This understanding allows watershed management efforts to be focused on areas where they are most needed and can be most effective. Significant natural heritage features applicable to the terrestrial ecology of the watershed are discussed in the following sections.

The Oak Ridges Moraine Conservation Plan has developed a natural heritage system that identifies key natural heritage features and linkages and provides a template for sustainable use of the moraine into the future. In addition, the Greenbelt Plan has also identified a Natural Heritage system that is based on the same principles, that is the identification of key natural heritage features and linkages supported by maps showing these areas. These land use designations are show in Chapter 4: Land Use.

Areas of Natural and Scientific Interest

Areas of Natural and Scientific Interest (ANSI) are areas that have been identified by the Ontario Ministry of Natural Resources as having provincially or regionally significant representative ecological or geological features. Life Science ANSIs (ANSI-lsc) are designated based on ecological significance, and Earth Science ANSIs (ANSI-esc) are designated based on geological significance. Although there are no fully designated ANSIs, 6 candidate ANSI sites exist within the Nonquon River watershed. These candidate ANSI (ANSI-c) sites encompass 17.5% of the total watershed area. **Table 9.6** describes each candidate ANSI site.

Table 9.6: Candidate ANSI sites in the Nonquon River watershed.

Name	Type	Area (km^2)	Description
Uxbridge Lobe Glacial River Deposits	ANSI-esc (Provincial)	13	This significant geologic feature is an elevated, wedge-shaped area of glacially-deposited sediment. The area is located on the ORM, in the south west section of the watershed.
Nonquon Headwaters (2 sites)	ANSI-lsc (Regional)	4.8, 1.8	The smaller of these 2 sites is located just north of the larger and just east of the Utica Bogs site. These sites are in the south west section of the watershed on the ORM. These areas are predominantly riparian forests with some wetland, and each contains a portion of provincially significant wetland.
Utica Bogs	ANSI-lsc (Provincial)	0.1	This wetland in the south west section of the watershed and on the ORM, is part of a larger wetland encompassing 50.6 ha. The larger wetland is referred to as Utica Swamp and is shared between the Nonquon River watershed and the Uxbridge Brook watershed to the west. The Uxbridge Swamp is a palustrine system comprised mainly of marsh with some bog and swamp.
Nonquon River Wetlands	ANSI-lsc (Regional)	26.4	This relatively large area encompasses 12% of the total watershed area, following the Nonquon River route from approximately Manchester to Seagrave. This area is a provincially significant wetland containing mainly swamp, marsh and shallow aquatic vegetation community types. This area contains the 526 ha Nonquon Provincial Wildlife Area, north of Port Perry, which is the site of the Nonquon Environmental Education Centre.
Uxbridge-Glen Major Forests	ANSI-lsc (Provincial)	0.2	This relatively small area is located in the south west section of the watershed immediately adjacent to the watershed boundary. This is a deciduous forest situated adjacent to an active aggregate extraction area.

Endangered, rare and threatened species habitat

Significant portions of endangered, rare and threatened species habitat exist within several areas of the watershed. These areas include a wetland complex south of Seagrave and north of Clements Road, wetlands within the Nonquon River Wetlands ANSI-lsc to the south east of Greenbank, and wetlands within the Nonquon River Wetlands ANSI-lsc roughly bordered by Scugog Line 9, Reach Street, and Highway 7.

Significant wildlife habitat

The identification of significant wildlife habitat (SWH) areas for the watershed was guided by the Oak Ridges Moraine Technical Paper #2 (Province of Ontario 2007), the Significant Wildlife Habitat Technical Guide (OMNR 2000), and mapping provided by the Ontario Ministry of Natural Resources.

SWH is defined by as: an area where plants, animals and other organisms live or have the potential to live and find adequate amounts of food, water, shelter and space to sustain their population, including an area where a species concentrates at a vulnerable point in its annual or life cycle and an area that is important to a migratory or non-migratory species (OMMAH 2002).

This discussion of SWH excludes types of habitat addressed in other sections of this report. SWH described in this section includes seasonal concentration areas, rare vegetation communities and animal movement corridors.

Seasonal Concentration Areas

Seasonal concentration areas include areas where a particular wildlife species congregates or that a species relies on during a certain time of year such as deer wintering yards, migratory bird stop-overs, or reptile hibernation areas. Known seasonal concentration areas for wildlife within this watershed include deer wintering yards.

Rare Vegetation Communities

Rare vegetation communities, identified as Key Natural Heritage Features, in the Oak Ridges Moraine Conservation Plan include sand barrens, savannahs and tallgrass prairies. None of these vegetation communities are known to exist within the watershed, however there is potential for them to exist in this area due to the presence of appropriate substrate types, climates, and their documented presence in adjacent watersheds.

Animal Movement Corridors

Animal Movement Corridors are typically long, narrow areas used by wildlife to move from one habitat to another. Such corridors facilitate seasonal migration, allow animals to move throughout a larger home range, and improve genetic diversity in species populations. To effectively serve their purpose, animal movement corridors must meet the needs of the species using the corridor. This includes consideration of corridor width, length, percent natural vegetation cover, and species composition.

The Oak Ridges Moraine, extending through the southern portion of this watershed, is a wildlife corridor that functions on a landscape scale. The areas of the Oak Ridges Moraine that are designated as Natural Core and Natural Linkage form a corridor that supports the movement of flora and fauna across the landscape.

Within the watershed there are areas of natural cover with the potential to function as wildlife corridors. These areas of natural cover are clustered primarily along the route of the Nonquon River and within the Oak Ridges Moraine boundary. The Nonquon River Wetlands ANSI-lsc has the potential to function as a north-south wildlife corridor, providing terrestrial and aquatic connectivity from Seagrave to Manchester. South of Manchester, the Nonquon River continues to provide a corridor for aquatic wildlife movement, however terrestrial habitat connectivity is lacking in this area.

Significant Woodlands

Significant woodlands within the Nonquon River watershed have been mapped by the Ontario Ministry of Natural Resources. Significant woodland locations are illustrated in **Figure 9.4**.

Woodlands are considered significant because of the features and functions that they provide. Significant woodlands may include areas that have supported a treed community for more than 100 years, contain significant species, contain or support other significant natural heritage features (such as significant wildlife habitat), provide supporting habitat for another KNHF, or act as an ecological linkage between KNHFs.

Significant woodlands within the watershed are clustered on the Oak Ridges Moraine within the riparian area of the Nonquon River between Seagrave and Manchester, within the riparian area of Layton River between Concession Road 2 and Regional Road 13, and within the riparian area of Layton River north of Concession Road 4.

Wetlands

Wetlands are identified as KNHFs and hydrologically sensitive features in the Oak Ridges Moraine Conservation Plan. **Figure 9.1** illustrates the location of wetlands within the watershed. **Figure 9.2** also illustrates wetland locations and provides a greater level of detail about each wetland by indicating the vegetation community series. Wetlands occur on the landscape as single vegetation communities, or as complexes made up of a grouping of several small wetlands. Wetland complexes may be under-represented on this figure due to the minimum classification unit sizes used in the Ecological Land Classification system.

Although all wetlands have high ecological value, and are of significance to the management of the watershed, the classification of provincially significant wetlands assists with prioritizing wetlands for conservation protection.

Environment Canada's guideline on wildlife habitat recommends that approximately 10% of each watershed, and 6% of each subwatershed in the Great Lakes basin should be wetland (Environment Canada 2004). This guideline is based on evidence that occurrences of high flows and floods decrease significantly as the amount of wetland in a watershed increases. This inversely proportional relationship holds true until the amount of wetland reaches 10% of the watershed, at which point the decrease in flood occurrences begin to level off.

The Nonquon River watershed contains approximately 36km^2 of wetland, which represents 18.7% of the total watershed area; this is well above the minimum recommended percentage of wetland cover. Of those wetlands, approximately 28km^2 (98%) have been designated as provincially significant. All evaluated wetlands including provincially significant wetlands (PSWs) are illustrated in **Figure 9.5**.

Wetlands have also been classified through air photo interpretation to a community series level using the Ecological Land Classification System for Southern Ontario, first approximation (Lee et al 1998). The wetland types identified are further described in **Table 9.2**.

The 26km^2 Nonquon River Wetland ANSI-lsc, described in **Table 9.6** is a wetland of particular significance for this watershed, encompassing 13.5% of the entire watershed area.

Forested wetlands, including headwater wetlands, are full of life and home to a complex food web that includes various microbes, bacteria, invertebrates and larger life forms. These include mammals, birds, reptiles, amphibians, fish, insects and other invertebrates that use wetlands as habitat for all or part of their life cycle, including for breeding and nesting seasons, migratory stopovers, resting and shelter, and food. In addition, wetlands perform these valuable functions within a watershed:

- Wetlands play a significant role as a water filter, having the capacity to remove great amounts of harmful impurities, bacteria and excess nutrients. In fact wetlands are so good at this process that constructed wetlands have been used to treat urban stormwater runoff in Europe (and now in Ontario) for several decades.

- Wetland plants are effective for stabilizing shoreline areas, trapping sediments and lessening the effects of erosion.

- Wetlands store water, reduce flood events, and help to replenish groundwater. Excess water is stored after storms or spring snow melt and is gradually released after it is filtered and purified.

- Wetlands release purified water into streams and rivers, and can be critical at maintaining stream flow during periods of drought.

9.7 Key Observations and Issues

- The watershed contains extensive areas of natural cover, which accounts for approximately 42% of the total watershed area. Natural cover is comprised of forests, wetlands and meadows.

- Forested areas account for approximately 29% of the total watershed area, and are comprised of cultural plantations (4%), cultural woodlands (1%), coniferous forest (4%), deciduous forest (5%), mixed forest (4%) and forested wetlands (11%). Forested areas are very close to meeting the minimum ecological requirements with respect to total watershed coverage (i.e., 30% of total watershed area). Many of these woodlands are considered provincially significant.

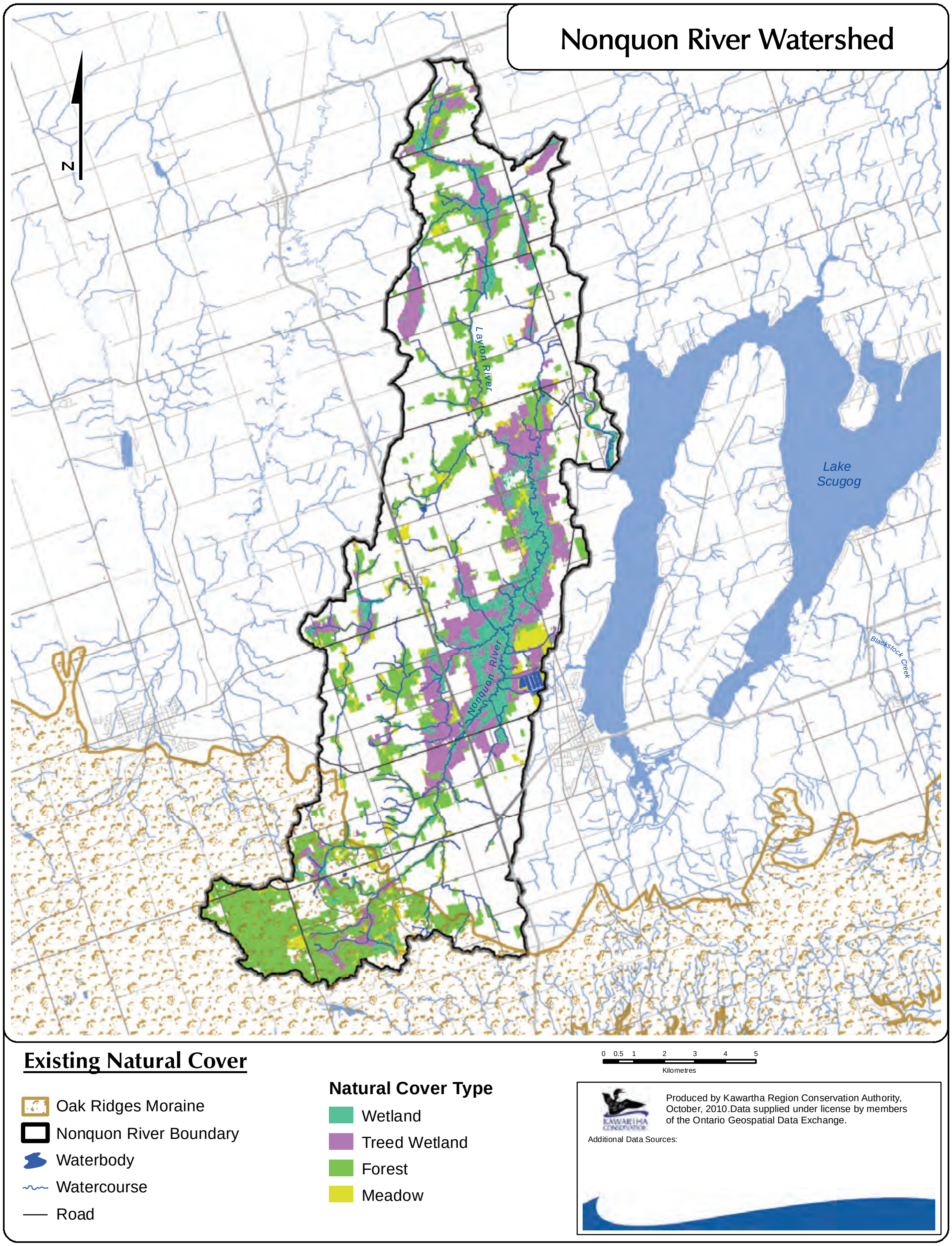
- The amount of interior forest habitat (i.e., at least 100 metres from the forest edge) accounts for approximately 7%, which does not meet the minimum ecological requirements of 10%. The amount of deep interior forest habitat (i.e., at least 200 metres from the forest edge) accounts for approximately 3%, which also does not meet the minimum ecological requirements of 5%.

- Wetland areas account for approximately 18-19% of the total watershed area, and are comprised of marshes (3%), shallow open waters (1%), and swamp (15%). Wetland areas meet the minimum ecological requirements with respect to total watershed coverage (i.e., 10% of total watershed area). The majority of these wetlands (approximately 98%) are considered provincially significant.

- A long history of agriculture and forestry-related activities have resulted in fragmentation of natural cover across the landscape. This results in a loss of habitat linkages, movement corridors, and quality habitat patches.

- Invasive species including insects, diseases and plants, are considered one of the key threats to the health of existing natural areas, particularly in woodlands. Climate change has the potential to exasperate these negative effects.

- Two terrestrial species of conservation concern (i.e., species at risk) have been documented within the watershed. These include the Least Bittern and Green-striped Darner. Nine additional terrestrial species of conservation concern have a high potential to exist within the watershed.



Produced by Kawartha Region Conservation Authority, October, 2010.Data supplied under license by members of the Ontario Geospatial Data Exchange.

Additional Data Sources:

Figure 9.1: Existing natural cover.

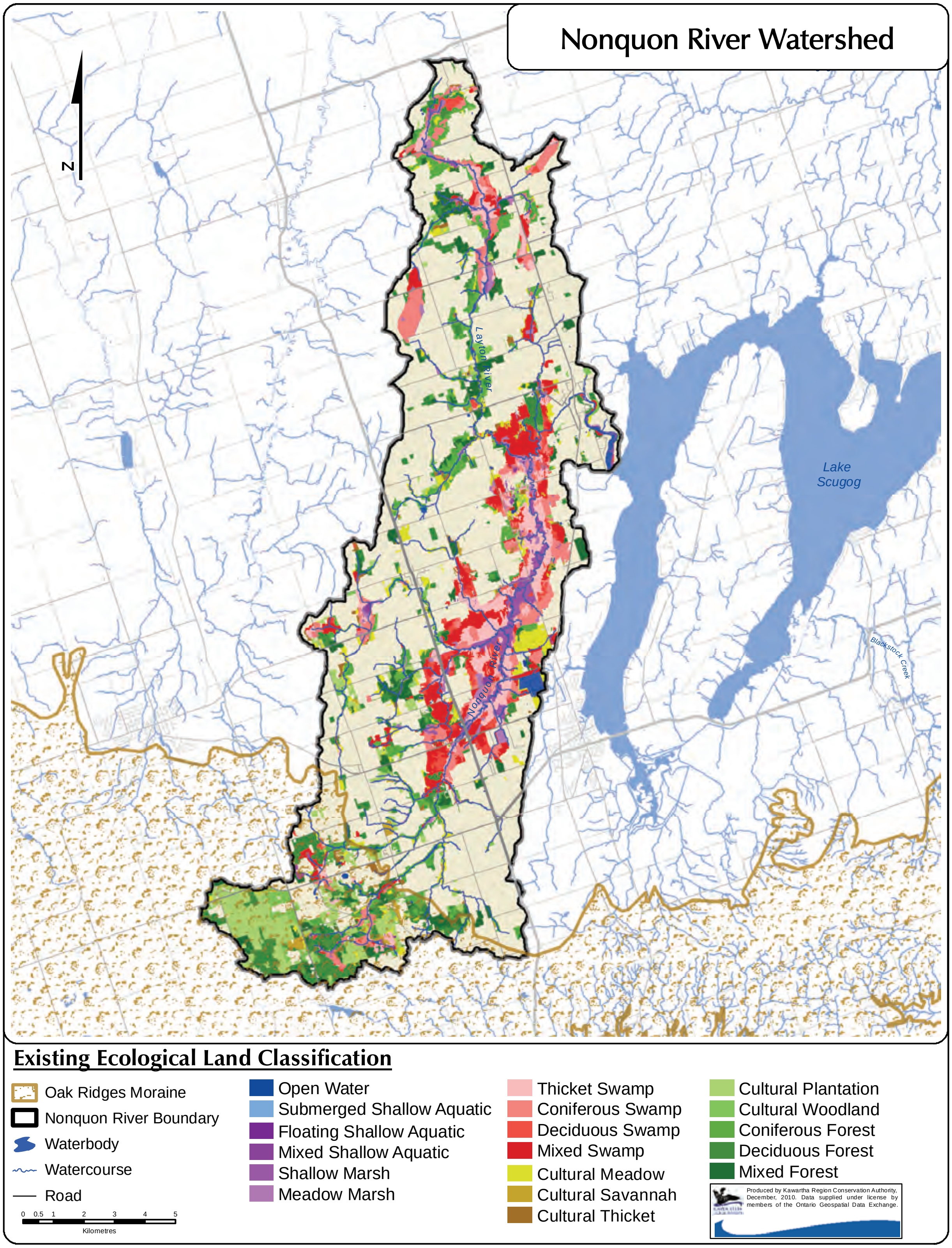


Figure 9.2: Existing ecological land classification.

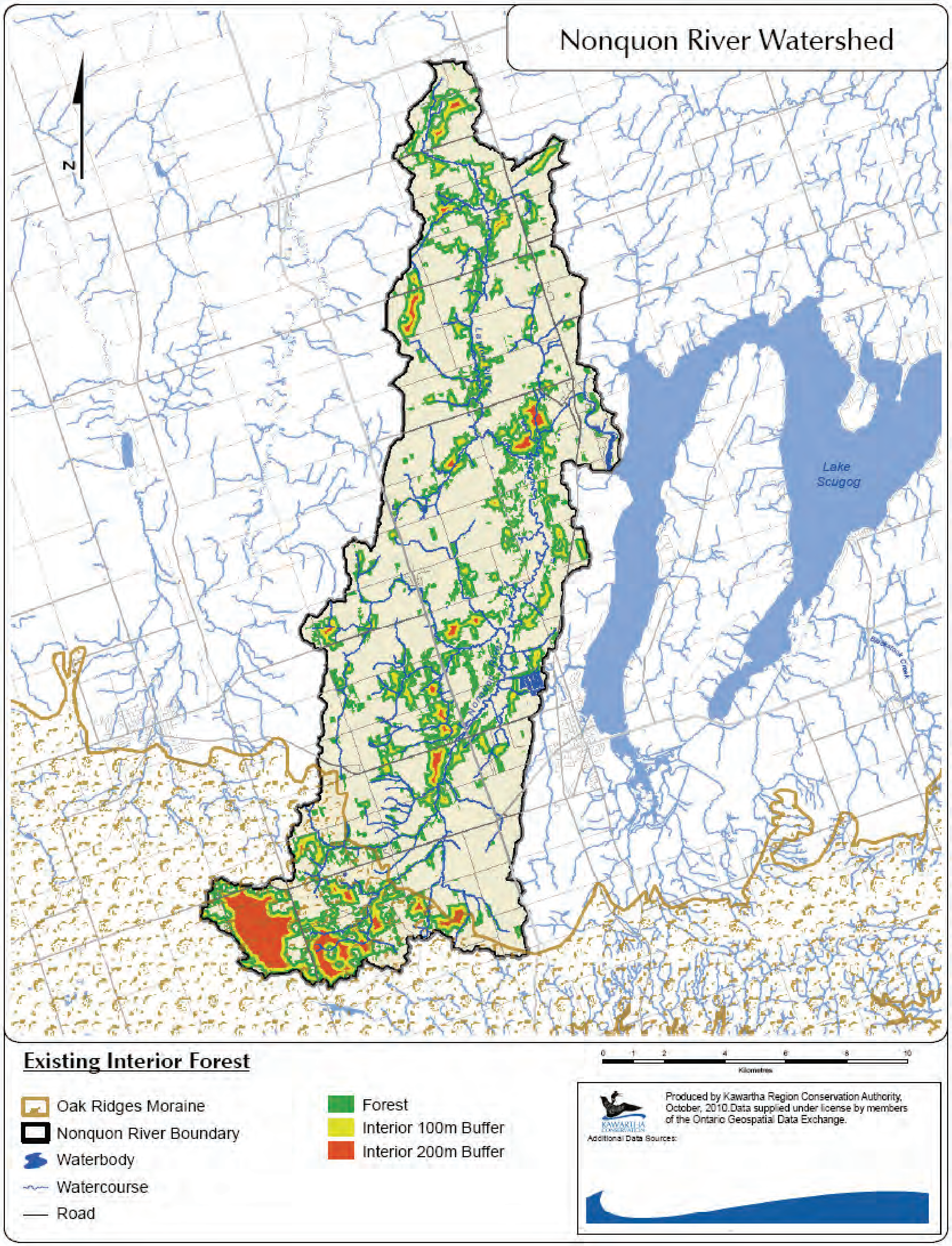
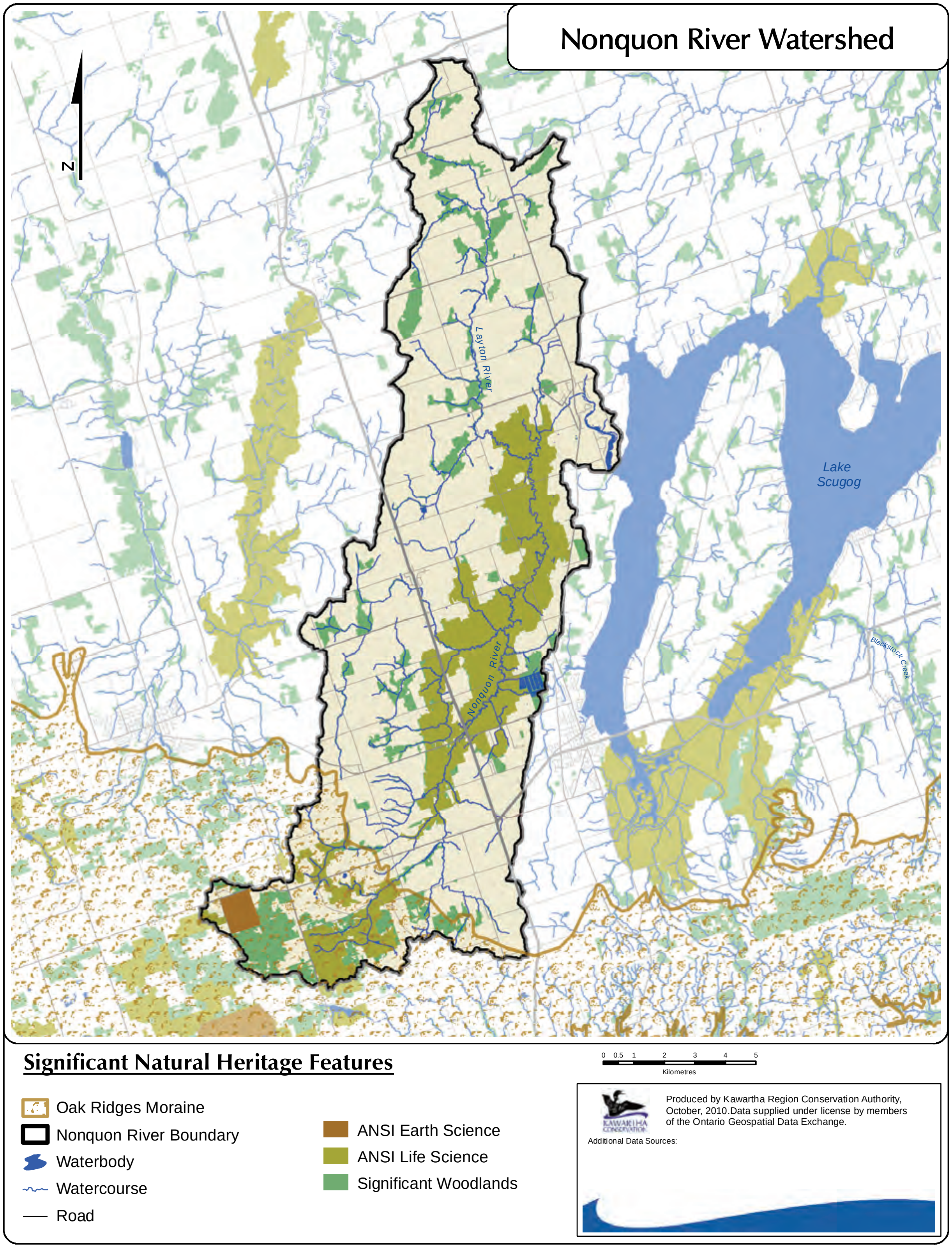


Figure 9.3: Existing interior forest.



Produced by Kawartha Region Conservation Authority, October, 2010.Data supplied under license by members of the Ontario Geospatial Data Exchange.

Additional Data Sources:

Figure 9.4: Significant natural heritage features.

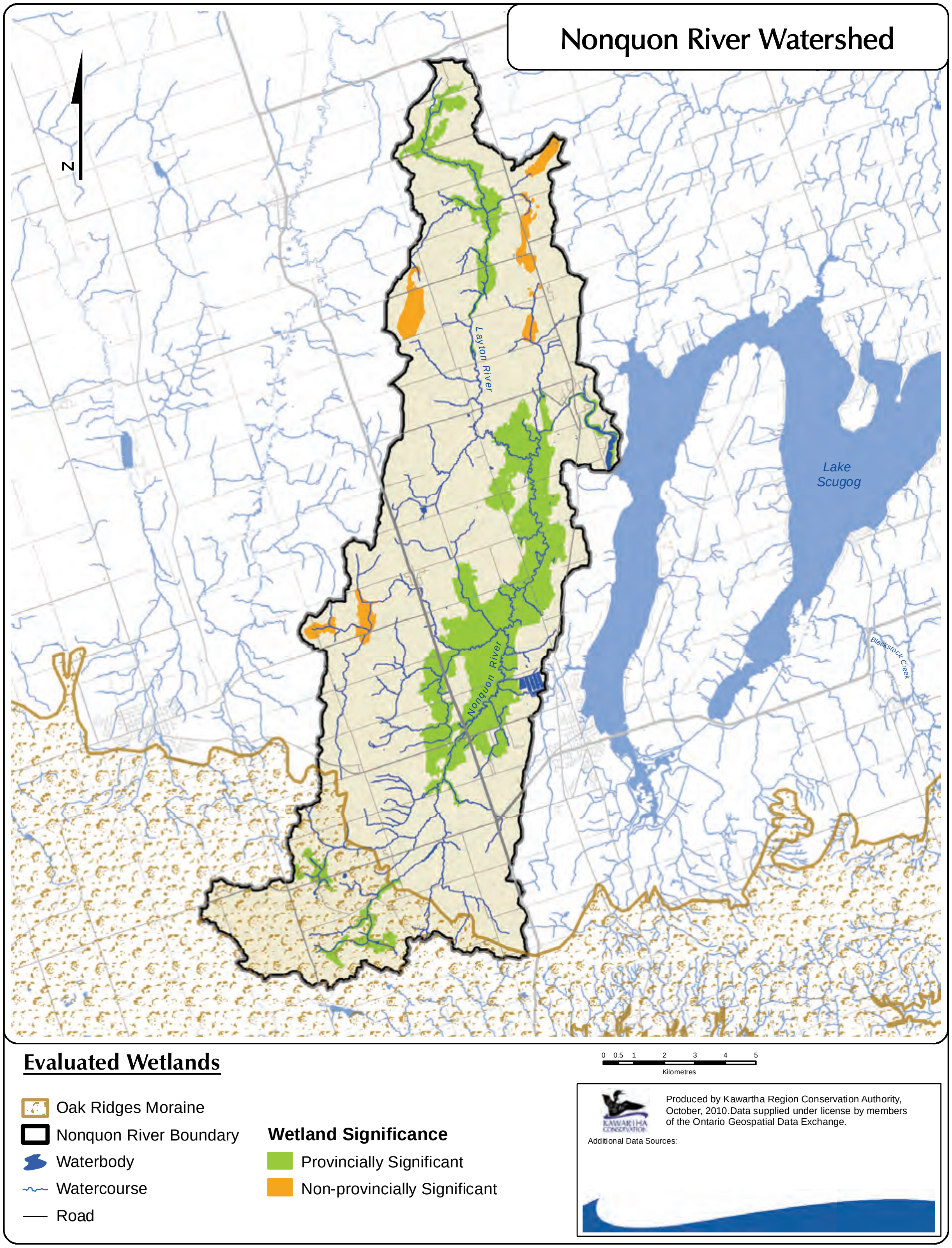


Figure 9.5: Evaluated wetlands.

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Appendix

Appendix A: Water Quality Parameters

Parameter	Units	Parameter	Units
Alkalinity	mg/L as CaCO3	Magnesium	mg/L
Aluminum	mg/L	Manganese	mg/L
Ammonia	mg/L	Molybdenum	mg/L
Anion Sum	meq/L	Nickel	mg/L
Anion-Cation Balance	% difference	Nitrate	mg/L
Antimony	mg/L	Nitrite	mg/L
Arsenic	mg/L	Phosphorus	mg/L
Barium	mg/L	Potassium	mg/L
Beryllium	mg/L	Saturation pH	pHs @20°C
Bicarbonate	mg/L as CaCO3	Saturation pH	pHs @ 4°C
Boron	mg/L	Selenium	mg/L
Cadmium	mg/L	Silver	mg/L
Calcium	mg/L	Sodium	mg/L
Carbonate	mg/L as CaCO3	Strontium	mg/L
Cation Sum	meq/L	Sulphate	mg/L
Chlorides	mg/L	Thallium	mg/L
Chromium	mg/L	Titanium	mg/L
Cobalt	mg/L	Total Suspended Solids	mg/L
Copper	mg/L	Total Dissolved Solids	mg/L
Ion Ratio		Total Kjeldahl Nitrogen	mg/L
Iron	mg/L	Uranium	mg/L
Langolier's Index	@4°C	Vanadium	mg/L
Langolier's Index	@20°C	Zinc	mg/L
Lead	mg/L		

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