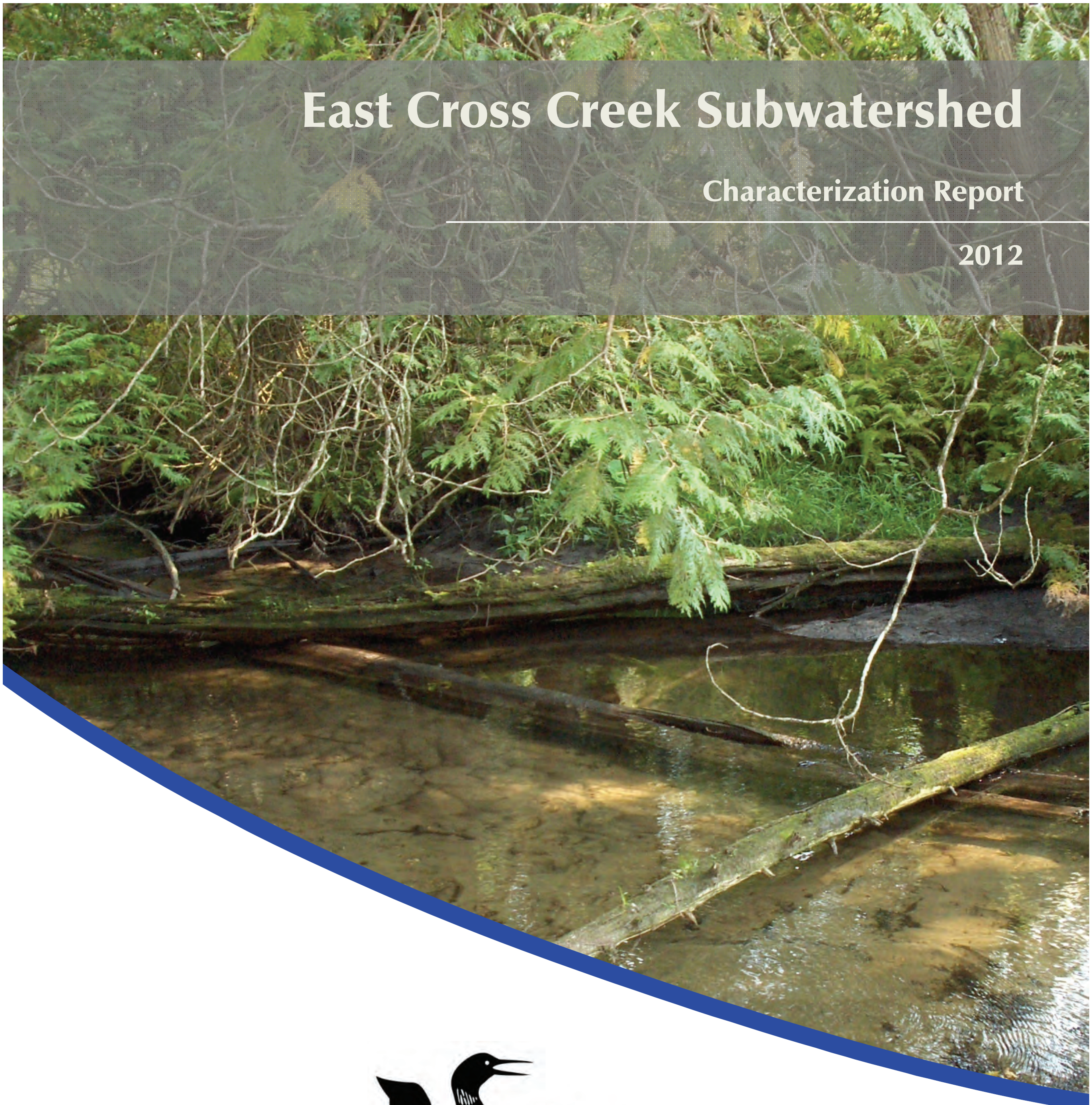
East Cross Creek Subwatershed

Characterization Report

2012



KAWARTHA
CONSERVATION

About Kawartha Conservation

A plentiful supply of clean 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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1.0 Introduction

East Cross Creek, north of Highway 7A

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 East Cross Creek Subwatershed Characterization Report is intended to be a complementary document to the East Cross Creek Subwatershed 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 East Cross Creek Subwatershed 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 abundance 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 East Cross Creek Subwatershed, the legislative requirements listed above need to be addressed within the East Cross Creek Subwatershed Plan. Technically, these provisions only apply to the portions of the East Cross Creek watershed that exist within the Oak Ridges Moraine Conservation Plan boundaries. However, in taking a watershed management approach, the entire East Cross Creek Subwatershed has been included in the planning area.

1.3 East Cross Creek Subwatershed 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 East Cross Creek Subwatershed Plan is consistent with the provisions within the Oak Ridges Moraine Conservation Plan, the approach in formulating the East Cross Creek Subwatershed 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 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.

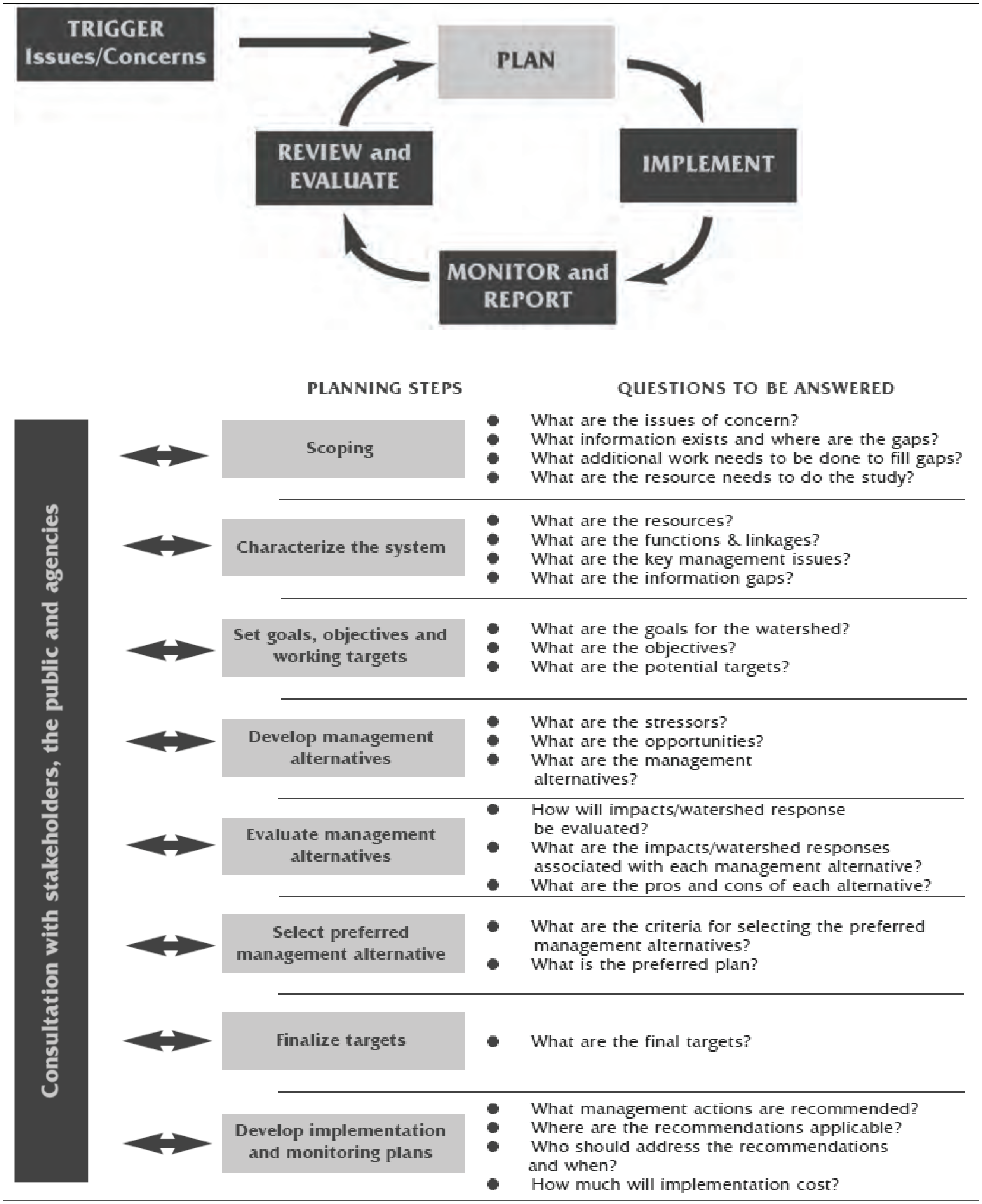
Step 1 (scoping), is outlined in the project terms of reference (Kawartha Conservation 2010). The East Cross Creek Subwatershed Characterization Report addresses step 2 (characterization). The purpose of this step in preparing the watershed plan is to identify, analyze, and evaluate watershed-specific 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 East Cross Creek subwatershed, 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.

East Cross Creek is a large watercourse flowing into the Scugog River, thus, maintaining the health of the East Cross Creek subwatershed is also crucial for maintaining the ecological integrity of the larger Scugog River watershed. The Scugog River 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). In addition. Scugog River is a primary source of water supply for Town of Lindsay (approximately 17,000 people).

1.4 Planning Area Boundaries

The East Cross Creek Subwatershed 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 lands that exist within the East Cross Creek subwatershed, upstream where Janetville Creek enters the main channel of East Cross Creek. The watershed boundaries and watercourse network were delineated using the ArcHydro tool, which is based on digital elevation mapping.

The East Cross Creek subwatershed is located immediately east of Lake Scugog, which is approximately 50km north-east of Toronto, Ontario. The watershed drains 78.9 km^2 of land into the East Cross Creek and outlets into the Scugog River, which in turn flows north into the chain of lakes known as the Kawartha Lakes. The portion of the East Cross Creek subwatershed in study is bounded by the downstream portion the East Cross watershed to the north, Blackstock Creek watershed to the west, Bowmanville Creek and Soper Creek watersheds to the south, and Janetville Creek and Pigeon River watersheds to the east. The Oak Ridges Moraine Conservation Plan planning area exists within the south-western portion of the East Cross Creek watershed, encompassing approximately 32.3km^2, or 40.9% of the subwatershed.



From Conservation Ontario (2003)

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

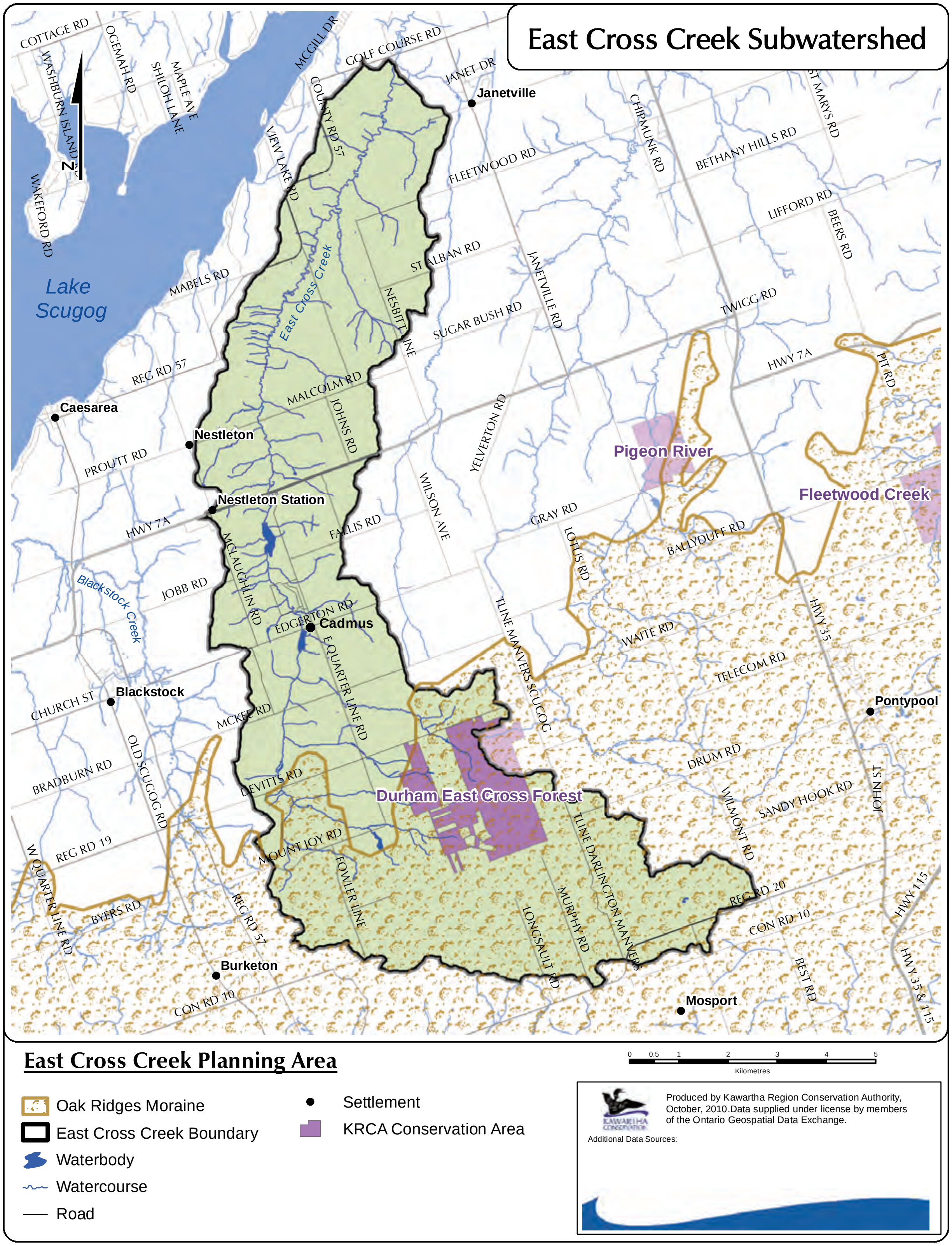


Figure 1.2: East Cross Creek Subwatershed planning area.

2.0 Physical Landscape

East Cross Creek, north of McKee Road

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 East Cross Creek subwatershed 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 East Cross Creek subwatershed, as well for three other watersheds (Southern Lake Scugog Tributaries, Blackstock Creek and Nonquon River). This section describes the geologic setting in the East Cross Creek subwatershed 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.

<u>Bedrock Geology</u>

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 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.

<u>Overburden Geology</u>

The unconsolidated sediments that overly 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 East Cross Creek subwatershed 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 East Cross Creek subwatershed, occupying approximately 24.8km^2 of the total subwatershed 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 East Cross Creek subwatershed. 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 (48.9km^2) of the subwatershed 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.

The Schomberg Clay Plain physiographic region occupies 5.2km^2 of the subwatershed 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 East Cross Creek subwatershed 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 East Cross Creek subwatershed 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 East Cross Creek subwatershed, especially on the Oak Ridges Moraine. Soils with moderate infiltration rates (Group B) occur throughout the majority of the East Cross Creek subwatershed 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 subwatershed.

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 potential when thoroughly wetted	Chiefly clay soils with a high swelling potential, soils with a permanent high water table, soils with a clay pan or clay layer at or near the surface or shallow soils over nearly impervious material	Very low rate of water transmission (0-0.15cm/hr)	Clay loam, silty clay loam, sandy clay, silty clay, clay

From USDA (1986)

2.5 Topography

The ground-surface elevations within the subwatershed generally slope from south-to-north. The highest elevations in the East Cross Creek subwatershed occur in the southern section 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 376.3 metres above sea level in the south-western portion of the subwatershed and declines to a minimum elevation of approximately 248.5 metres above sea level at the subwatershed outlet (**Figure 2.6**). The average slope of the terrain is approximately 5.3%

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

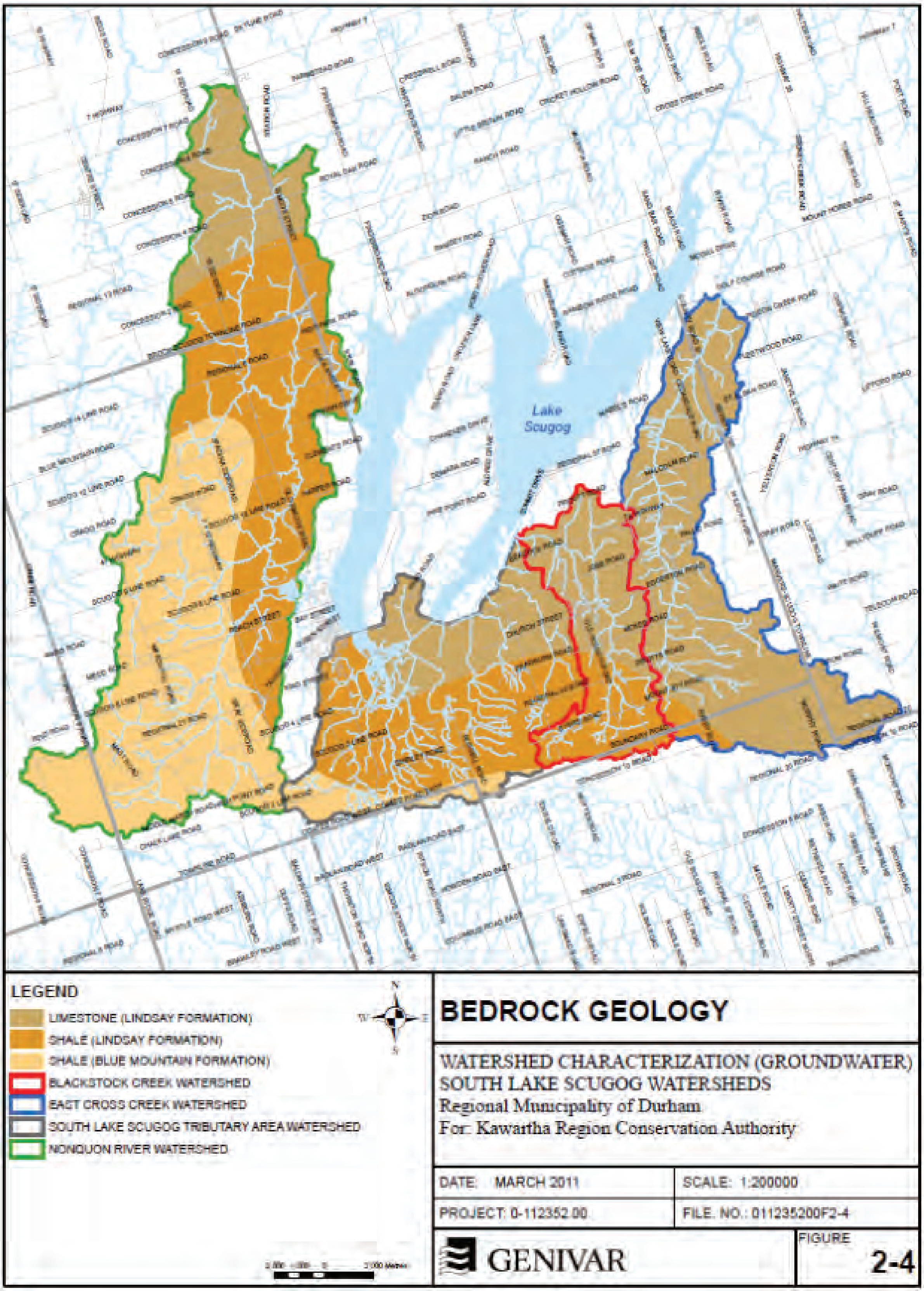
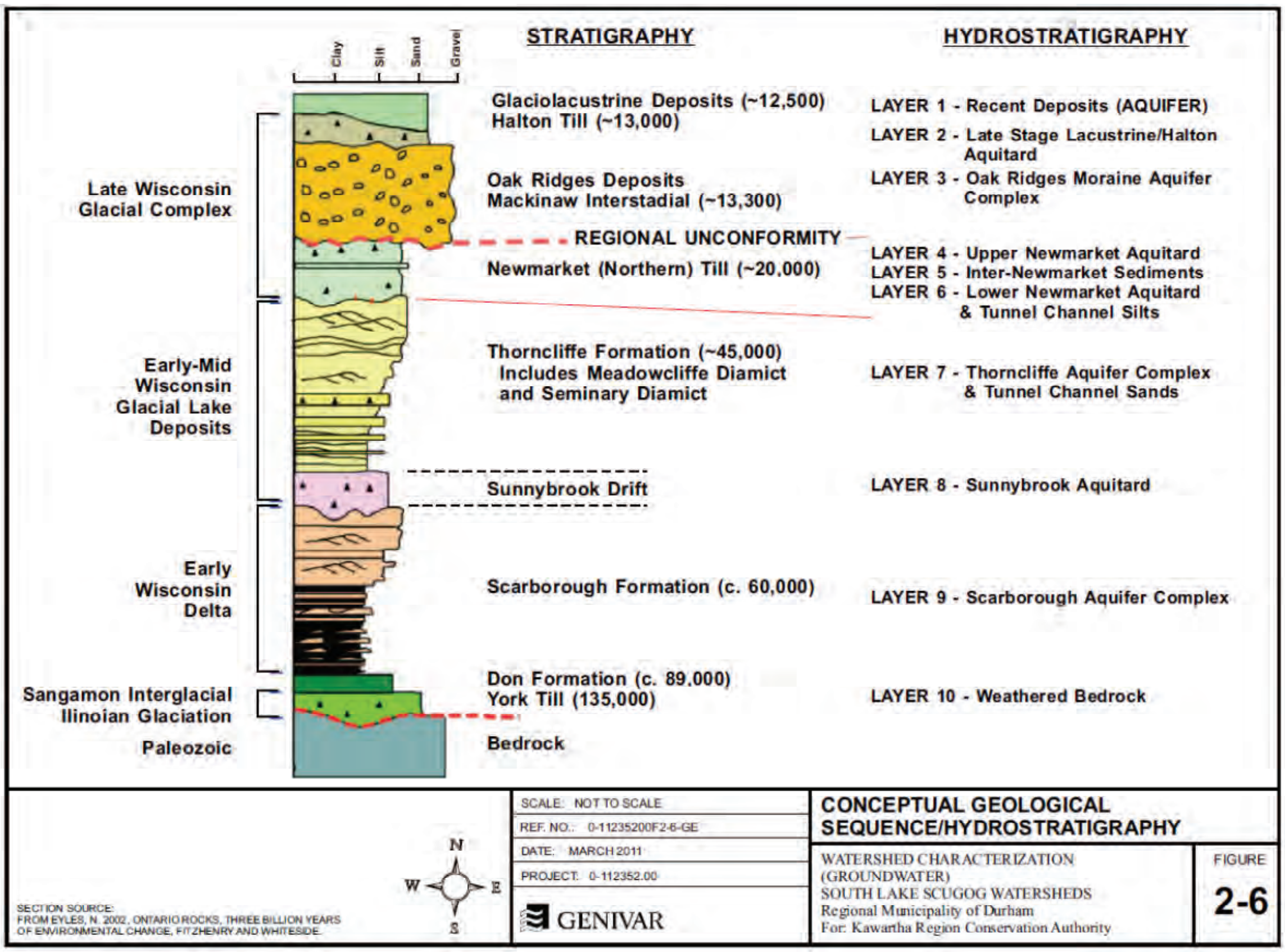


Figure 2.1: Bedrock geology.



From GENIVAR (2011)

Figure 2.2: Geological profile of Pleistocene sediments.

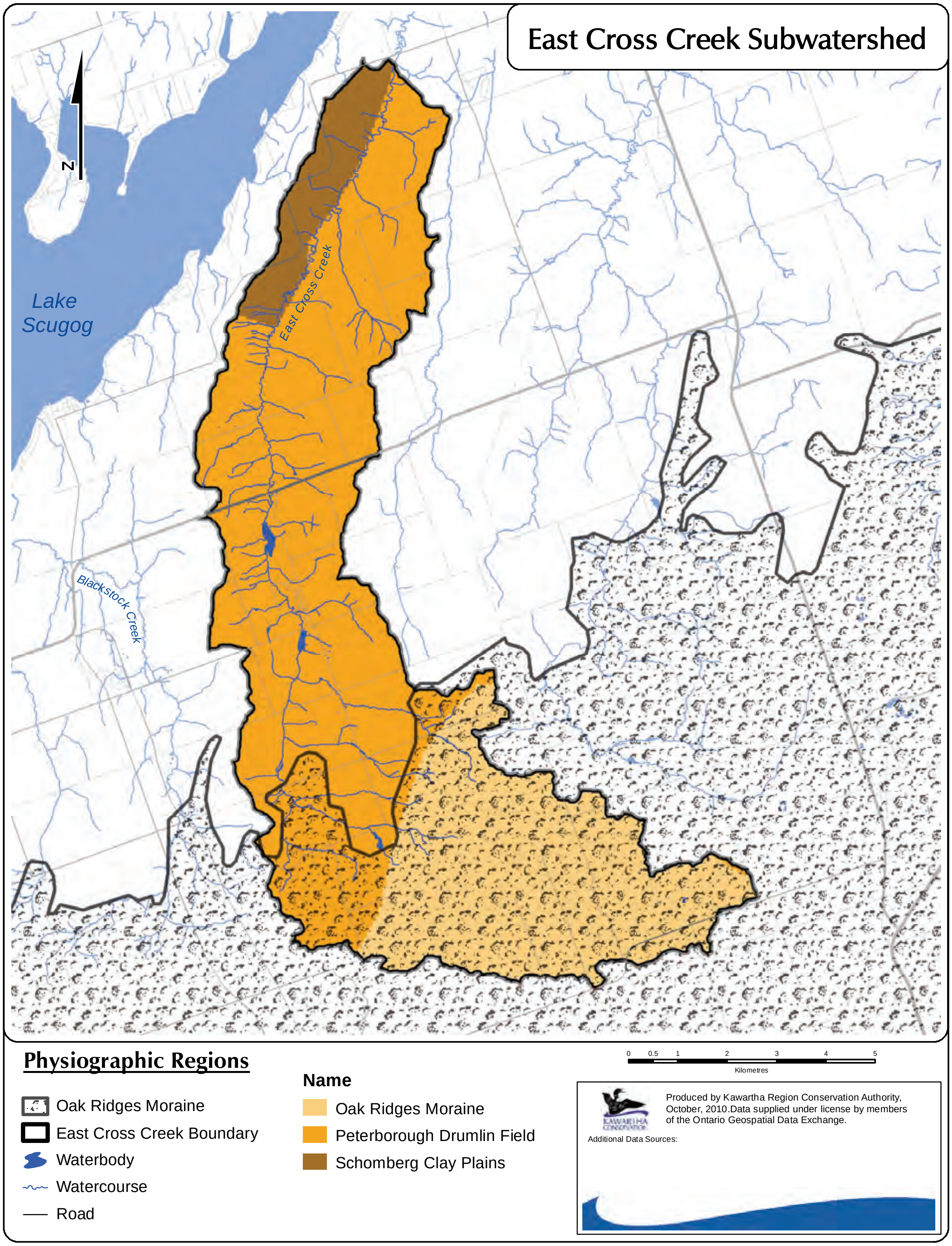


Figure 2.3: Physiographic regions.

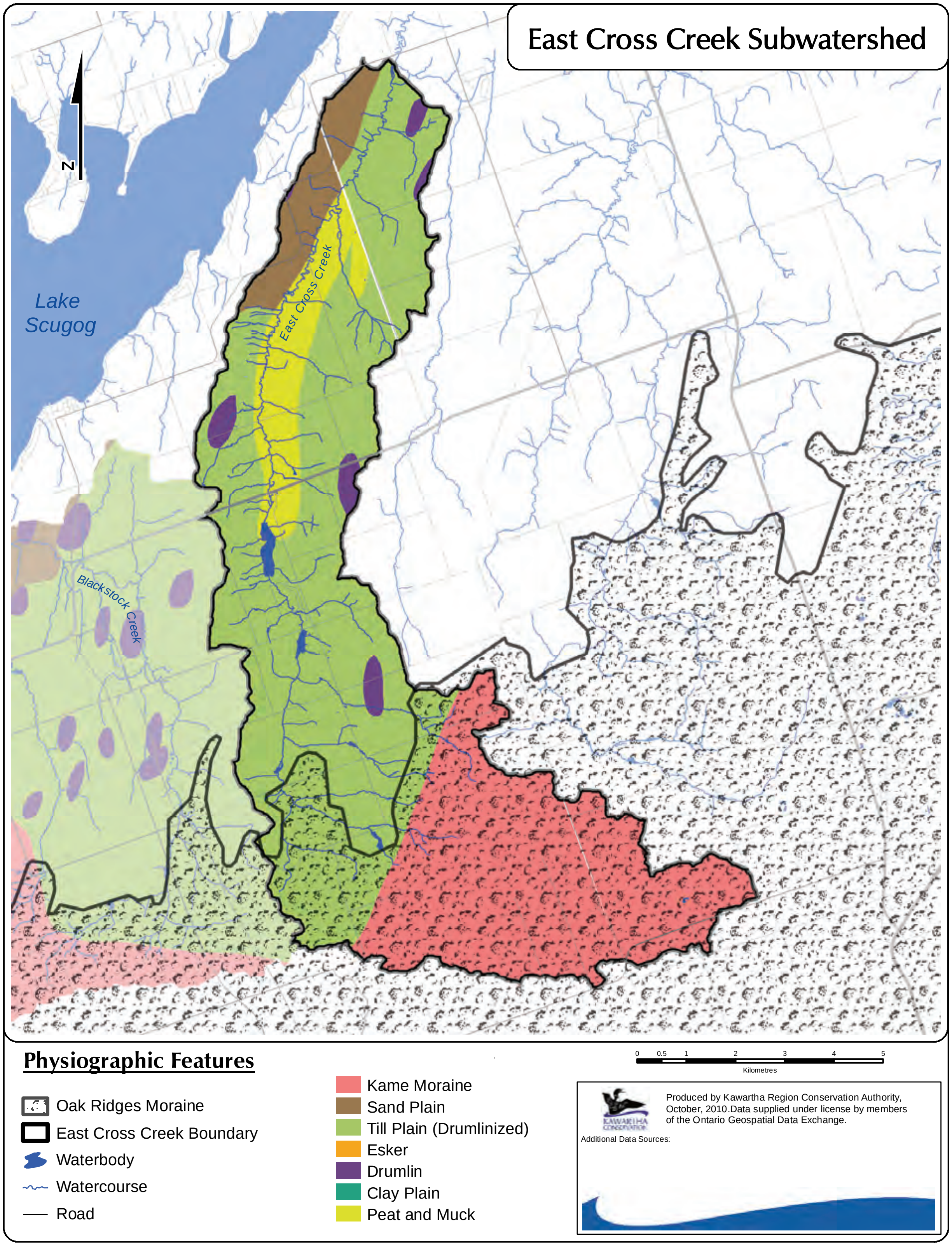


Figure 2.4: Physiographic features.

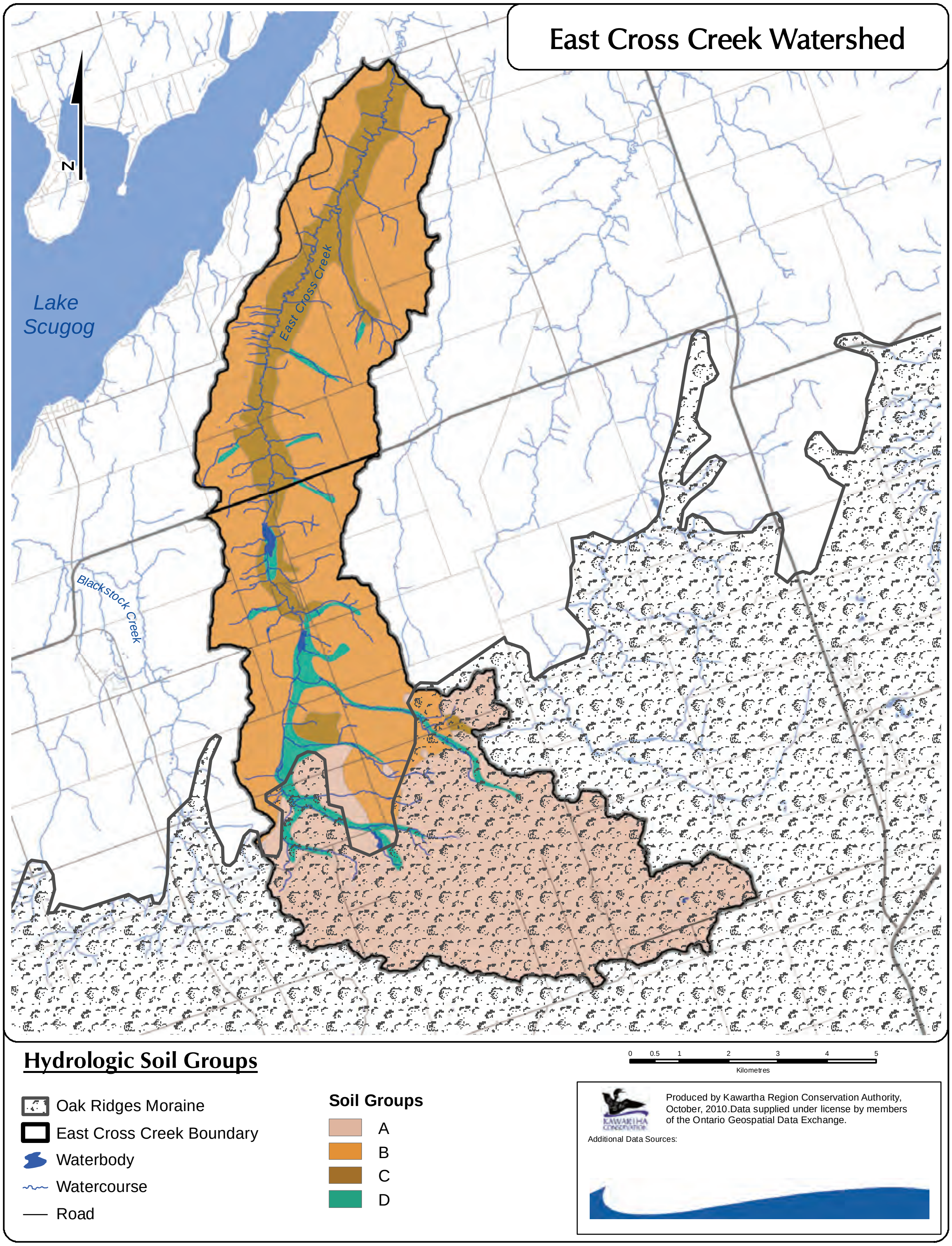


Figure 2.5: Hydrologic soils groups.

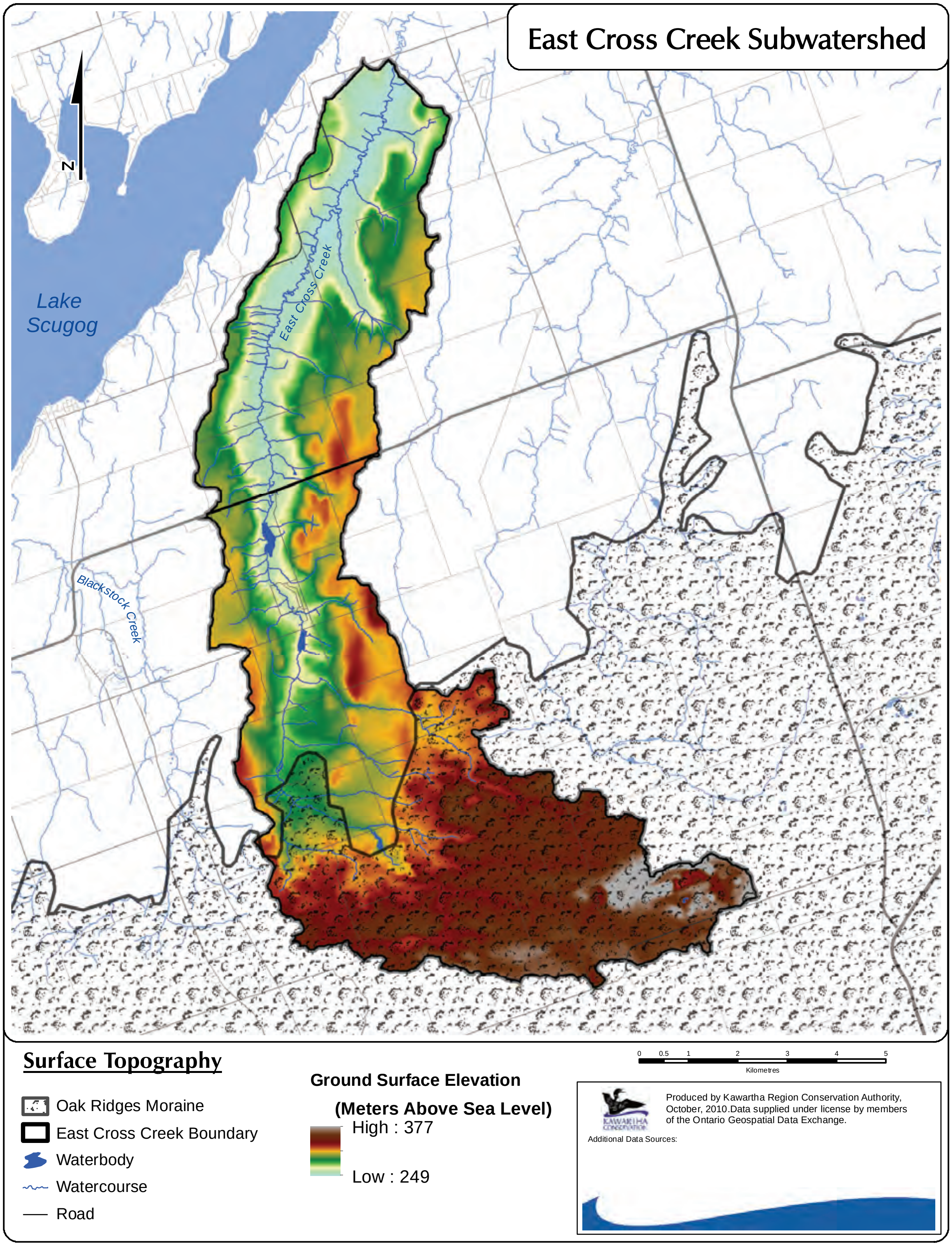


Figure 2.6: Surface topography.

3.0 Regional Climate

East Cross Creek, north of Edgerton 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 subwatershed.

The East Cross Creek subwatershed 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 East Cross Creek subwatershed, 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 6.6°C. January is the coldest month, with average daily temperatures ranging from -7.7 to -8.9°C. Average monthly temperatures rise above freezing in April and reach a peak of about 20°C 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 1.2°C.

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 2.5^0C to 3.7^0C compared to 1961-1990 average values;

- the range of the projections, from minimum change to maximum change, is from 2.3^{0}C to 3.0^{0}C in the south of the province, to 3.2^{0}C to 4.0^{0}C 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.).

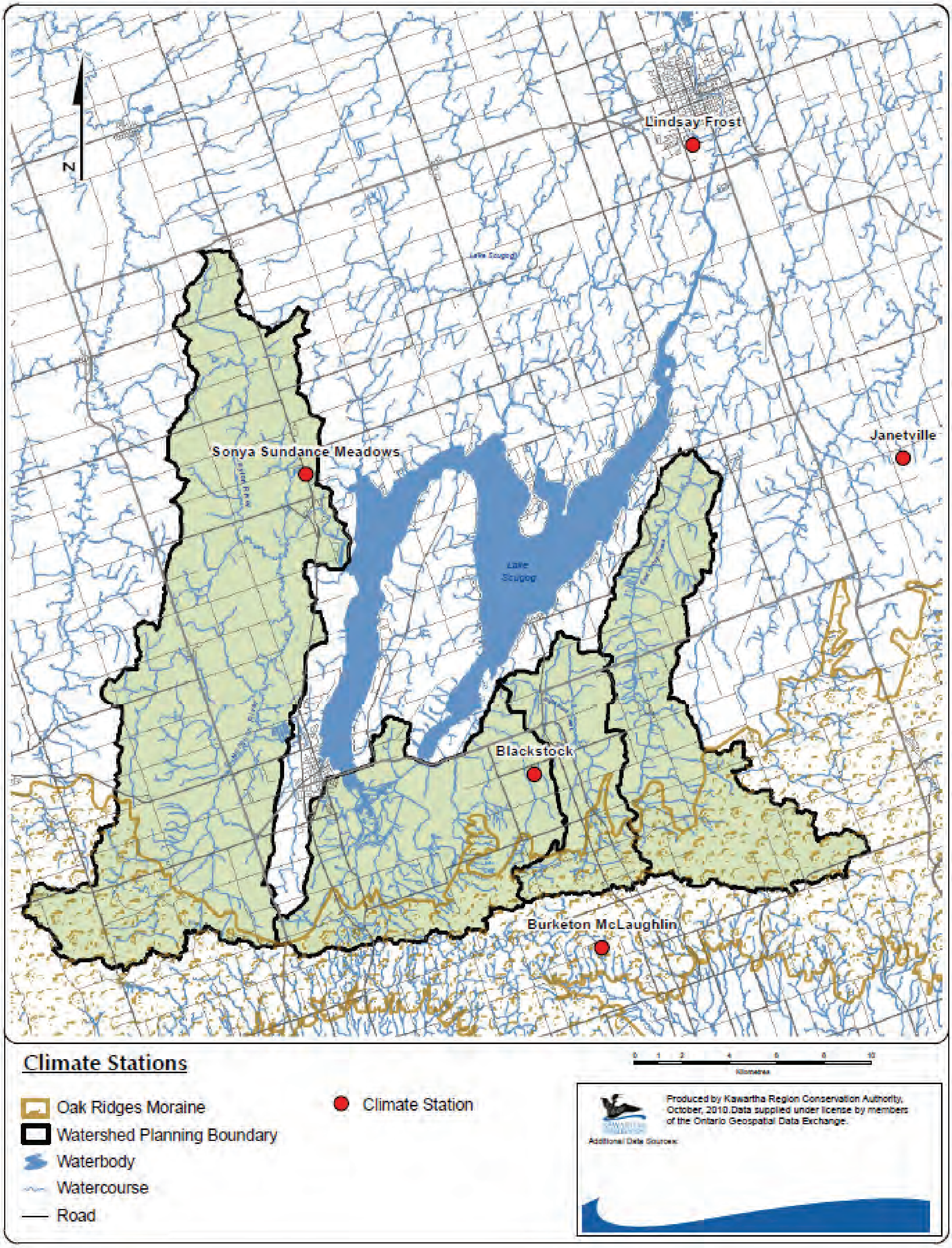
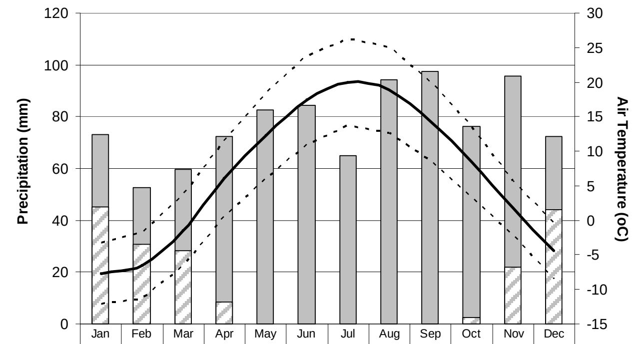
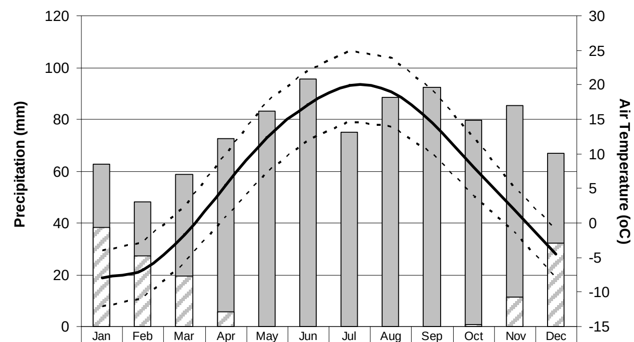


Figure 3.1: Climate stations.



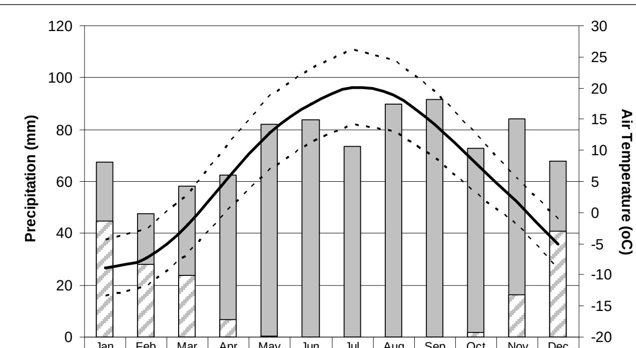
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Precipitation - total	73.2	52.7	59.7	72.3	82.7	84.3	64.9	94.4	97.4	76.4	95.7	72.5
Precipitation - snowfall	45.3	30.8	28.2	8.5	0.0	0.0	0.0	0.0	0.0	2.4	21.8	44.1
Air Temperature - daily max	-3.2	-1.7	3.6	11.5	18.3	23.8	26.3	25.1	19.9	13.5	5.7	-0.4
Air Temperature - 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

East Cross Creek, south of Highway 7A

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 East Cross Creek subwatershed remained 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 subwatershed 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** list the various hamlets that were formed during these periods. **Figure 4.1** shows a historical map of the former Cartwright Township.

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
Nestleton Station	1904
Nestleton	Unknown
Cadmus	Unknown

Current Demographics

The East Cross Creek subwatershed is not densely populated. Most residents live either in small hamlets or scattered across the rural portions of the subwatershed. 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. 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 East Cross Creek subwatershed 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 East Cross Creek subwatershed 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 subwatershed.

Natural Cover

Natural Cover exists within 41.3km^2 or 52.3% of the subwatershed, which is the dominant land cover type. These areas mainly consist of natural forests, wetlands and cultural plantations that are concentrated within the central, low-lying areas of the subwatershed. The Durham East Cross Forest Conservation Area is a significant area of natural cover within the subwatershed. Areas of extensive natural cover also exist in the southwestern portion of the subwatershed on the Oak Ridges Moraine, and along the main channel of the creek. 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 subwatershed. Please refer to Chapter: 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 0.6km^2 or 0.7.% of the subwatershed and include the hamlets of Cadmus, the eastern portion of Nestleton Station, and the private community of Donaushwaben Park.

Rural Development

Areas considered rural development account for 2.5km^2 or 3.2% of the subwatershed and generally include single or small groups of rural lots (i.e., rural-residential) or other small-scale developments that dot the landscape.

Agriculture - Intensive

Intensive agriculture refers to lands that are annually cultivated and planted with row crops. These areas account for 29.3 km^2 or 37.1% of the land area. 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 3.1km^2 or 4.0 % 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 <0.1km^2 or <0.1% of the subwatershed. They consist of "regularly-maintained" open grassy areas that are primarily used for recreational purposes.

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 2.1km^2 or 2.6% of the total land cover. Small operations exist in the south-east portion of the subwatershed 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 East Cross Creek subwatershed there are 69.1km of roads, with a density of 0.9 km/km^2. These include two provincial roads (Highway 7A and Highway 35), several regional and county roads (20, 57), and numerous minor roads. Generally, roads intersect the subwatershed 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 lower East Cross Creek main channel. In addition, a rail network running east-west exists within the southern portion of the subwatershed.

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 subwatershed 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 East Cross Creek subwatershed accounts for 1.0 km^2 or 1.2% of the total 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 East Cross Creek subwatershed.

4.6 Waste Disposal Sites

There are no known waste disposal sites within the subwatershed.

4.7 Land Use Planning

Land use planning and policy within the East Cross Creek subwatershed 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.

<u>Oak Ridge Moraine Conservation Plan</u>

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 32.3km^2 or 40.9% of the entire subwatershed. The Oak Ridges Moraine portion of the subwatershed includes: Natural Core Areas (16.9km^2), Natural Linkage Areas (5.1km^2), and Countryside Areas 10.3km^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 39.0km^2 or 49.4% of the entire subwatershed. Within the Greenbelt lands in the subwatershed, 23.3km^2 is Natural Heritage System, and 15.7km^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 East Cross Creek subwatershed is located within the jurisdiction of four municipalities (**Figure 4.5**). These include the Regional Municipality of Durham, Scugog Township, Municipality of Clarington, and City of Kawartha Lakes. The upper tier Regional Municipality of Durham jurisdiction covers 65.1km^2 or 82.5% of the subwatershed, which includes the lower tier municipalities of Township of Scugog (53.0km^2), and Municipality of Clarington (12.1km^2). The single tier municipality of City of Kawartha Lakes covers 13.8km^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 2008) designates most of the land throughout the East Cross Creek subwatershed 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 subwatershed 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.

<u>Conservation Authority Regulations</u>

The East Cross Creek subwatershed 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 2012a) 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.

<u>Durham East Cross Forest Conservation Area Management Plan</u>

Durham East Cross Forest Conservation Area (DECFCA) is located in the south east corner of the Township of Scugog in the Regional Municipality of Durham. This property, owned and managed by Kawartha Conservation, lies within the Natural Core Area of the Oak Ridges Moraine Conservation Plan. DECFCA is a high priority area for conservation protection because of its many ecological and social values combined with the high level of impending threats to these values. The purpose of the DECFCA Management Plan (Kawartha Conservation 2009) is to protect and restore the ecological integrity of the property while providing a conservation area to be enjoyed by the public now and in the future.

<u>East Cross Creek Aquatic Resources Management Plan</u>

In recognition of the significance of the aquatic resources of East Cross Creek, Regional Municipality of Durham and Kawartha Conservation partnered to initiate the East Cross Creek Aquatic Resources Management Plan (ECCARMP) to help better manage land and resource use pressures affecting East Cross Creek (Kawartha Conservation 2012b). The intent of the ECCARMP is to provide specific strategies in which public agencies, stakeholders and citizens can work in partnership for the benefit the aquatic ecosystem. As such, the overall aim of the ECCARMP process is to: (1) report on the current and historical status of aquatic resources within East Cross Creek and summarize watershed processes that influence them; (2) use a multi-stakeholder approach to develop management strategies to protect, restore and/or enhance aquatic resources; and, (3) collaborate with landowners, resource agencies and other stakeholders to implement the management strategies outlined in the plan. It is anticipated that this plan will be finalized in late 2011.

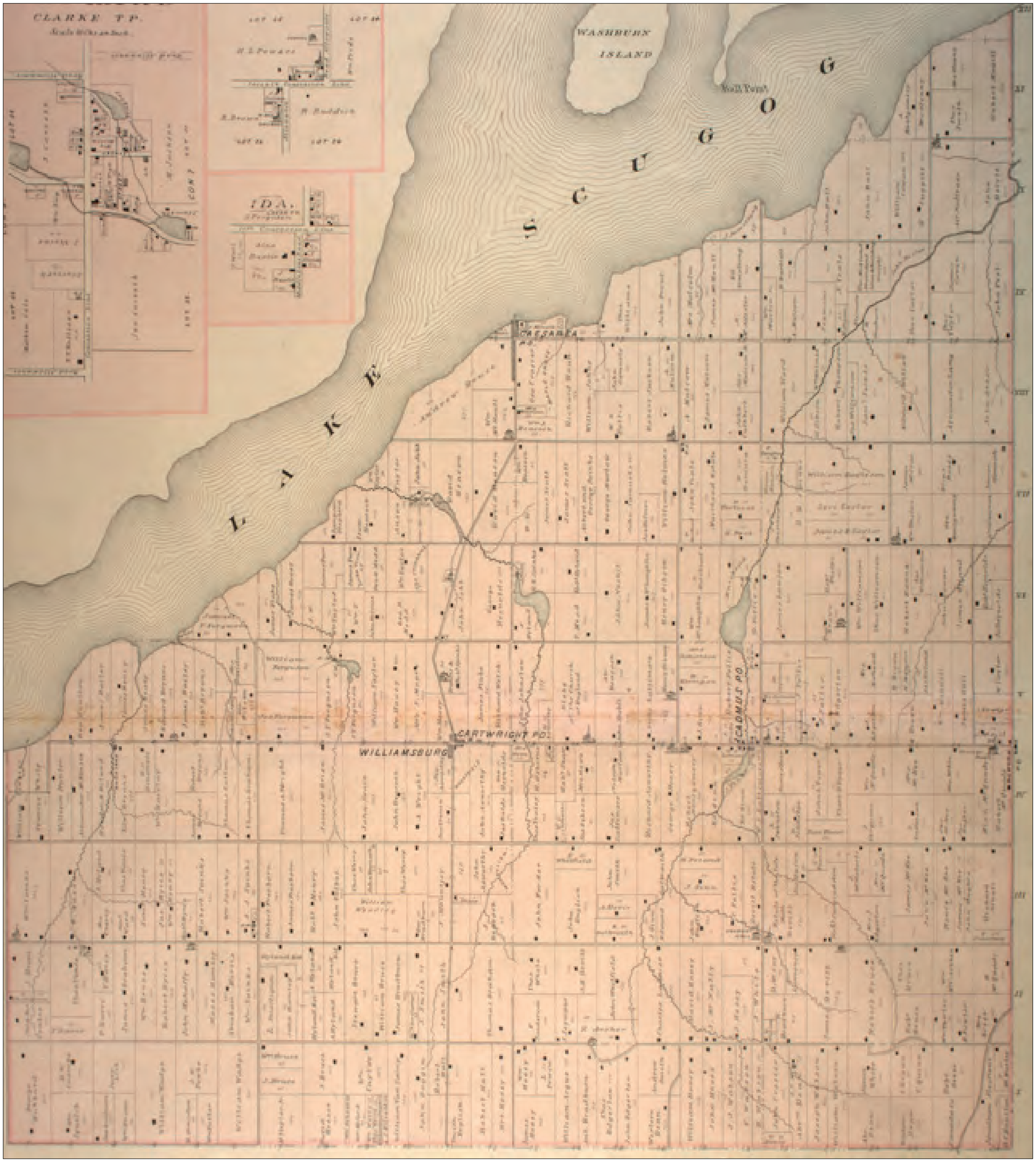
4.8 Key Observations and Issues

- The dominant land use within the subwatershed is agriculture, which comprises approximately 41% of the total land area. No major urban growth and expansion is expected to occur within the next 25 years, and as such the subwatershed will remain distinctly rural in nature for the foreseeable future.

- Extensive areas of natural cover still exist within the subwatershed, comprising approximately 52% of the total land area. These include large wetland complexes in the central portion of the subwatershed and large forested areas that exist within the Oak Ridges Moraine.

- The subwatershed is located within the jurisdiction of 4 municipalities. These include the Region of Durham (83% of the total land area, which includes Scugog Township and Municipality of Clarington) and the City of Kawartha Lakes (17% of the total land area).

- The southern portion of the subwatershed lies within the Oak Ridges Moraine Conservation Plan planning boundary (41% of total area), while the majority of the subwatershed lies within the Greenbelt Plan planning boundary (50% of total area).



Source Traimaines

Figure 4.1: Historical map of Cartwight Township (circa 1880).

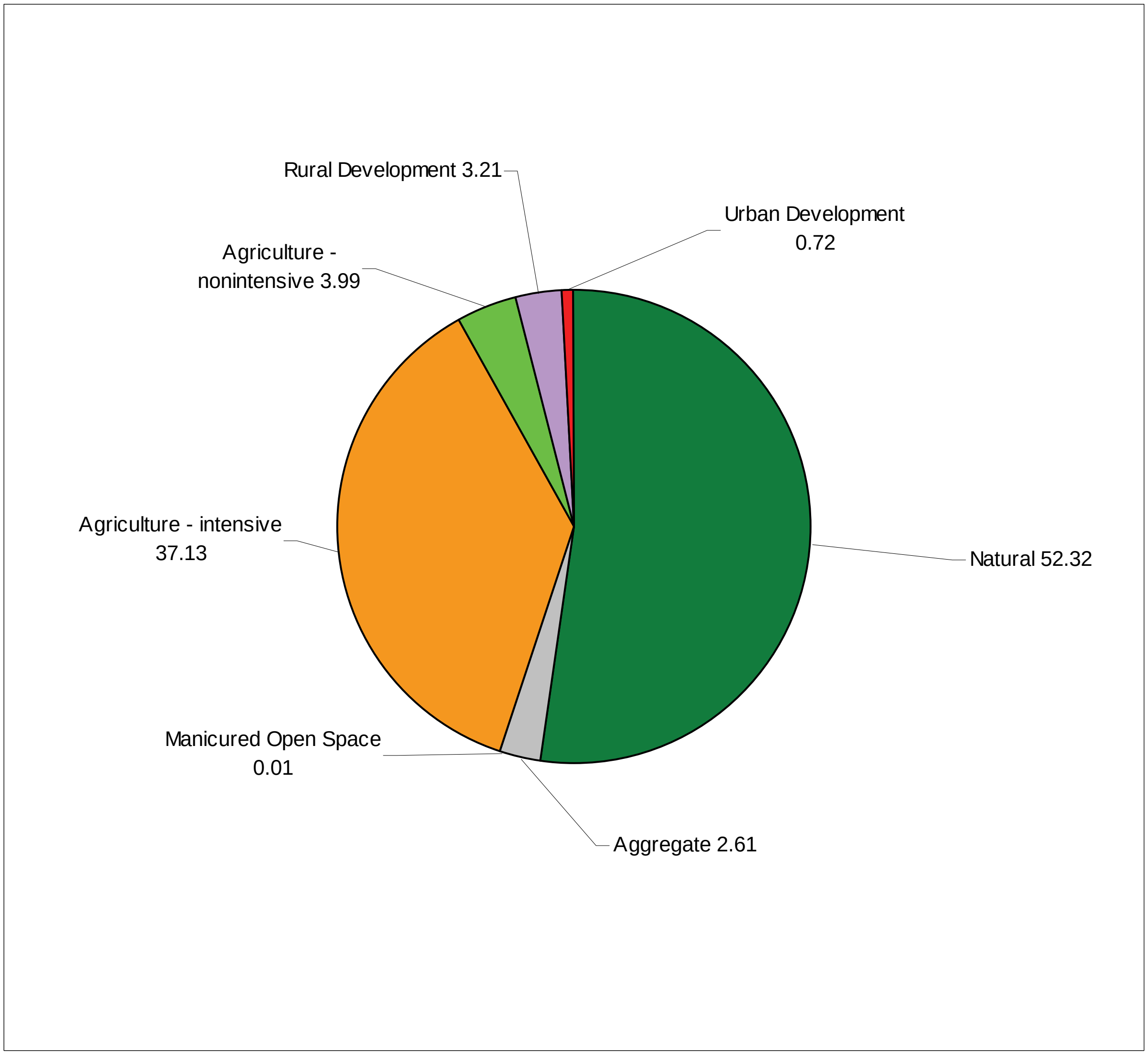


Figure 4.2: Percentage of major land cover types.

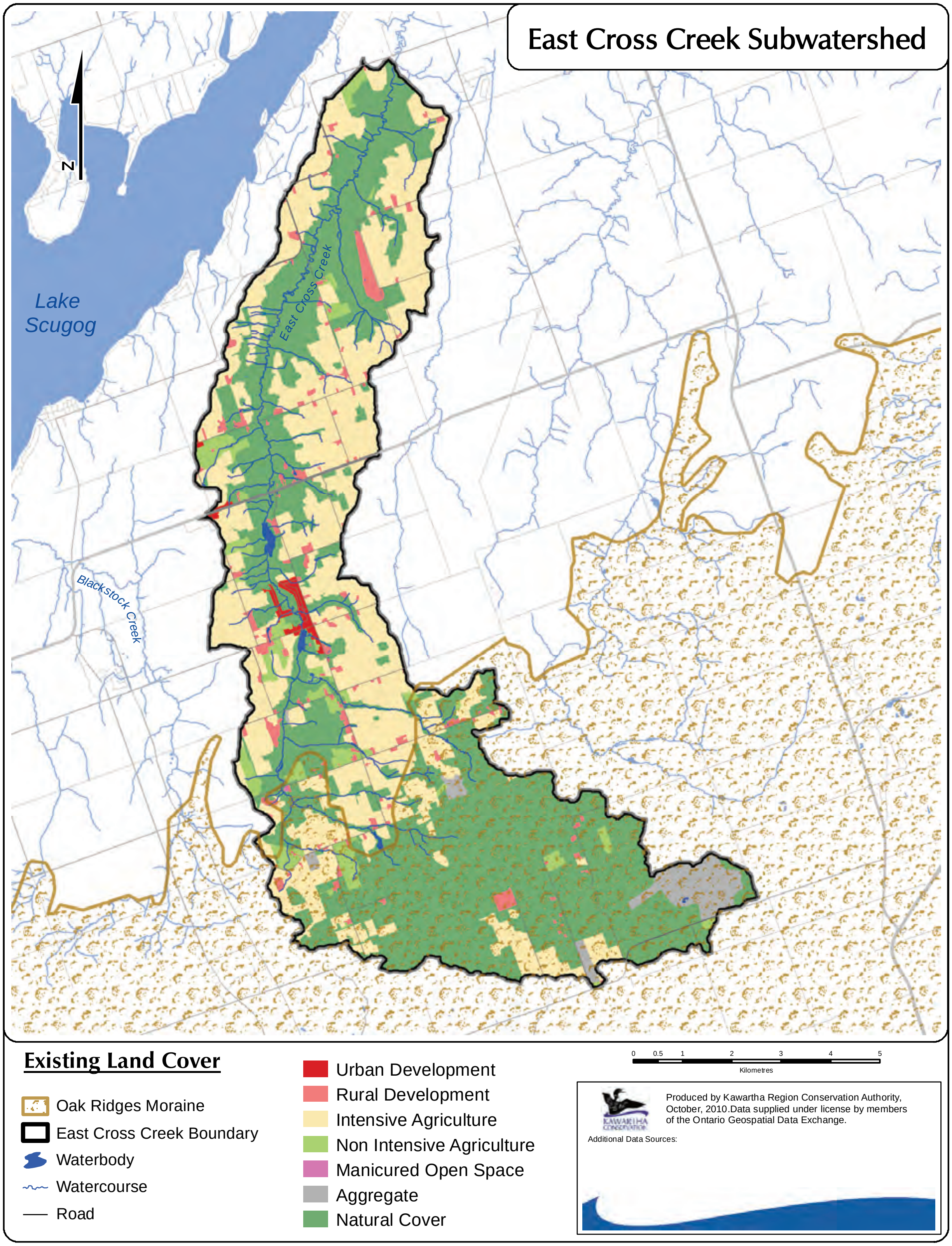


Figure 4.3: Existing land cover.

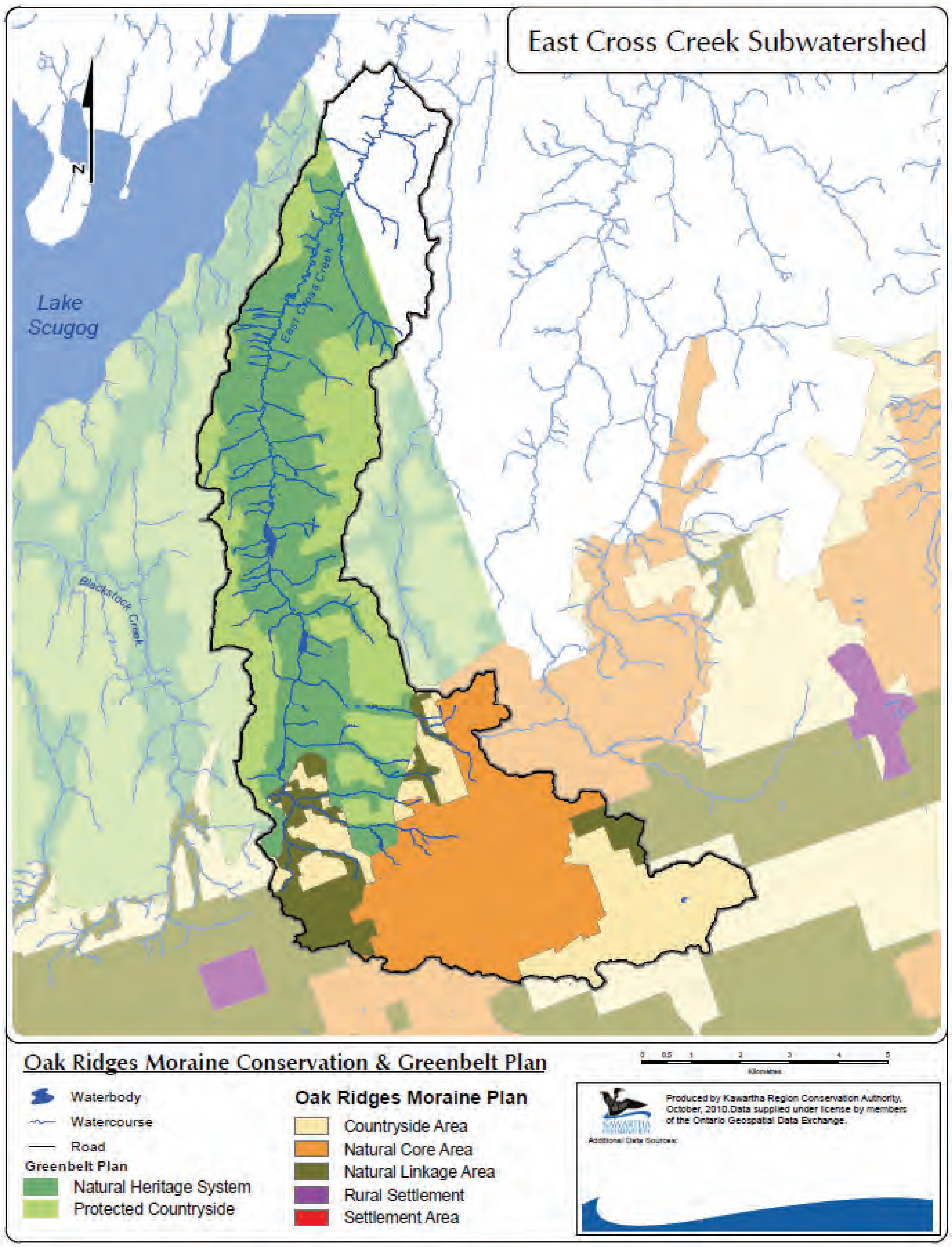


Figure 4.4: Oak Ridges Moraine and Greenbelt land use designations.

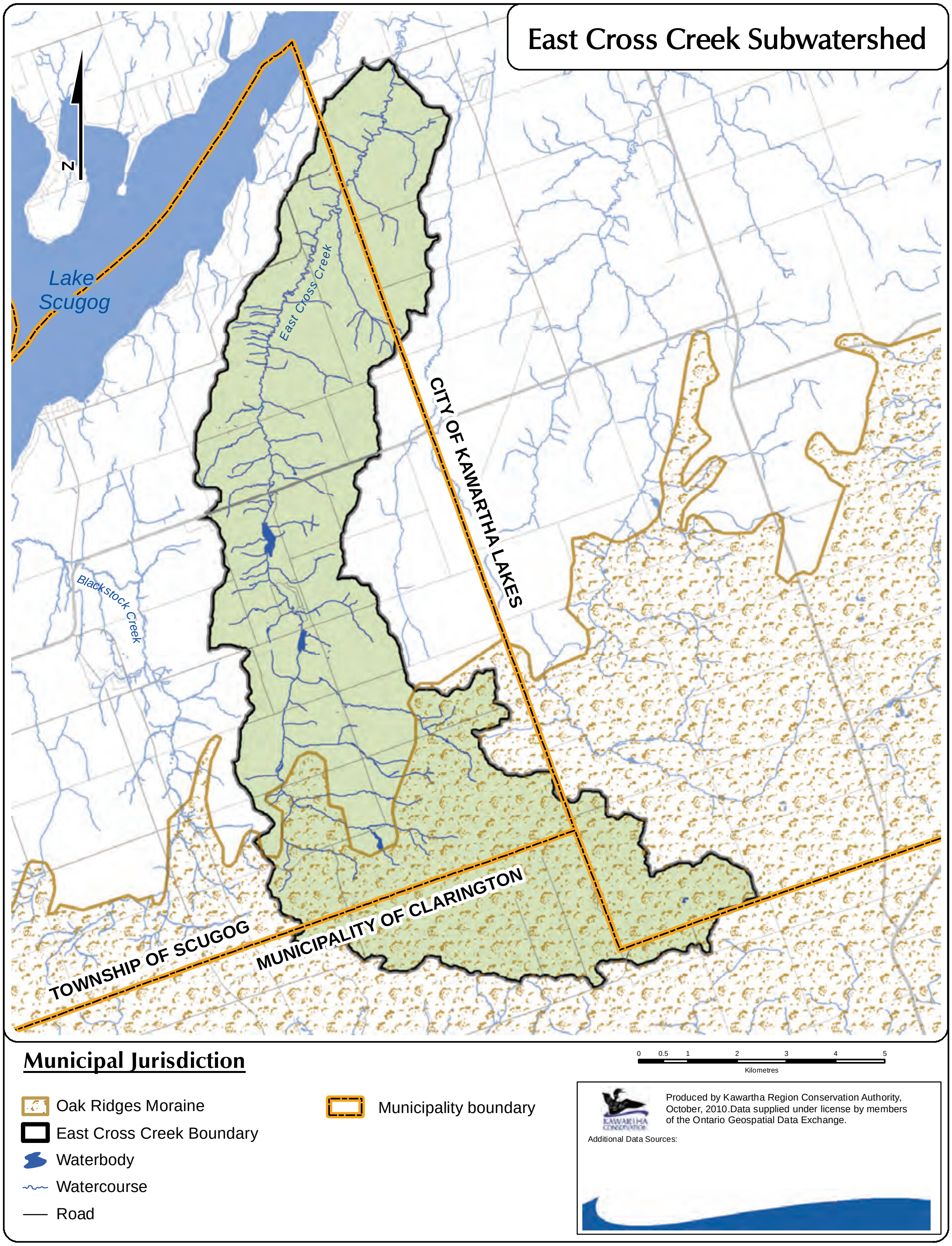


Figure 4.5: Municipal jurisdiction.

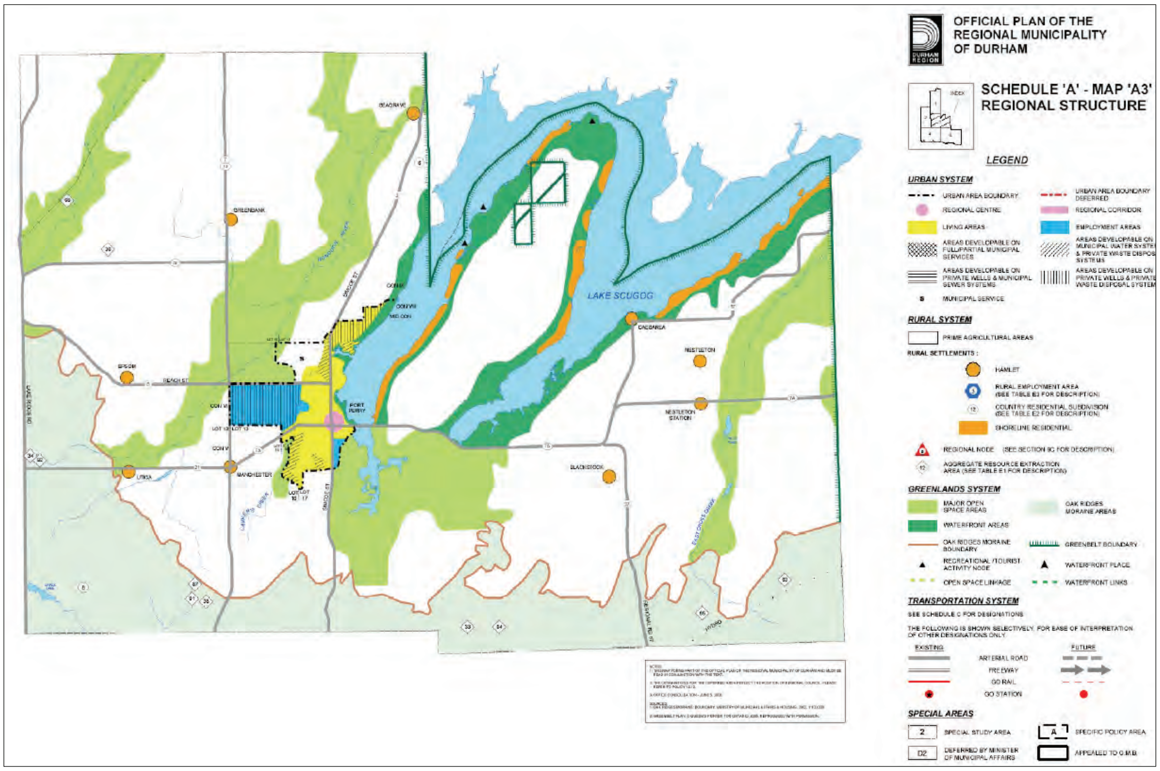


Figure 4.6: Regional Municipality of Durham Official Plan land use designations.

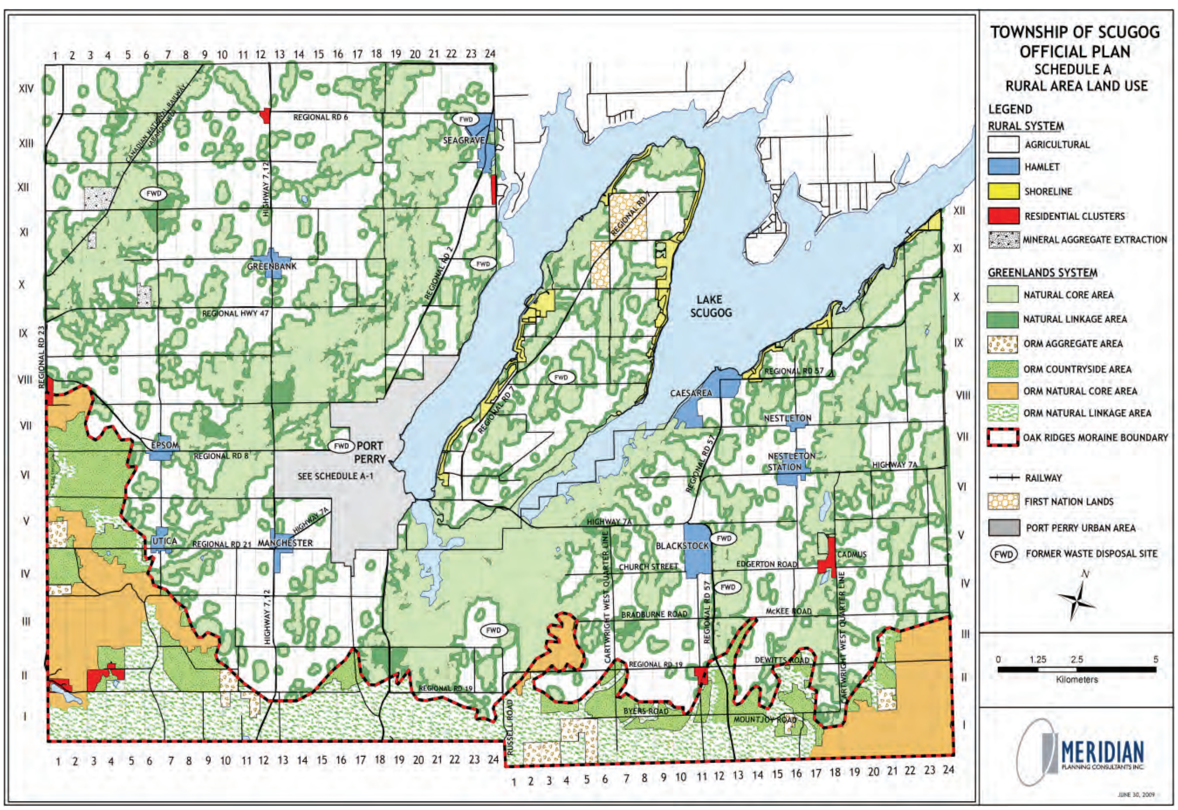


Figure 4.7: Township of Scugog Official Plan land use designations.

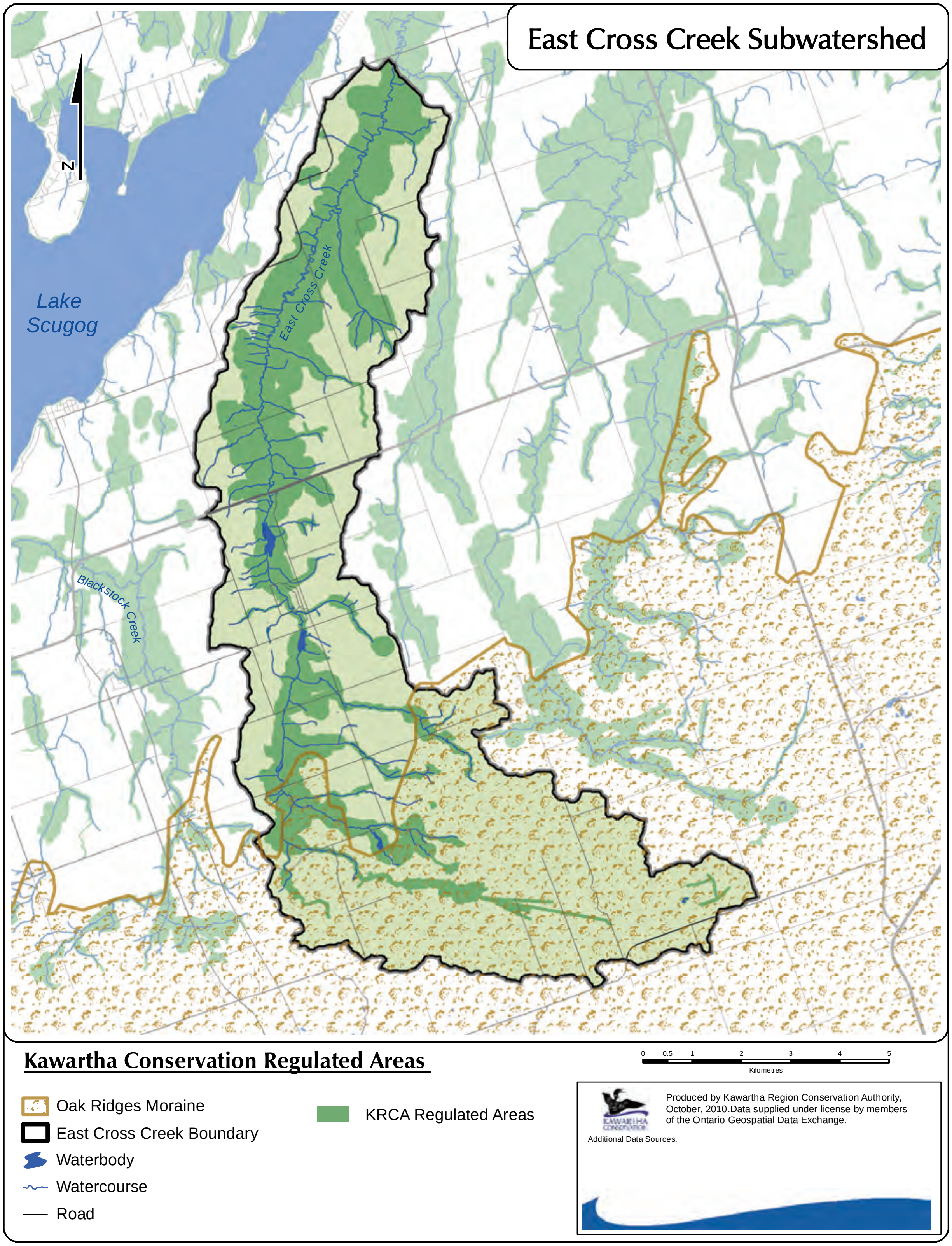


Figure 4.8: Conservation Authority Regulated Areas.

5.0 Water Use

Fallis Pond on East Cross Creek, south of Highway 7A

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 East Cross Creek subwatershed.

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 subwatershed. The best available data was provided for active permits within the subwatershed (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 three active Permits to Take Water within the East Cross Creek subwatershed (**Figure 5.1**, **Table 5.1).** Two of these employ surface water as a source and one uses groundwater. Water is withdrawn from Lake Scugog for irrigation purposed (up to maximum 684 m^3/day) and from East Cross Creek for recreational use (up to 52 m^3/day). The only permitted groundwater taking is considered to be industrial and is used for aggregate washing. Therefore, all water is used on seasonal basis and is returned to the subwatershed (non-consumptive use).

There are no municipal drinking water supply systems within the East Cross Creek subwatershed.

Table 5.1: Permits to take water.

Permit Number	Surface or Ground Water Source	Source	Max Taking (L)	Category	Purpose	Issue Date	Expiry Date
01-P-3003	Surface Water	Lake Scugog	684,000.00	Commercial	Golf Course Irrigation	2/28/2002	2012/12/31
6810-6DTLNH	Surface Water	East Cross Creek	52,370.00	Recreational	Other - Recreational	7/6/2005	2015/12/31
97-P-4080	Ground Water	Well 2	115,200.00	Industrial	Aggregate Washing	7/15/1988	n/a
97-P-4080	Ground Water	Well 3 - 12 inch well	1,800,216.00	Industrial	Aggregate Washing	7/15/1988	n/a
97-P-4080	Ground Water	Well 4 - 6 inch well	261,850.00	Industrial	Aggregate Washing	7/15/1988	n/a
	Total Groundwater Taking		2,177,266.00				

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 subwatershed (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 subwatershed have not been registered and many are no longer in active use.

Most rural residences within the subwatershed rely on water supplied by private wells. An estimated 261 private wells are located within the East Cross Creek subwatershed (**Figure 5.2**). A typical private household uses approximately of 1,000 litres of water per day (Shrubsole and Draper 2007). This would equate to a total water use in the order of 261,000 litres/day or 261 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 East Cross Creek subwatershed 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

There are no municipal drinking water supply systems within the subwatershed.

5.5 Wastewater Treatment

There are no municipal wastewater treatment facilities within the East Cross Creek subwatershed. As a result, wastewater is typically discharged to private septic systems.

5.6 Key Observations and Issues

- Groundwater is the dominant source of private water supply.

- The majority of residents within the subwatershed obtain their water from private, individual groundwater wells. There are approximately 261 wells within the subwatershed. The estimated total amount of groundwater being extracted from these sources is 261,000 litres per day.

- There are no municipal water supply systems.

- There are 3 active Permits to Take Water in the subwatershed. One of these are allocated for groundwater extraction (aggregate washing) and 2 of these are allocated for surface water extraction (1 for golf course irrigation and 1 for recreation).

- The total estimated water taking for the subwatershed is 2,438,000 litres per day. This estimate considers the total Permitted Water Taking rate for private permits plus 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.

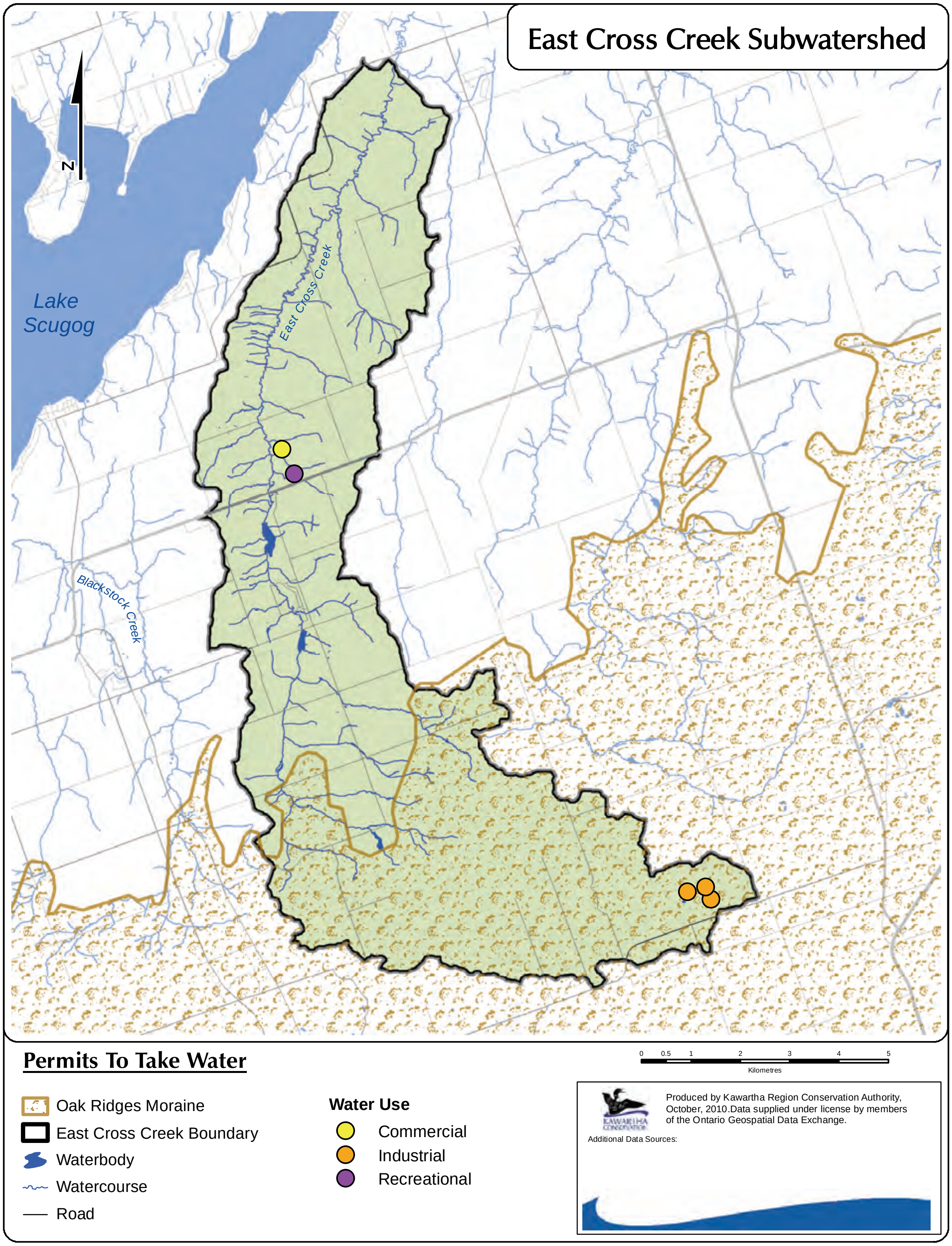


Figure 5.1: Permits to take water.

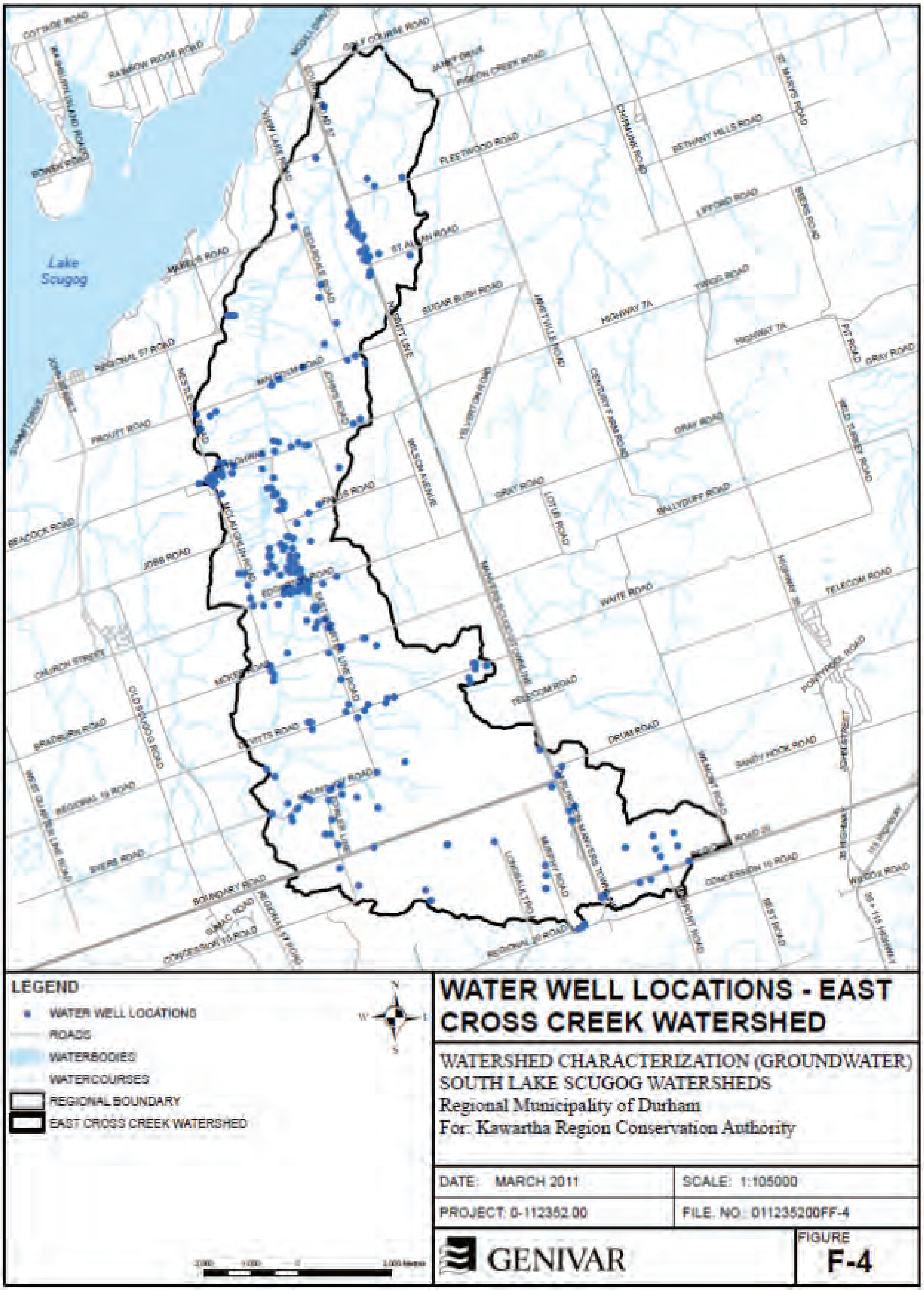


Figure 5.2: Water well locations.

6.0 Water Quantity

East Cross Creek, east of Cartwight East Quarter Line

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 East Cross Creek subwatershed, 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 East Cross Creek subwatershed has a drainage area of 78.9km^2, and contains approximately 114.7km of flowing watercourses. East Cross Creek originates on the Oak Ridges Moraine at an elevation of 325 masl and flows in a northerly direction, turning to the east for the last 5 kilometers before inflowing into the Scugog River at the elevation 249m. As it was mentioned before, not all but portion of the East Cross Creek watershed was characterized for purpose of the watershed planning. Janetville Creek, a major tributary of the East Cross Creek is excluded from the East Cross subwatershed area. The drainage area of the studied part of the watershed is 72.5% of the total East Cross Creek watershed area. The length of the main channel within the study area is about 28.8 km, or 81% of total East Cross Creek length.

Overall, East Cross Creek subwatershed is a narrow, oblong-shaped catchment with floodplain and channel characteristics that change according to the physiography. Well-defined valleys and narrow floodplains at the upstream portion of subwatershed are replaced by large meanders within the flat floodplain at the middle and lower sections. Watershed characteristics clearly depict differences in topography of upper and lower sections of the East Cross Creek subwatershed. The average slope of the terrain in the upper portion is 5.9%, with a main channel gradient of 5.6 m/km. In the middle and lover portion, the main channel gradient is only 1.2 m/km. The main channel length of East Cross Creek, within the study area, is 28.8km with average gradient of 2.6m/km.

Substantial portion of the East Cross Creek subwatershed, more than 35%, is covered by forest. It provides significant benefits to the watercourse, as forest helps to moderate streamflow, provides high and low flow mitigation and assists in groundwater recharge. Additional benefits come from the large wetland massive, that occupy more about 13% of the study area. Similarly to forest, wetlands provide peak flow mitigation and flood storage as well as assist in improving water quality by sediment trapping and nutrient retention and removal.

The watershed characteristics of the East Cross Creek subwatershed, as well as it's portion that lies within the Oak Ridges Moraine 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 (%)
East Cross Creek subwatershed	78.8	114.7	28.8	2.6	52.3	41.1	0.7
East Cross subwatershed within the ORM	32.2	15.8	-	-	70.8	20.5	0.0

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 by a gauge station on East Cross Creek, located where it crosses McKee Road. The monitoring gauge consists of a sensor that measures water level on a preset interval (30 min) and a data logger that records measured values (**Figure 6.1, Table 6.2**).

The gauge station at McKee Road provides information on flow regime of the headwaters of the East Cross Creek subwatershed. Station is located downstream of the Oak Ridge Moraine, and monitors flow that is mostly generated at the ORM as eighty two percent of the catchment area upstream of gauge at McKee Road are located within the Oak Ridge Moraine. The station is installed temporarily and maintained by Kawartha Conservation.

In order to convert water levels, that represent heights of water above the sensor, to flow (amount of water that passes through the given transect in one second), a rating curve is developed. Flow and corresponding 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 relationship. Once the rating curve and an equation, that describes it, are developed, water level values are converted to discharges that characterize water quantity at the gauging location. An example of a rating curve is shown in **Figure 6.2**. The dashed line demonstrates how curve can be used to translate the measured water level into a discharge rating.

Since gauge station has a recording length of four years, dataset is not satisfactory for the statistic analysis. As such, the conclusions derived from these data should be treated as strictly preliminary.

Table 6.2: Continuous flow monitoring location, East Cross Creek

Location	Data Interval	Data Record	Type	Ownership	Drainage Area (km^2)	Natural Cover (%)	Agriculture (%)	Urban Development (%)
East Cross Creek at Mckee Road	30 min	2006 - current	Temporary, pressure transducer	KRCA	32.5	64.0	27.4	0.0

Flow Regime

River flow varies over time and space. Floods and low-flow periods occur, sometimes in a predictable seasonal pattern, and sometimes less predictably. Rivers in variable climates tend to have variable flows, and river flows that are groundwater fed tend to have more constant and predictable flows. Flow regime describes the average seasonal flow variability for a particular river 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 existing stream gauge at McKee Road does not have sufficient data to determine average discharges, monthly flows as observed in 2007, 2008 and 2009 are used for interpretation (**Table 6.3**). They are graphed at **Figure 6.3**.

Climate data demonstrate that precipitation amount in 2007 was below the normal, so 2007 is considered as a 'dry' year, and two consequent years were 'wet' years when yearly amounts of precipitation exceeded a long-term average. The difference in precipitation values is clearly depicted by the hydrographs on the **Figure 6.3**. The values of monthly average discharges in 2007 are considerably lower than they are in 2008 and 2009. The largest difference in flow values is noted to occur during the spring freshet, in March-April, when the component of the surface run off is most significant. Average monthly discharge in April 2009 is 275% of average discharge observed in April 2007. Difference in September, a month with the lowest observed flow, when groundwater component of streamflow prevails, is only about 130%.

The data confirms that the East Cross Creek has a well-defined seasonal pattern, reflecting seasonal variations of water inflow. The highest flows were observed in April for all three years of monitoring, caused by a spring freshet. However, during the recent years, increases of water levels and flows as a result of winter thaws that occur in December-February, accompanied by abundant rain, are resulting in a change in the flow regime. 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 (December 26-28 2008, February 12-14 2009). It is believed, that these anomalies, observed recently, may become more frequent in the future as a result of climate change.

The lowest average monthly flow was observed in August-September, when sporadic 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 that time is groundwater. Water levels increase in October-November, responding to higher precipitation levels and lower rates of evapotranspiration.

Typically, during the winter months (December-February), ice cover establishes on East Cross Creek and its tributaries. However, it has been observed that the ground water fed, fast flowing upper reaches of the creek, including locations of the monitoring gauge, remain open longer than the lower reaches. They eventually freeze up when temperature falls below (-10) – (-15)° C. It proves that the groundwater component is very significant for East Cross Creek, especially at the headwaters portion of the watershed. In winter months, groundwater is the only source of water supply to the watercourse system. Abundance of groundwater inflow that is characterized by higher and more steady temperature keeps creek open longer.

Table 6.3: Average monthly flow, 2007-2009, East Cross Creek at McKee Rd.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2007	0.210	0.157	0.286	0.303	0.199	0.189	0.202	0.146	0.153	0.210	0.226	0.230
2008	0.304	0.273	0.289	0.569	0.221	0.203	0.197	0.216	0.196	0.301	0.355	0.546
2009	0.325	0.606	0.692	0.829	0.517	0.216	0.262	0.219	0.197	0.267	0.293	0.296

High/Low Flows

The highest flows on East Cross Creek 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 become barriers to flow. Although no significant flood damage has occurred within the East Cross Creek watershed, road overtopping and washouts may create dangerous situation. Areas susceptible to this kind of situation should be monitored closely. **Table 6.4** demonstrates all available highest instantaneous and daily discharges for monitoring location on East Cross Creek at McKee Road.

The data shows that during monitoring period, high water events have occurred in late March-early April. They have resulted from snowmelt, combined with rain events in 2007 and 2009. As it was noted earlier, the lowest average monthly flow is generally observed during August-September. However, the minimum daily flow recorded as early as July 6th.

Baseflow index was calculated as a part of baseflow separation analysis that was performed for monitoring location on East Cross Creek at McKee Road. The baseflow index indicates proportion of baseflow in the total runoff of a catchment and describes the influence of watershed's geology and soils on river flows. It might vary between 0 and 1, indicating the range of conditions, from an absence of the groundwater inflow to the fully groundwater fed watercourses, respectively.

Results of analysis show, that baseflow (that basically is a groundwater component of the streamflow) made up to 78 % of the total flow at the gauge at McKee Road during 'dry' 2007 year. In 2008 and 2009, 'wet' years, in average 70% of total streamflow of East Cross Creek at McKee Road has come from groundwater (**Table 6.5**).

It proves that the portion of East Cross Creek Subwatershed upstream of McKee Road is an important area that provides significant groundwater discharge to the East Cross Creek overall.

Table 6.4: Maximum and minimum discharge, East Cross Creek at McKee Road

Year	Maximum instantaneous discharge			Maximum daily discharge			Minimum daily discharge		
	m^3/sec	$L/sec/km^2$	Date	m^3/sec	$L/sec/km^2$	Date	m^3/sec	$L/sec/km^2$	Date
2007	1.439	62.9	03/14	1.060	46.3	03/14	0.126	5.51	8/17
2008	8.155	356.6	04/01	3.846	168.2	04/01	0.136	5.95	07/06
2009	7.579	331.4	04/03	4.334	190.25	02/12	0.171	7.48	07/21

Table 6.5: Yearly baseflow indexes, East Cross Creek at McKee Road

Year	2007	2008	2009
Baseflow Index	0.78	0.71	0.69

Flow Duration Curve

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 river basin, providing an estimate of the percentage of time a given streamflow was equaled or exceeded over a historical 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 at al 1994). Although FDCs 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 the stream and basin 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 moderate 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 the FDC 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 flow of 40-60 probability %;

- Dry conditions zone described by flows of 60-90 % of probability; and,
- Low flow zone includes flows that happen in more than 90 %.

Figure 6.4 and **Figure 6.5** demonstrate the daily flow duration curve for monitoring location on East Cross Creek at McKee Road, whereas **Table 6.6** contains the flow values that correspond to the probabilities. The curve is characterized relatively steep high flow portion, what means the high flows are typically driven by rain or/and quick snow-melting events. The lower portion of the curve is fairly flat that confirms the existence of the sustainable groundwater supply or a storage capacity within the drainage area that moderate flows.

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 %**
> 0.491	0.491-0.253	0.253-0.207	0.207-0.158	<0.158

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 East Cross Creek subwatershed 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. 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. To this date there are no records of observed flooding sites within the East Cross Creek subwatershed. However, no flood risk studies have been undertaken for the East Cross Creek subwatershed.

6.2 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 best baseflow dataset for the East Cross Creek subwatershed was obtained during the summer of 2006. In total, 16 sites throughout the East Cross Creek subwatershed were visited during July 21-25, 2006. No precipitation was recorded over these 5 days, allowing for comparison and analysis of spot measurements to interpret the spatial distribution of baseflow. Fourteen sites were found flowing and measurements were taken. Two 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 in drainage network are shown in the flow diagram, **Figure 6.6**. Further data analysis involved the calculation of net discharges at every measuring point, net discharges per a square kilometre and proportion of net baseflow within the watershed. The results of the analysis are depicted on **Figure 6.7**.

Data collected during the baseflow survey have been used to illustrate the magnitude and distribution of baseflow discharge within the East Cross Creek subwatershed.

Baseflow analysis has revealed that:

- Oak Ridges Moraine portion of the watershed (upstream of Devitts Road) does not produce significant baseflow, on average it is less than 2 l/sec/km^2.

- The portion of the watershed located just downstream of the (from Devitts Road north to Edgerton Road) is an important groundwater discharge area. This area contained the highest discharge rates within the East Cross Creek subwatershed averaging more than 10 l/sec/km^2, up to17.4 l/sec/km^2.

- Loss of the discharge is observed between Edgerton Road and Highway 7A. A large pond (Fallis Pond) is located in this area, which could contribute to the flow loss.

- Middle portion of the East Cross Creek subwatershed, between Highway 7A and Malcolm Road, is characterized abundant groundwater inflow.

- There is no baseflow data for the portion of the watershed downstream from Malcolm Road. It should be considered as a significant data gap, and further investigation must be conducted to define the baseflow gains/loses in this section of the East Cross Creek watershed.

Table 6.7: Baseflow monitoring sites 2006.

	Number of baseflow sites			
	Flowing		Dry / Standing Water	Total
	Measured	Unsuitable		
East Cross Creek	14	0	2	16

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 East Cross Creek subwatershed, as well as the other three watersheds (Southern Lake Scugog Tributaries, Blackstock Creek and Nonquon River) that require watershed plans. Surficial geology plays an important role in the regional drainage and recharge patterns of East Cross Creek subwatershed. 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 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 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 6.8** shows the locations of two representative cross-sections are provided for each subwatershed to show how the layers interrelate. **Figure 6.9** and **Figure 6.10** 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 – East Cross Creek Subwatershed

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 East Cross Creek subwatershed. The results of this analysis are summarized in **Figure 6.11**.

Figure 6.11 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 to/from the adjacent Blackstock Creek Watershed that drains to Lake Scugog are quantified separately. The lateral transfers from watersheds on the north, east, and south sides of the East Cross Creek subwatershed are presented as one value.

Some observations drawn from analysis include:

- Recharge from infiltration is primarily received in the two upper hydrostratigraphic layers (Surficial/Weathered Till/Halton Till). Recharge accounts for 62.2% of the input to the groundwater flow system. Lateral inflow from adjacent watersheds accounts for 37.8% 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 Aquifer Complex. Discharge to streams accounts for approximately 41% of the flow out of the groundwater flow system. There is no direct discharge to Lake Scugog.
- Lateral outflow accounts for approximately 59% of the flow out of the groundwater system. There is a net outflow on the order of 17,036 m3/day transferred laterally to adjacent watersheds. Approximately 12% of this outflow is transferred to the Blackstock Creek Watershed. The lateral transfer is primarily within the Oak Ridges Moraine Aquifer Complex and the Thorncliffe Aquifer Complex layers. There is a net inflow in the Scarborough Aquifer Complex Layer. The lateral outflow is directed both to the north and to the south. It is apparent that the flux to the south may represent a substantial portion of the lateral outflow.
- The total permitted groundwater taking is less than 4% of the estimated recharge to the groundwater system and less than 3% 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 the permitted use will ultimately be recharged to the groundwater system.
- The total groundwater use for residential purposes by the private water wells is on the order of 0.5% of the estimated recharge to the groundwater system and less than 0.5% 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 – East Cross Creek Subwatershed

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 East Cross Creek subwatershed is 50,882 m^3/day. **Figure 6.12** illustrates the distribution of recharge to the groundwater system as obtained from the numerical groundwater flow model. The recharge was estimated by Earthfx (2009).

The spatial patterns of recharge correlate with the distribution of coarse and fine-grained sediments. The average recharge over much of the area to the north of the Oak Ridges Moraine 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 6.13**.

Discharge Flux to Surface Water – East Cross Creek Subwatershed

The total discharge to surface water within the East Cross Creek subwatershed is calculated to be 33,843 m3/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. There is no direct discharge to Lake Scugog. A portion of the lateral transfer of water along the northern and western boundary of the East Cross Creek subwatershed will likely be transferred directly to Lake Scugog.

Figure 6.14 illustrates the observed distribution of the groundwater discharge to streams within the East Cross Creek subwatershed. 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* to protect drinking water sources, two studies were completed for the Assessment Report to evaluate groundwater vulnerability for the Kawartha Haliburton Source Protection Region, including the East Cross Creek subwatershed. 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 Source Protection Assessment Report. The map illustrating the vulnerable areas is shown in **Figure 6.15**.

In addition to the above analyses, GENIVAR prepared vulnerability mapping for each individual aquifer within the 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 6.16**).

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.

<u>Methodology</u>

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:

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

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 includes headwaters of the East Cross Creek Subwatershed, SWin is considered to be zero. The SWout component is quantified by discharge values (Q), measured at the McKee Road gauge station. Therefore, the symbol Q will be used further.

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

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

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”:

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

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 East Cross Creek subwatershed 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 McKee Road from 2007-2009.

<u>Findings</u>

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

As data demonstrate, 63% of precipitation that falls on the subwatershed evaporates back to the air from the ground surface or is transpired into the air by vegetation; about 46% of precipitation runs out of the subwatershed as surface water and approximately 9% leaves the subwatershed as groundwater.

As previous research shows, the groundwater flux is negative for the headwaters of the Oak Ridges Moraines 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 East Cross Creek subwatershed.

Additionally, a long-term monthly water budget was calculated for East Cross Creek at McKee Road (refer **Table 6.10** and **Figure 6.17**).

Negative values of change in storage (ΔS) in March, April, May, June, July and August indicate that more water evaporates 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 (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 months when outputs of water resources to the subwatershed 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)
East Cross Creek Subwatershed	913	580	-79	418	-164

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	15	25	49	163	173	77	43	23	7	2	**580**
GW (mm)	-7	-7	-7	-7	-7	-7	-7	-7	-7	-7	-7	-7	**-79**
Q (mm)	33	37	49	64	37	23	26	23	21	30	33	42	**418**
ΔS (mm)	27	8	-17	-21	-3	-106	-125	-21	19	16	43	16	**-164**

6.7 Key Observations and Issues

- The subwatershed 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.

- Vast wetlands and forested areas (up to 40% of the watershed), mostly located at the Oak Ridges Moraine portion of the watershed and along the East Cross Creek valley, provide significant benefits to the surface water, moderating streamflow, providing high and low flow mitigation and assisting in groundwater recharge.

- Climate change as it is forecasted has the potential to impact the flow regime of the East Cross Creek and its tributaries, by reducing duration and intensity of spring runoff and increasing potential for dry conditions and extreme high flow events during the summer.

- The subwatershed contains significant areas where groundwater discharges to the watercourses. Areas of particular significance are located at the middle portion of the watershed. The groundwater discharge supports baseflow and is a main component of the streamflow during the dry periods.

- Significant groundwater recharge areas are located within the Oak Ridges Moraine as well as throughout the watershed. They are extremely important, as 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.
- Groundwater use within the watershed is low, estimated below 3.0% of total available groundwater resources. Therefore, water withdrawals are not considered a major threat to the resource. Further, existing groundwater use is non-consumptive, and returned as recharge to shallow aquifers.
- According to the water budget, on the average, East Cross Creek watershed receives 913 mm of precipitation. Five hundred and eighty millimeters, or 63% of that are returned to the atmosphere through the evaporation and evapotranspiration. Four hundred and eighteen millimeters (46%) leaves the watershed as stream flow and approximately 79 mm (9%) as groundwater.
- Currently, there are no records of existing flood prone areas within the East Cross Creek subwatershed. However, several sites throughout the watershed may be considered potential for adverse effects of high-water situations such as roads overtopping and erosion.
- 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.

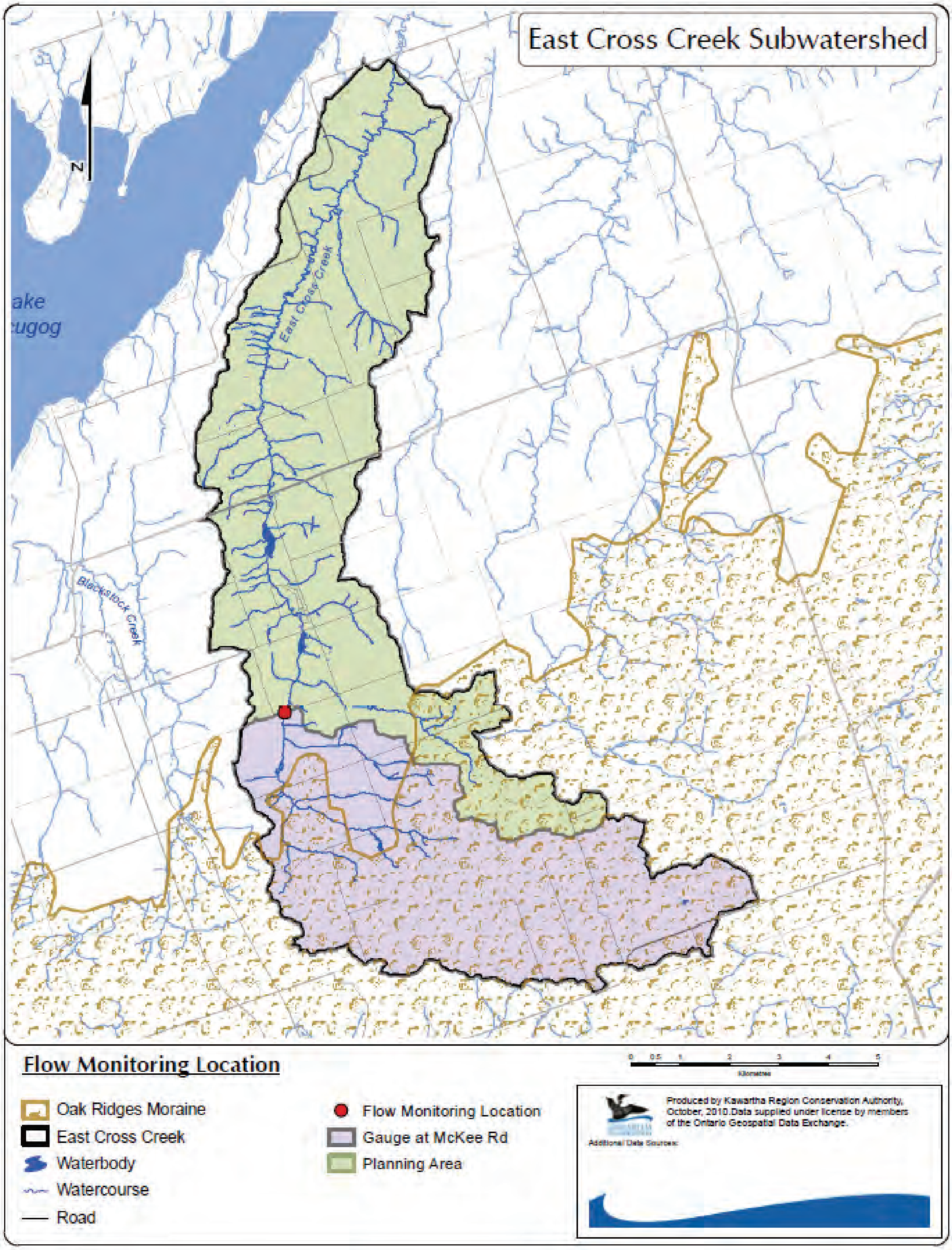


Figure 6.1: Continuous flow monitoring locations.

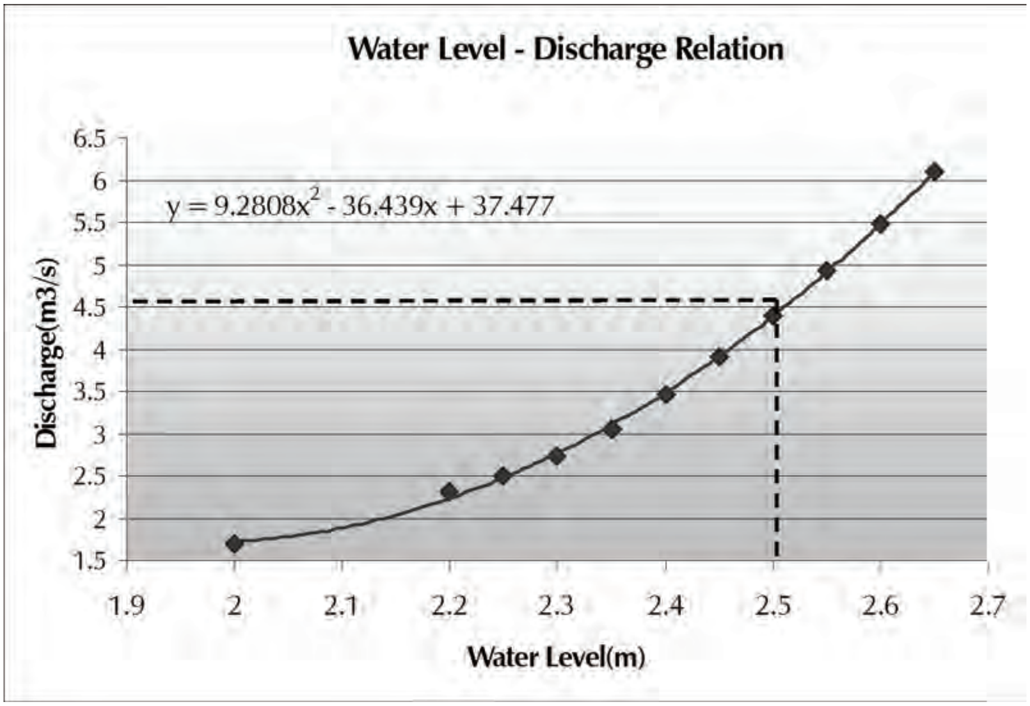


Figure 6.2: Sample rating curve.

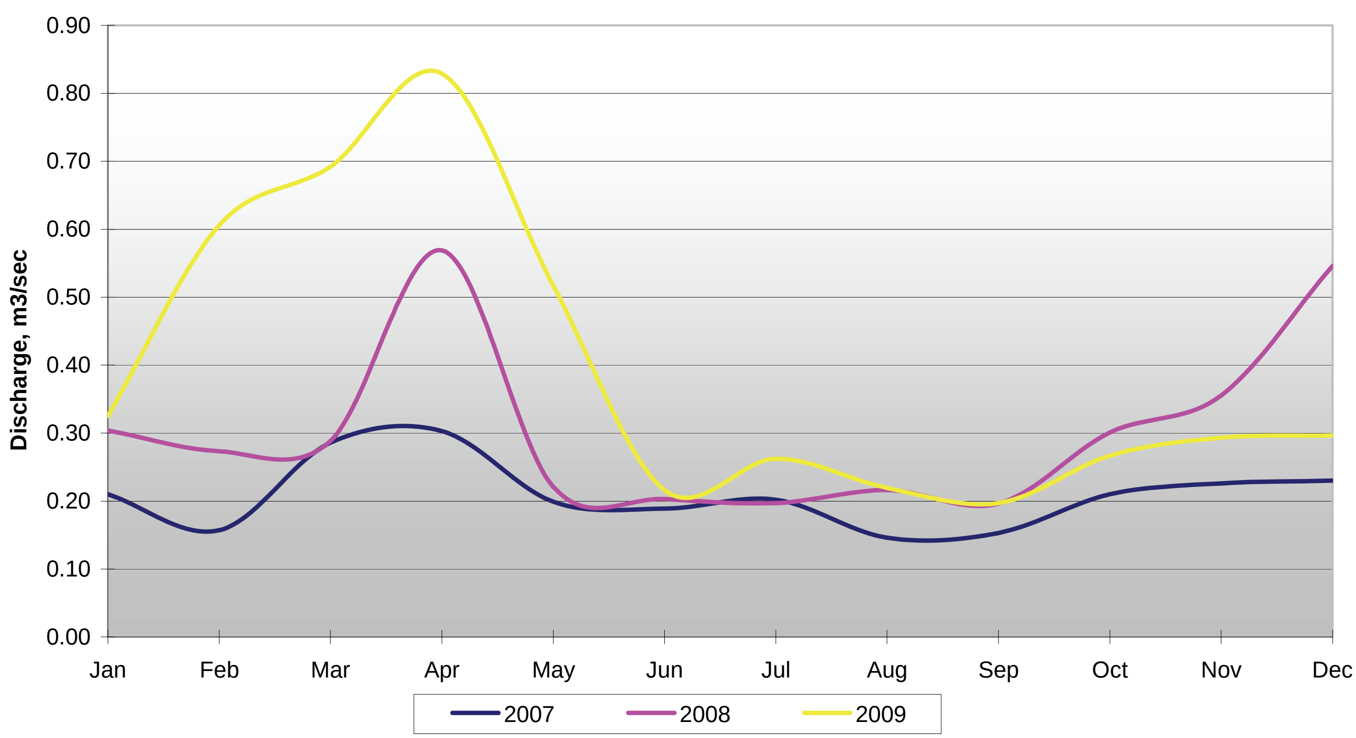


Figure 6.3: Monthly Discharge of East Cross Creek at McKee Road, 2007, 2008 and 2009.

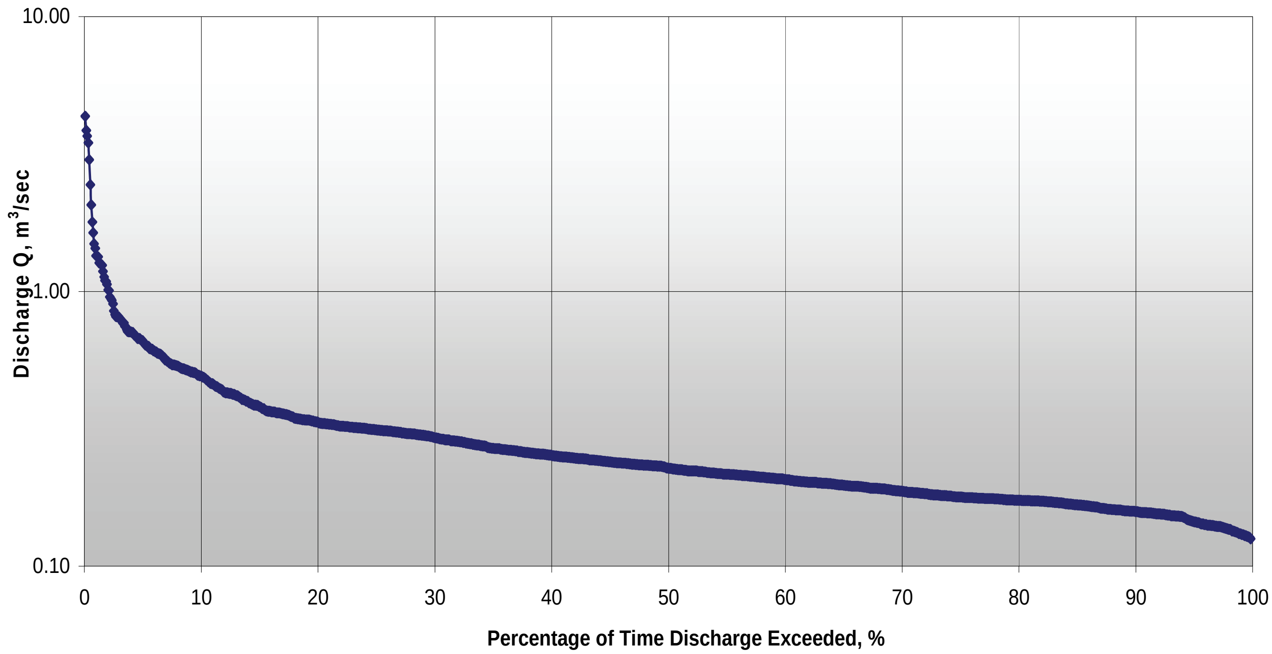


Figure 6.4: Semi-log plot of Flow Duration Curves, East Cross Creek at McKee Road.

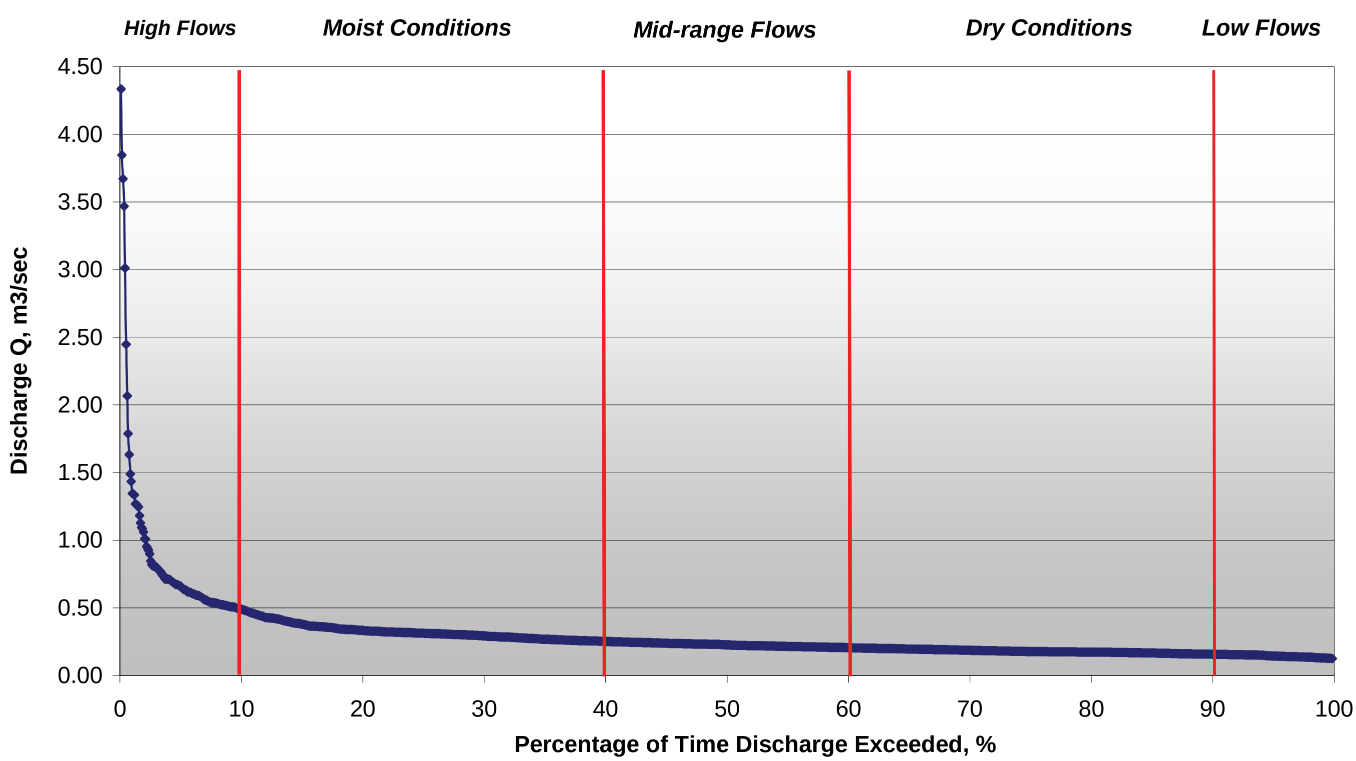


Figure 6.5: Flow Duration Curve, East Cross Creek at McKee Road.

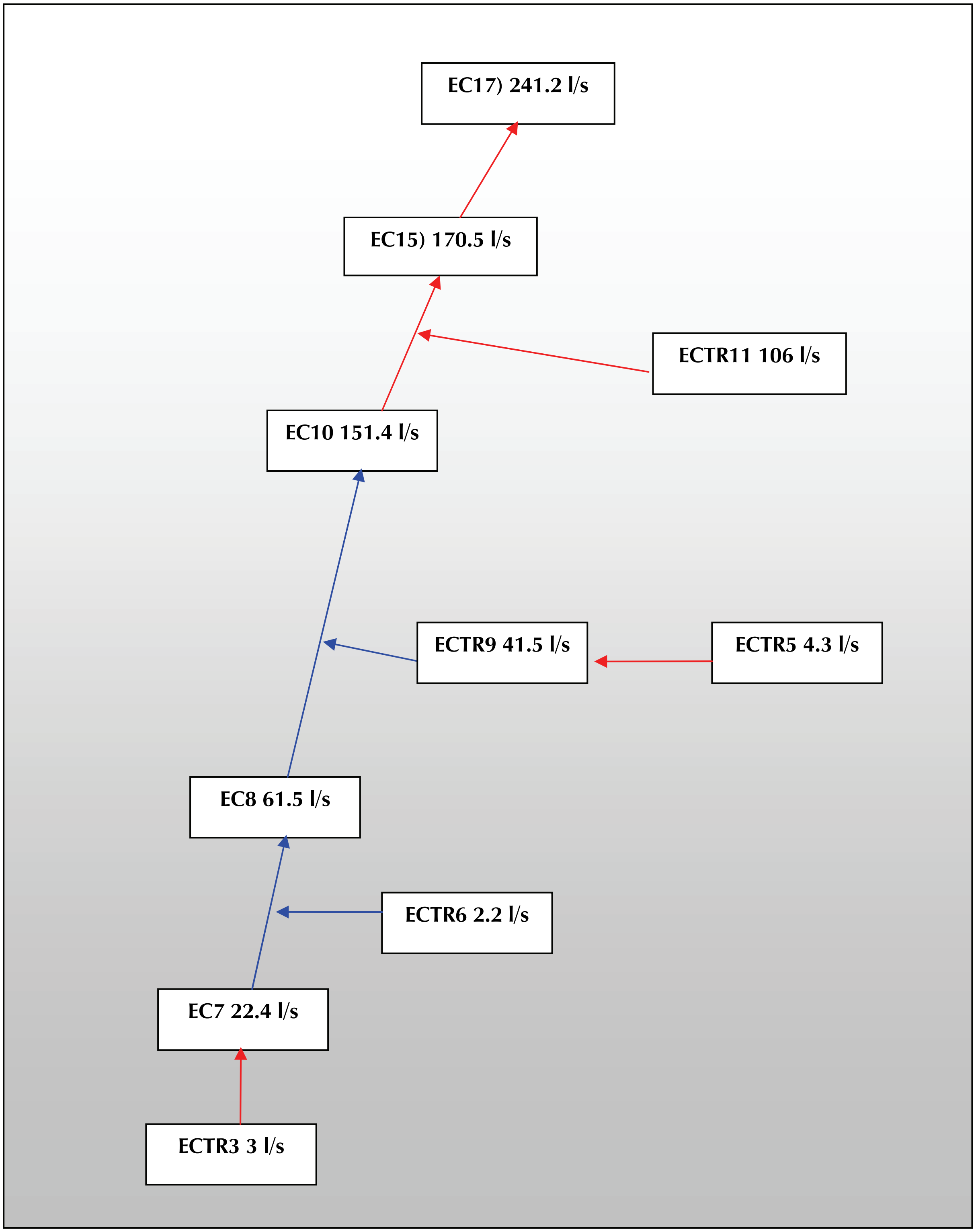


Figure 6.6: Flow diagram, baseflow study, East Cross Creek

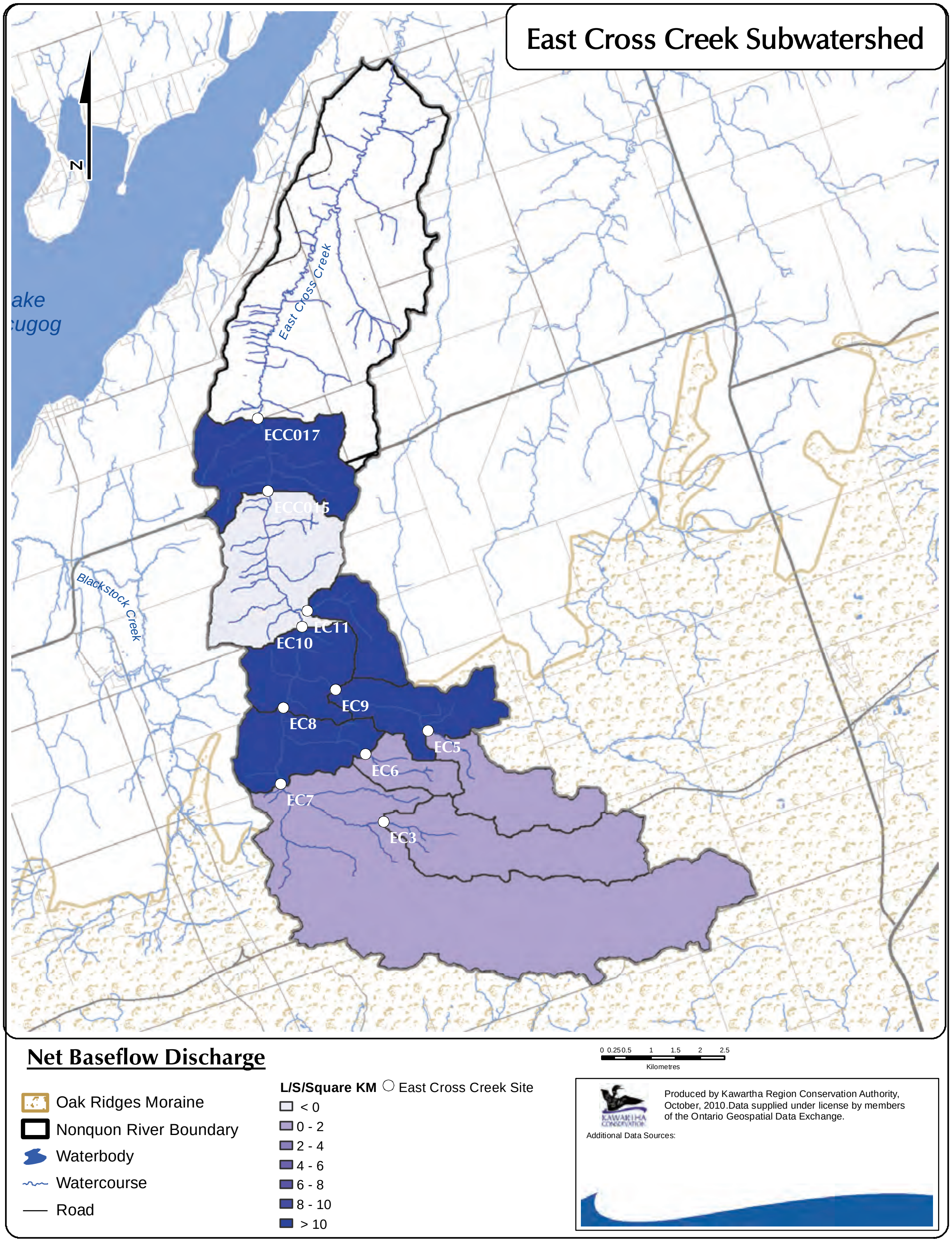


Figure 6.7: Net baseflow discharge per unit area.

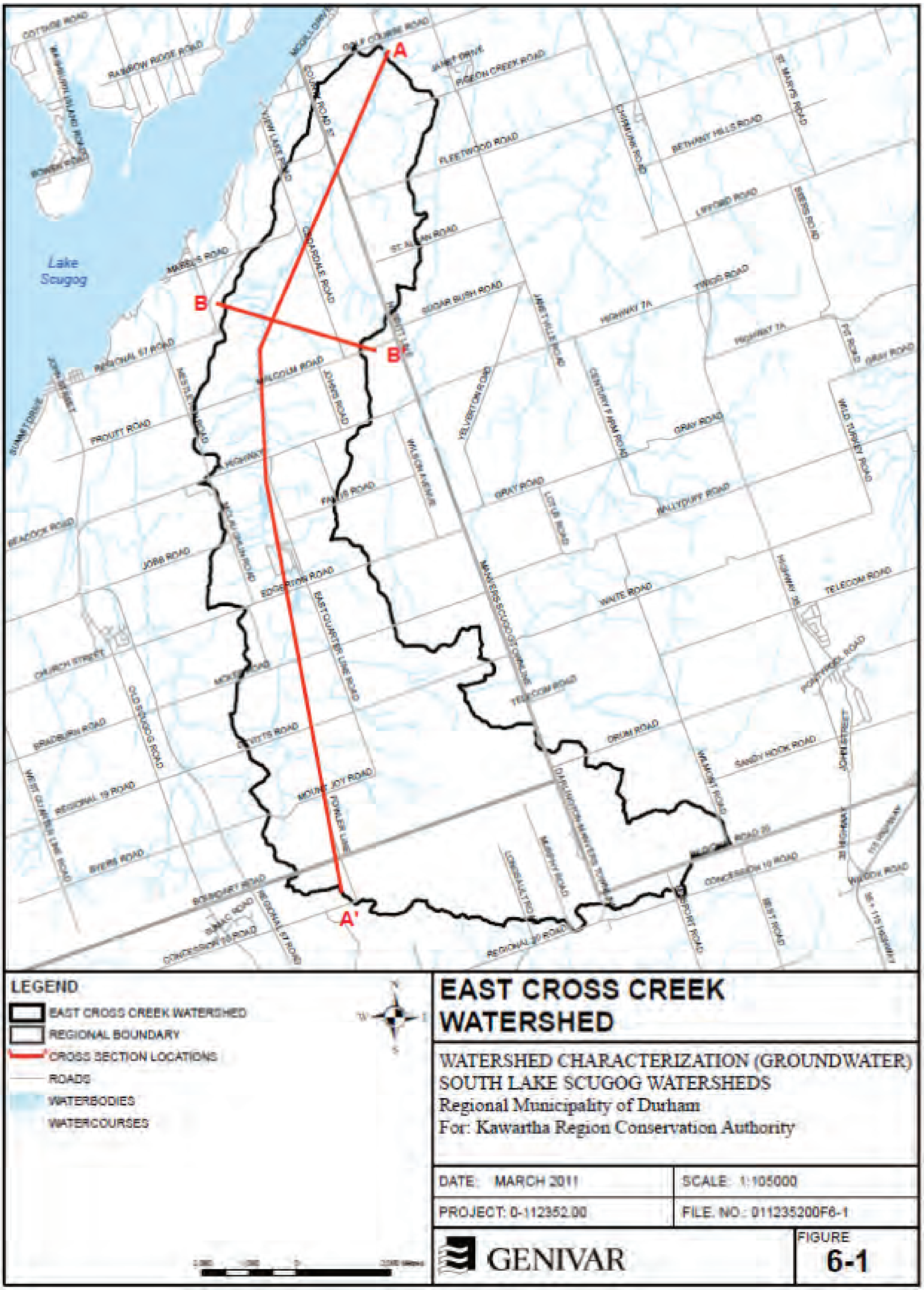


Figure 6.8: Locations of stratigraphic crosssections.

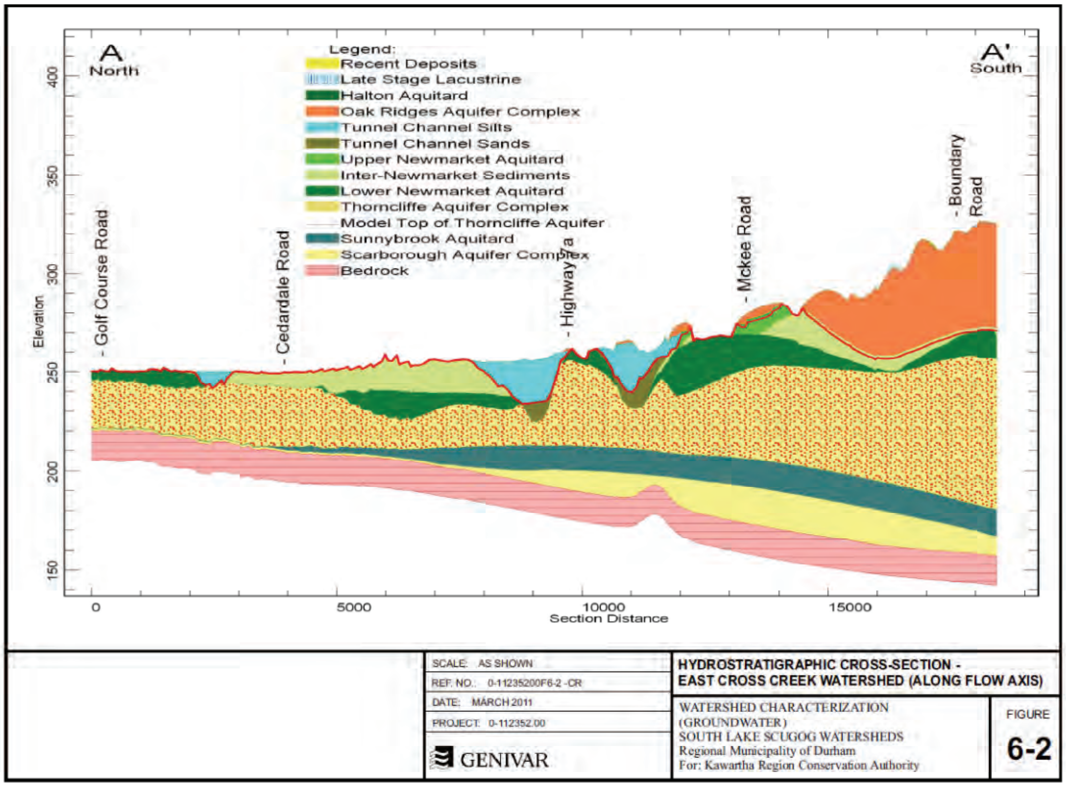


Figure 6.9: Crosssection A - A'.

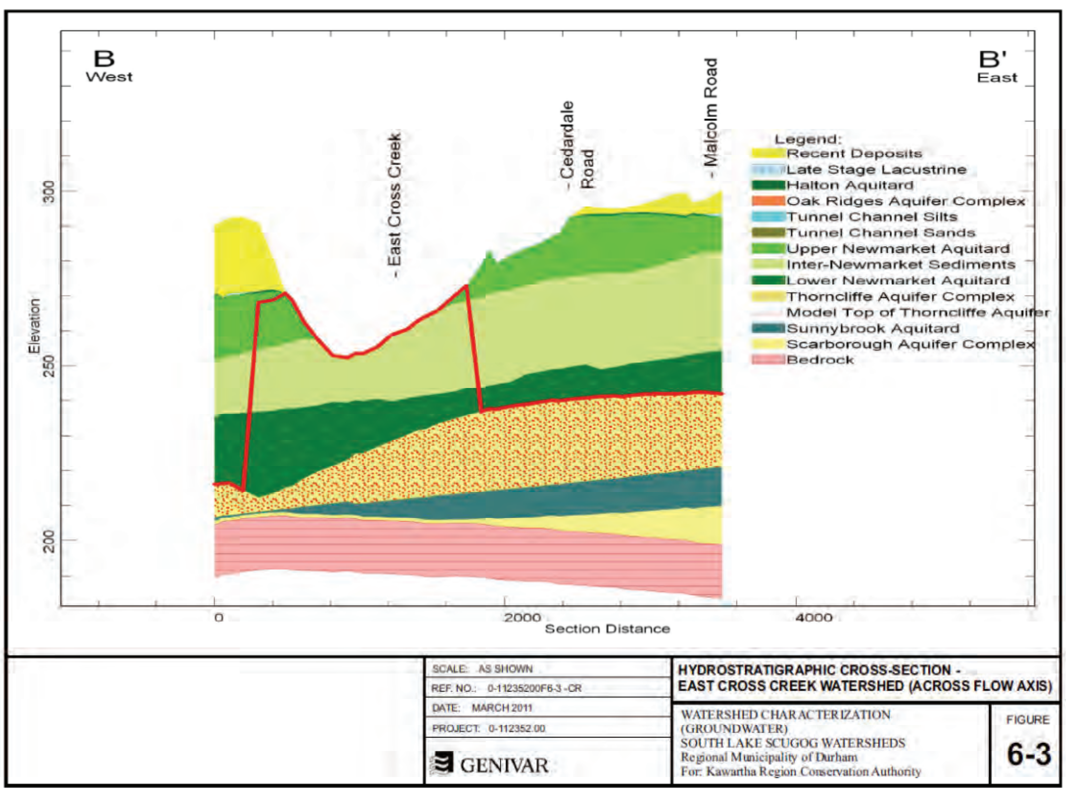
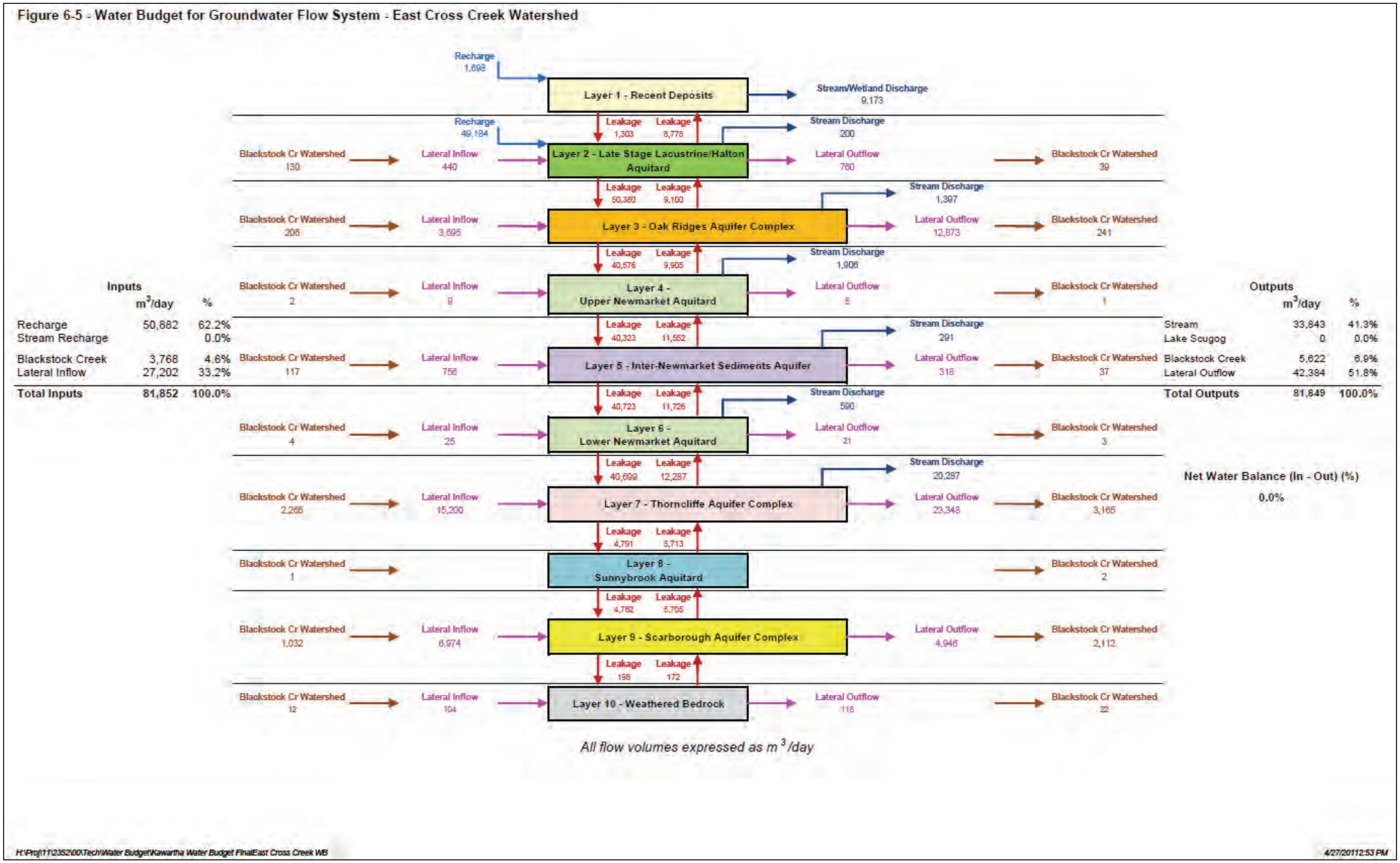


Figure 6.10: Crosssection B - B'.



From GENIVAR (2011)

Figure 6.11: Water budget for groundwater flow system

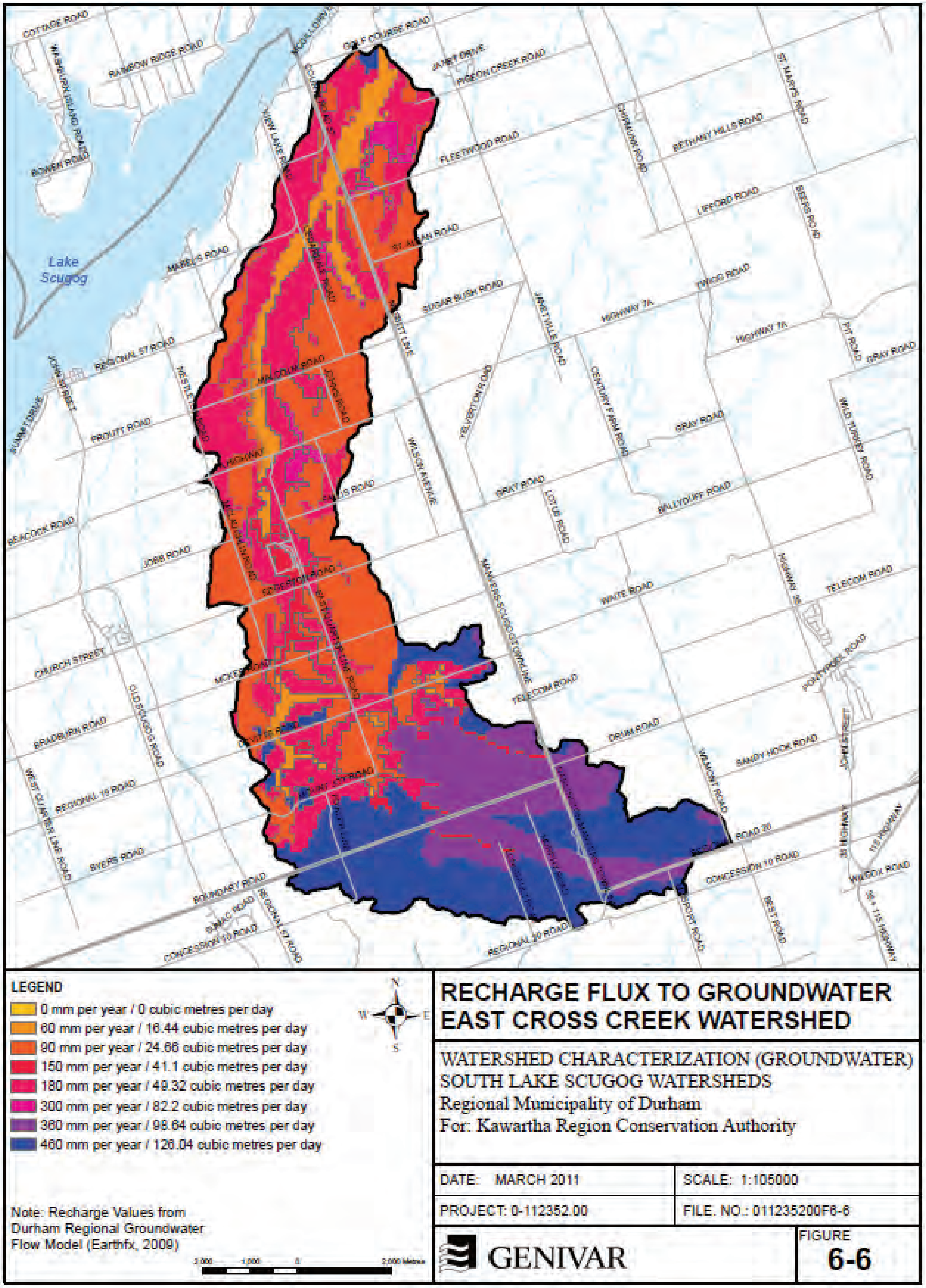


Figure 6.12: Recharge flux to groundwater.

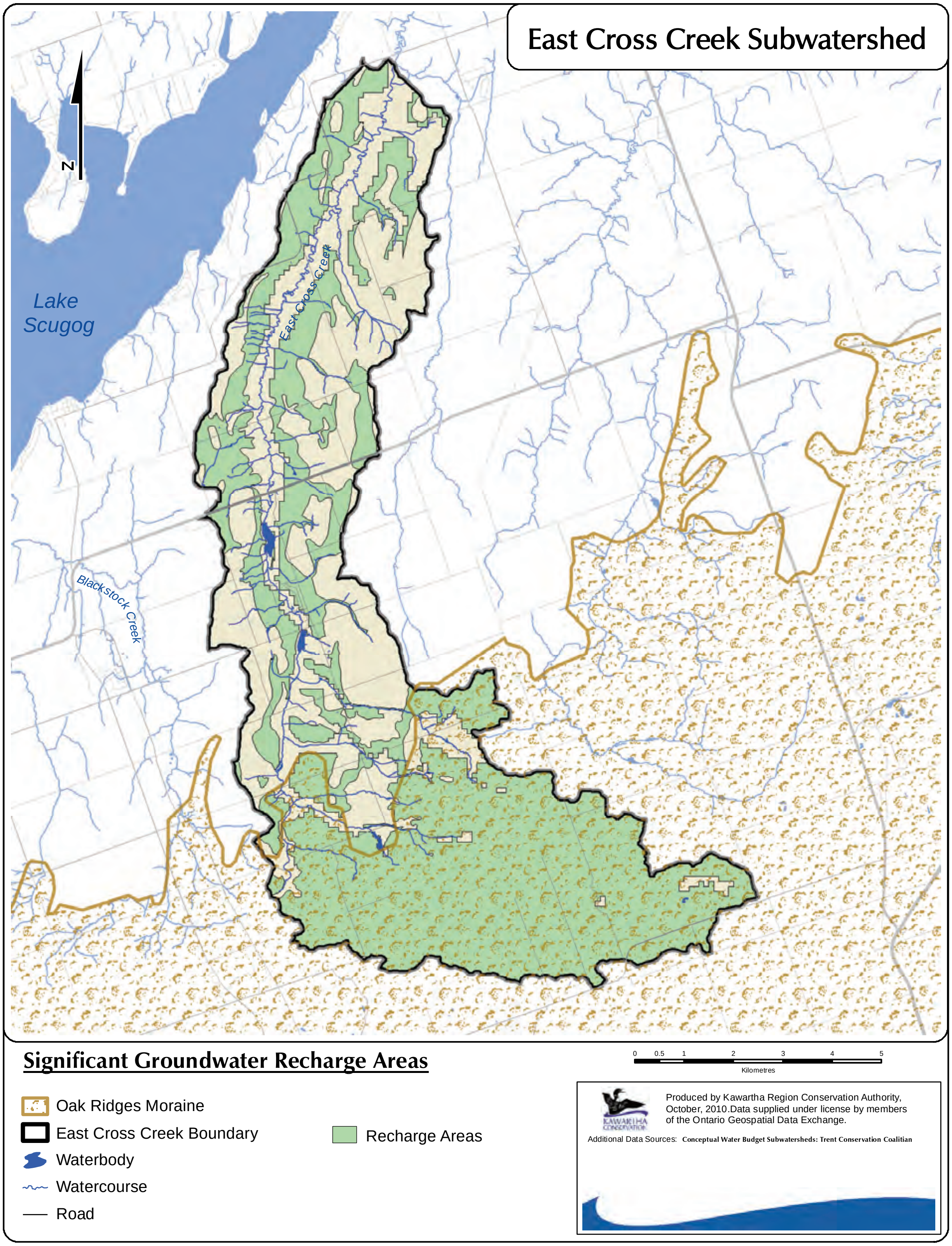


Figure 6.13: Significant groundwater recharge areas.

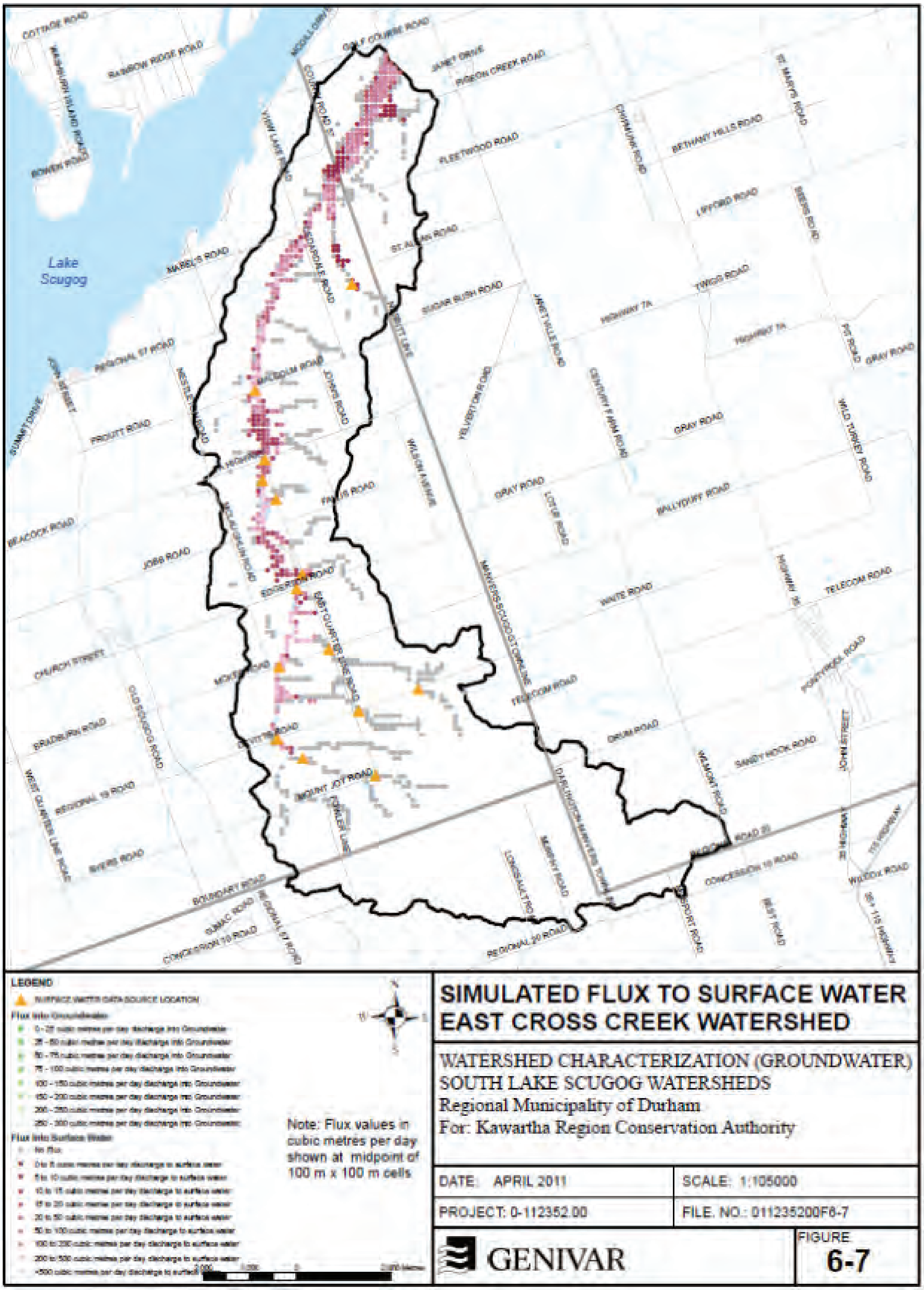


Figure 6.14: Simulated flux to surface water.

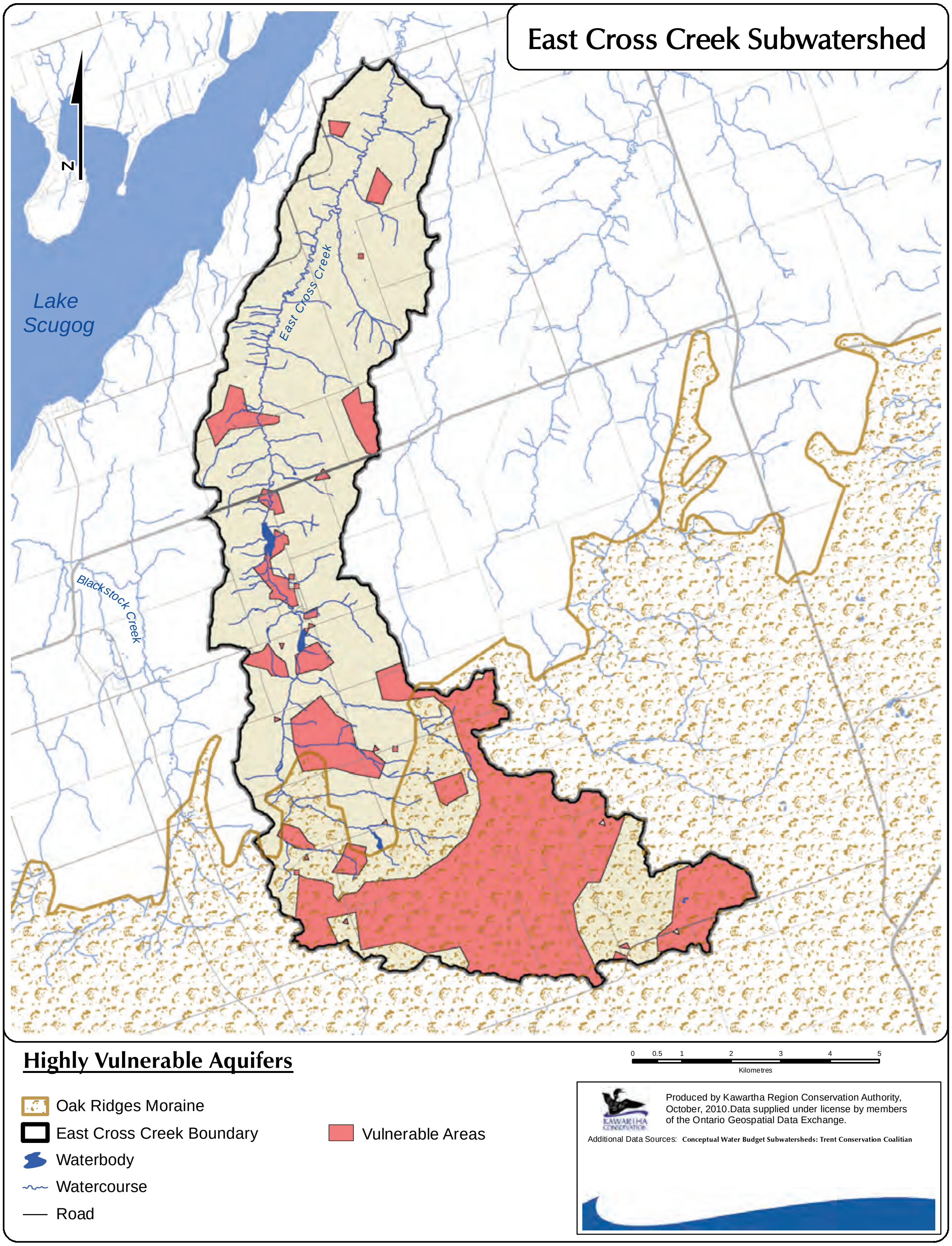


Figure 6.15: Highly vulnerable aquifers.

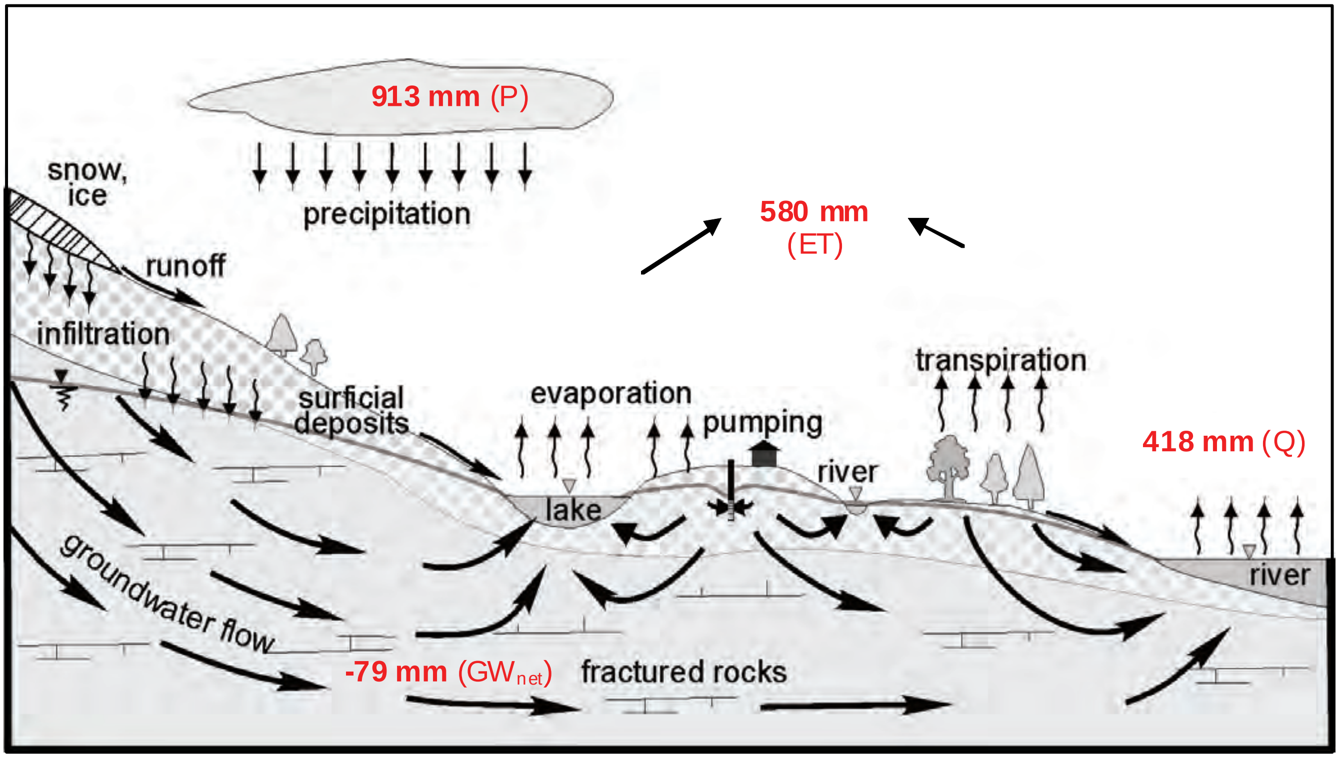


Figure 6.16: Hydrological cycle and water budget components.

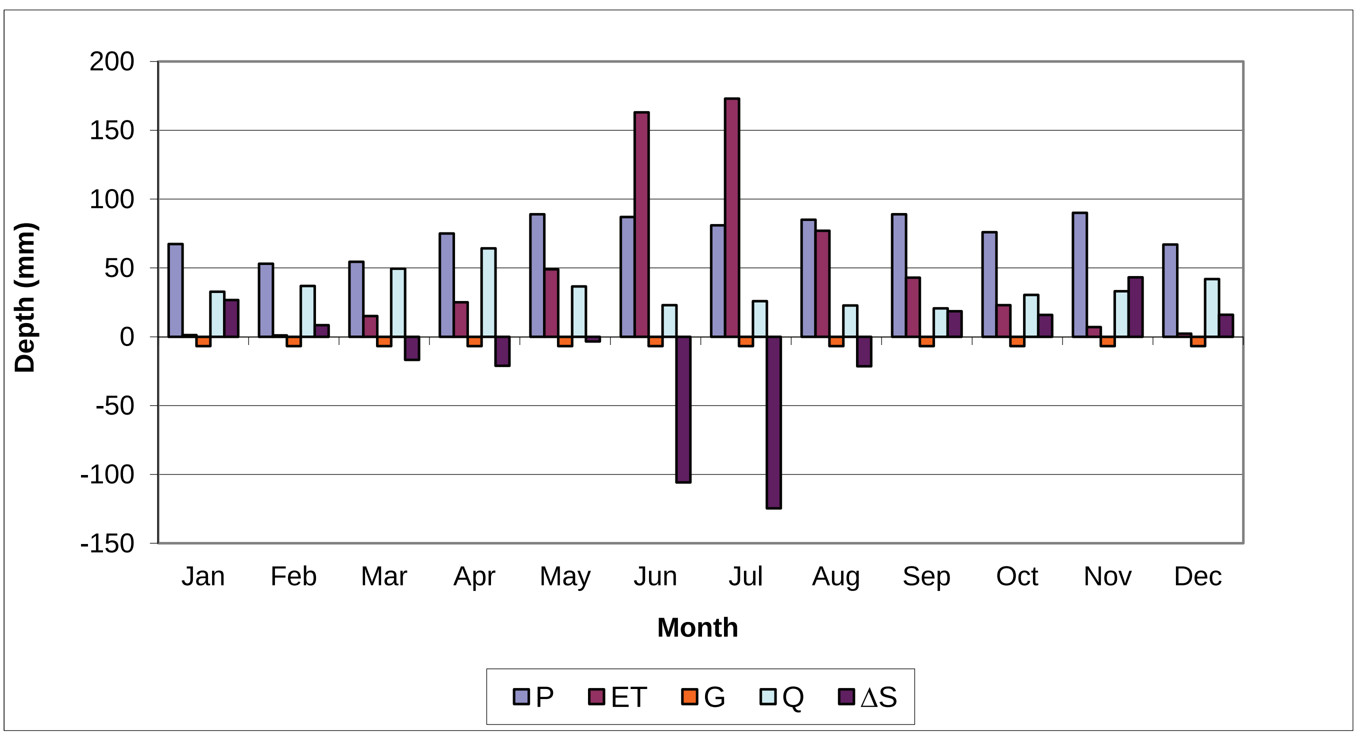


Figure 6.17: Monthly water budget components.

7.0 Water Quality

East Cross Creek, east of Cedardale Road

7.1 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
TSS	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 study area of the East Cross Creek subwatershed. As of 2010, East Cross Creek has four monitoring stations (ECC1, ECC1A, ECC2 and ECC3) specifically established in 2006 for the purposes of the East Cross Creek Subwatershed Plan development (**Figure 7.1**). There were also three monitoring sites in Durham East Cross Forest Conservation Area located upstream of station ECC1A on the same tributary that have been sampled several times in 2008 for the purposes of the Durham East Cross Forest Conservation Area Management Plan development (**Table 7.2**).

Three monitoring stations are located along main channel starting at outskirts of Oak Ridges Moraine. Another one represents major tributary of the creek, which also flows from the Oak Ridges and begins in East Cross Forest (See **Figure 7.1**). At each site water samples are collected by grab method according to the planned monitoring schedule and then sent to a certified private laboratory 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. In the framework of the East Cross Creek Subwatershed Plan samples were collected three-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 ECC1, ECC1A, ECC2 and ECC3 as only these sites have enough samples for such analysis. **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 East Cross Creek subwatershed.

Station ID	Location	Number of Samples	Most Recent Sample
ECC1	East Cross Creek at McKee Road	12	Oct-10
ECC1A	East Cross Creek Tributary at Cartwright E ¼ Line	10	Oct-10
ECC2	East Cross Creek at Malcolm Road	12	Oct-10
ECC3	East Cross Creek at Regional Road 57	25	Oct-10
ECF1	East Cross Forest Tributary	4	Sep-08
ECF2	East Cross Forest Tributary	4	Sep-08
ECF3	East Cross Creek Tributary at Devitts Road	5	Sep-08

* Station BR4 is also monitored through the LSEMP and PWQMN monitoring programs. Grey highlights indicate sites with enough samples to warrant statistical analysis.

7.2 Surface Water Quality Assessment

Surface water in upper headwaters of East Cross Creek can, overall, be characterized as clean, pure and with good water quality. Small streams in that area are virtually not affected by anthropogenic activity and still have very low concentrations of chloride and sulphate, and relatively low levels of phosphorus and nitrogen. At the same time water has high alkalinity and consequently good buffering capacity.

The major water quality concern through the entire East Cross Creek subwatershed is elevated concentrations of phosphorus in its water. As well, high levels of nitrates have been detected at station ECC1A. Other parameters of concern include metals such as aluminum and iron. In water of the tributary in East Cross Forest elevated concentrations of iron and manganese have been revealed during monitoring activities in 2008. In this case it can be suggested that they have a natural origin as a result of process of desorption because there are no known sources of contamination.

All other parameters of the interest, heavy metals in particular, have very low concentrations far below the corresponding PWQOs or CWQGs and do not present any threat to the aquatic life or human health.

Phosphorus

Since the beginning of monitoring activities in 2006, phosphorus concentrations in East Cross Creek have mostly exceeded the PWQO set for total phosphorus (TP). 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.

Monitoring results collected during 2006-2010 don't show any apparent temporal trend in total phosphorus levels in East Cross Creek. Additional regular sampling will be required in order to determine if such trend can come into view.

Current monitoring stations across the study area has shown that in recent years sites in lower portion of the subwatershed (ECC2 and ECC3) have average total phosphorus concentrations well over the PWQO of 0.030 mg/L (**Table 7.3**). Generally, average total phosphorus concentrations are increasing along the creek from headwaters towards the lower portion of the watershed and range from 0.030 to 0.049 mg/L (**Figure 7.2**). Located furthest downstream, station ECC3 has the highest level of total phosphorus with an average of 0.049 mg/L and with individual results ranging from 0.016 to 0.126 mg/L (**Table 7.4**). The maximum recorded value of 0.126 mg/L was observed in March of 2006.

The lowest phosphorus concentrations have been observed at ECC1A station with an average of 0.030 mg/L and a range of 0.006 to 0.113 mg/L. Low phosphorus concentrations found at this station can be related to a significant groundwater discharge within area immediately upstream according to baseflow monitoring data. Phosphorus levels exceeded the PWQO the most often at station ECC3 (75%) and the least at station ECC1A (33%) (See **Table 7.3**). In total, thirty-four of the fifty-five samples taken from all East Cross Creek monitoring stations had TP readings over the PWQOs limit.

Seasonal distribution of total phosphorus in East Cross Creek is characterized by the highest readings in springtime during intensive snowmelt and corresponding freshet. In summertime phosphorus concentrations are also usually quite high during both high and low flow conditions. This fact can indicate that phosphorus coming into the watercourse with both stormwater runoff and groundwater discharge. The lowest TP concentrations are usually observed throughout late autumn to early spring.

As the studied portion of the subwatershed is mainly agricultural and does not have any substantial urban areas, it can be assumed that elevated phosphorus levels in water of the creek are the result of the cumulative effect of agricultural land use in the area. Since TP concentrations are steadily increasing towards downstream it is most likely that phosphorus is entering the river system along its entire length but especially downstream from rural settlements. For example, hamlet of Cadmus located downstream of stations ECC1 and ECC1A and upstream of station ECC2. As it can be seen on **Figure 7.2**, phosphorus level is considerably higher downstream of Cadmus.

Generally, water in upper East Cross Creek can be characterized as one that belongs to meso-eutrophic class (0.020–0.035 mg/L) of natural waters according to the CCME classification with a distinctive increase in phosphorus concentrations in water of the downstream stations. As a result, water in the lower East Cross Creek with TP concentrations above 35 ug/L belongs to eutrophic class (0.035-0.100 mg/L).

Table 7.3: Average and Percent of Exceedences of TP, NO3, Al and Fe Concentrations in East Cross Creek and Tributaries 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
ECC1	0.033	45	11	1.14	0	11	0.050	17	12	0.170	8	12
ECC1A	0.030	33	9	4.59	78	9	0.123	17	6	0.167	17	6
ECC2	0.043	73	11	0.90	0	11	0.046	0	9	0.200	22	9
ECC3	0.049	75	24	1.06	0	24	0.025	0	12	0.141	0	12

Table 7.4: Total Phosphorus Concentrations at East Cross Creek Water Quality Monitoring Stations during 2006 - 2010.

	ECC1	ECC1A	ECC2	ECC3
75-%	0.041	0.032	0.053	0.057
Max	0.070	0.113	0.067	0.126
Min	0.015	0.006	0.022	0.016
25-%	0.024	0.011	0.032	0.034
Mean	0.033	0.030	0.043	0.049
Median	0.027	0.017	0.043	0.044

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. 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 1.0 mg/L but occasionally can considerably exceed this value.

Very often in streams nitrates compose most of the total nitrogen amount, 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 East Cross Creek study area nitrates from time to time exceed the limit set by the Canadian Water Quality Guidelines for the Protection of Aquatic Life (CWQGs) at 2.93 mg/L. At the same time average nitrate levels in East Cross Creek are well below the guideline except at station ECC1A (**Figure 7.3**). Nitrate concentrations are the highest in water of this station ranging from 2.1 mg/L to 5.8 mg/L and averaging at 4.59 mg/L (**Table 7.5**). It is observed that 78% of samples from this station had nitrate concentrations above the CWQGs limit (See **Table 7.3**). Interestingly, station ECF3 that is located about 2 km upstream of ECC1A has, according to 2008 data, very low nitrate levels. Average NO3- value in that location was 0.122 mg/L with maximum result reaching only 0.204 mg/L. When baseflow results from these two locations have been compared, it became obvious that somewhere between stations ECF3 and ECC1A considerable discharge of groundwater into the creek occurs.

Similar to other streams in the area East Cross Creek usually has the highest nitrate readings in vicinity of the substantial groundwater discharges. Examination of gathered hydrological and hydrochemical information suggests that shallow groundwaters in the area have elevated nitrate levels due to intensive agricultural activities and are the major source of inorganic nitrogen for the aquatic system of East Cross Creek. As all water samples have been collected in summer time it is possible to assume that similar to other watercourses in the region East Cross Creek has much higher nitrate concentrations in wintertime.

After station ECC1A nitrate concentrations in water of the creek generally decrease downstream due to intensive uptake of NO3- by aquatic biota. As a result, anthropogenically generated nitrates along with phosphorus play important role in the process of eutrophication of the creek.

Seasonal distribution of nitrates in the East Cross Creek is characterized by higher concentrations in wintertime, late autumn and early spring. In general, the highest levels of nitrates in the creek (station ECC3) were detected in the middle of winter – during January and February, when groundwater contributes the most to the flow in rivers and creeks and natural processes of nitrate assimilation are very slow.

Taking into consideration available monitoring data it is possible to conclude that the main source of inorganic nitrogen in the East Cross Creek subwatershed is groundwater discharge. In turn, high levels of nitrates in groundwater are most likely caused by agricultural activities in the watershed.

Table 7.5: Nitrate Concentrations at East Cross Creek Water Quality Monitoring Stations during 2006 - 2010.

	ECC1	ECC1A	ECC2	ECC3
75-%	1.445	5.600	1.125	1.391
Max	1.760	5.800	1.200	2.453
Min	0.440	2.100	0.283	0.244
25-%	0.878	4.497	0.733	0.753
Mean	1.136	4.589	0.901	1.061
Median	1.040	5.000	1.000	0.924

Aluminum

Aluminum can be toxic to various aquatic organisms, fish in particular, in concentrations above 0.100 mg/L (CCME 2002). 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 have been observed on several occasions at two monitoring stations (ECC1 and ECC1A). At station ECC1A the highest concentration of aluminum (0.582 mg/L) within the study area was recorded in September of 2009 but it was only exceedence at this location. Nevertheless, so high number significantly skewed average aluminum concentration at this station (**Figure 6.4**), while median value was only 0.032 mg/L (**Table 7.6**). At the same time, station ECC1 has the highest number of exceedences above the CWQG: 17% of all samples (See **Table 7.3**). No exceedences were detected in water of stations ECC2 and ECC3 that can be explained by the fact that further downstream total suspended solids and aluminum attached to them already settled down through the processes of sedimentation and sorption thus show decrease in its concentrations in water (See **Figure 7.4**).

Generally speaking, aluminum concentrations in water of East Cross Creek are usually higher in headwater sections of the stream that can be explained by more intensive erosion in that portion of the watershed. In addition, elevated levels of aluminum were detected under high flow conditions and can be easily correlated with high TSS concentrations in the water. As well, high aluminum concentrations usually coincide with increased iron and manganese concentrations after rain events and during snowmelt. Local soils, which are probably rich in aluminum, seems are the major source of this element, as no anthropogenic sources of aluminum contamination are known in the watershed.

Table 7.6: Aluminum Concentrations at East Cross Creek Water Quality Monitoring Stations during 2006 - 2010.

	ECC1	ECC1A	ECC2	ECC3
75-%	0.048	0.049	0.070	0.021
Max	0.181	0.582	0.088	0.099
Min	0.011	0.014	0.021	0.005
25-%	0.022	0.026	0.026	0.015
Mean	0.050	0.123	0.046	0.025
Median	0.034	0.032	0.032	0.019

<u>Iron</u>

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 2002).

Throughout the period of observation all East Cross Creek monitoring stations had average iron concentrations well below the PWQOs and CWQGs limit of 0.30 mg/L (**Figure 7.5**). Only four exceedences above the PWQO were detected at four monitoring stations that are only 10% of all samples. The highest iron concentration (0.76 mg/L) was detected at station ECC1A in September of 2009 under high flow conditions. On the same date iron levels in water samples from stations ECC1 and ECC2 also exceeded the limit. At station ECC2 22% of all samples exceeded the PWQO (See **Table 7.3**). No exceedences have been detected at station ECC3 where iron levels ranged from 0.07 to 0.23 mg/L (**Table 7.7**).

It is necessary to mention that in 2008 very high levels of iron have been detected at the East Cross Forest stations ECF1 and ECF2, ranging from 0.25 to 2.49 mg/L. Highly elevated concentrations of iron as well as manganese in water of those stations are associated with swampy nature of water in that area. Acute deficit of dissolved oxygen in combination with low pH values has been frequently observed during sampling events. Low DO and pH values create reducing environment in bottom sediments and at the water – sediment interface that causes 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, manganese and phosphorous in water without known external sources of contamination are usually the indicators of the above-mentioned processes.

At the same time iron and manganese concentrations in water from stations ECF3 and ECC1A have been much lower during summer of 2008 as in that locations fast water flow combined with high dissolved oxygen and pH levels in water has been observed. Looking at the entire East Cross Creek aquatic system it can be seen that levels of iron are decreasing towards the mouth of the creek (See **Figure 7.5**). It can be explained by considerable inflow of water with elevated levels of iron from plenty of small tributaries in the upper part of the watershed. Those tributaries often begin their way to the main channel from swamps and marshy areas, which, as it was described above, have favorable conditions for the enrichment of water with iron and manganese that are widespread in natural environment metals. Further downstream, iron and manganese are settled down through the processes of sedimentation and sorption thus show decrease in their concentrations in the stream water.

Table 7.7: Iron Concentrations at East Cross Creek Water Quality Monitoring Stations during 2006 - 2010.

	ECC1	ECC1A	ECC2	ECC3
75-%	0.195	0.068	0.210	0.163
Max	0.450	0.760	0.440	0.230
Min	0.070	0.020	0.090	0.070
25-%	0.100	0.043	0.130	0.108
Mean	0.170	0.167	0.200	0.141
Median	0.129	0.055	0.160	0.144

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. Because 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 East Cross Creek subwatershed are usually 1-2 mg/L. Occasionally, after rain events, TSS concentrations increase substantially in water of some monitoring stations (**Table 7.8**). From time to time elevated TSS levels have been observed in water of station ECC1A at Cartwright East Quarter Line. Maximum TSS concentration detected at this location was 43 mg/L that is above the guideline. Another location where somewhat elevated TSS concentrations were detected several times was station ECC2. Average TSS concentrations in water of all monitoring stations are well below the CCME guideline (**Figure 7.6**).

Table 7.8: TSS Concentrations at East Cross Creek Water Quality Monitoring Stations for the Period of 2006 - 2010.

	ECC1	ECC1A	ECC2	ECC3
75-%	6.3	16.3	10.3	3.5
Max	17.0	43.0	21.0	6.0
Min	1.0	1.0	2.0	1.0
25-%	2.0	2.8	3.8	1.5
Mean	5.3	10.4	7.7	2.7
Median	3.5	6.0	5.0	3.0

Chloride

During the monitoring period chloride concentrations in water of all water quality monitoring stations in the East Cross Creek watershed were far below the recently developed CWQG for Chloride for the Protection of Aquatic Life, which is set at 128 mg/L (CCME 2010).

Looking at **Figure 7.7** one can see that chloride concentrations increase downstream the creek. Headwater station ECC1 has the lowest chloride levels with an average of 7.6 mg/L and a range of 6.4 to 8.6 mg/L, while station ECC3 has the highest levels among three main channel stations with an average of 16.7 mg/L and a range of 7.9 to 25.0 mg/L (**Table 7.9**).

Analyzed data indicate that if in future chloride concentrations in water of the lower East Cross Creek continue to rise they can negatively affect water quality in the creek.

Table 7.9: Chloride Concentrations at East Cross Creek Water Quality Monitoring Stations during 2006 - 2010.

	ECC1	ECC1A	ECC2	ECC3
75-%	8.2	14.0	15.0	19.3
Max	8.6	14.0	21.0	25.0
Min	6.4	9.2	13.0	7.9
25-%	7.0	12.3	14.0	15.0
Mean	7.6	12.7	15.6	16.7
Median	7.9	13.5	15.0	16.0

7.3 Point and Non-point Sources of Contamination

Within the East Cross Creek subwatershed there are no point sources of contamination such as wastewater treatment plant effluents or industrial plant effluents.

Non-point sources include runoff from agricultural fields that occupy more than 46% of the study area, urban runoff from several hamlets scattered across the subwatershed (3.06% of the study area) and runoff from road network in the subwatershed. Non-point sources are the most significant contributors of phosphorus and nitrogen into aquatic system of the creek.

7.4 Groundwater Quality Assessment

Groundwater is an important component of natural water resources and an essential source of drinking water supply for the rural population in both Ontario and nationwide. Groundwater aquifers of the Oak Ridges Moraine are a source of drinking water for 250,000 people in Southern Ontario. In the East Cross Creek subwatershed all drinking water for the municipal water supply system, farms and private rural dwellings is coming 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 soil, sedimentary material and bedrock that water moves through. When water from rain or snow moves over the land and infiltrates into the ground, it may dissolve various 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 can potentially affect water use.

Groundwater quality assessment within the study area is based on data obtained from two recently constructed in East Cross Forest groundwater monitoring wells (W484 and W485), which currently are part of the Provincial Groundwater Monitoring Network (PGMN) (See **Figure 7.1**). Wells extend 45.00 m and 16.52 m into the overburden intermediate aquifer of the lower sediments. According to the 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.

These wells have been sampled for a full suite of parameters in October of 2008. Groundwater samples have been analyzed for organochlorinated pesticides (OC), organophosphorus pesticides (OP), polycyclic aromatic hydrocarbons (PAHs), E.coli and total coliform, nutrients (TP, TKN, NH3 + NH4+, NO2-, NO3-), anions (SO42-, Cl-, F-), alkalinity, carbonates and bicarbonates, and dissolved metals. Dissolved oxygen, pH, conductivity and temperature have been also measured with YSI meter during sampling.

Analysis of water quality data was based on a number of parameters, including general chemistry, metals, nutrients, microbiology, pesticides and other organic artificial compounds. However, number of samples is dissimilar for different parameters. In municipal wells raw water is tested most often for E. coli and total coliform, in compliance with the *Safe Drinking Water Act*, 2002. For other chemical compounds raw water samples analyzed only annually or semi-annually. **Table 7.10** shows the number of samples collected from both wells and analyzed for each group of parameters. 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).

Similar to surface waters within the Durham East Cross Forest Conservation Area, groundwaters are clean, pure and have an excellent water quality. All analyzed parameters but one are below the PWQOs and ODWQS. In water of both wells low concentrations of total coliform have been detected. In northern well (W485) it was 2 cfu/100 mL and in southern well (W484) near parking lot it was 5 cfu/100 mL. No E.coli has been detected in water from any well. In northern well slightly elevated concentrations of nitrate (2.7 and 3.8 mg/L) have been revealed. All trace metals are present in very low levels. Water in both wells has also very low concentrations of iron, sodium and chloride. Groundwater belongs to calcium-bicarbonate type of water with relatively high hardness due to high calcium and magnesium concentrations. Based on available data it is possible to conclude that groundwater in both wells is in pristine condition. Unfortunately, there are quite limited groundwater quality data to allow for the comprehensive analysis on the entire watershed scale.

Although the groundwater monitoring results show good water quality, it is important to recognize that sampled wells represent limited number of aquifers in only two locations of the study area. In many locations, several aquifers may provide adequate volumes of water. The greatest immediate concern for groundwater quality that can be used for drinking water supply is bacteriological contamination. To address this concern municipal and private drinking water supply wells should be frequently tested to ensure public health.

Table 7.10: Number of Groundwater Samples Since 2003.

Well ID	Metals	Nutrients	Pesticides	E.coli & Total Coliform
Well # 484	1	1	1	1
Well # 485	2	2	1	2

7.5 Key Observations and Issues

- Results indicate that a considerable portion of East Cross Creek has elevated total phosphorus levels caused by human activities in the watershed. Elevated concentrations of nitrates in water of the creek are also the significant concern. While high phosphorus levels represent the major problem in the lower portion of the watershed, nitrate concentrations are notable concern in the upper portion of the watershed, especially in areas of groundwater discharges.

- In general, 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.

- 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.

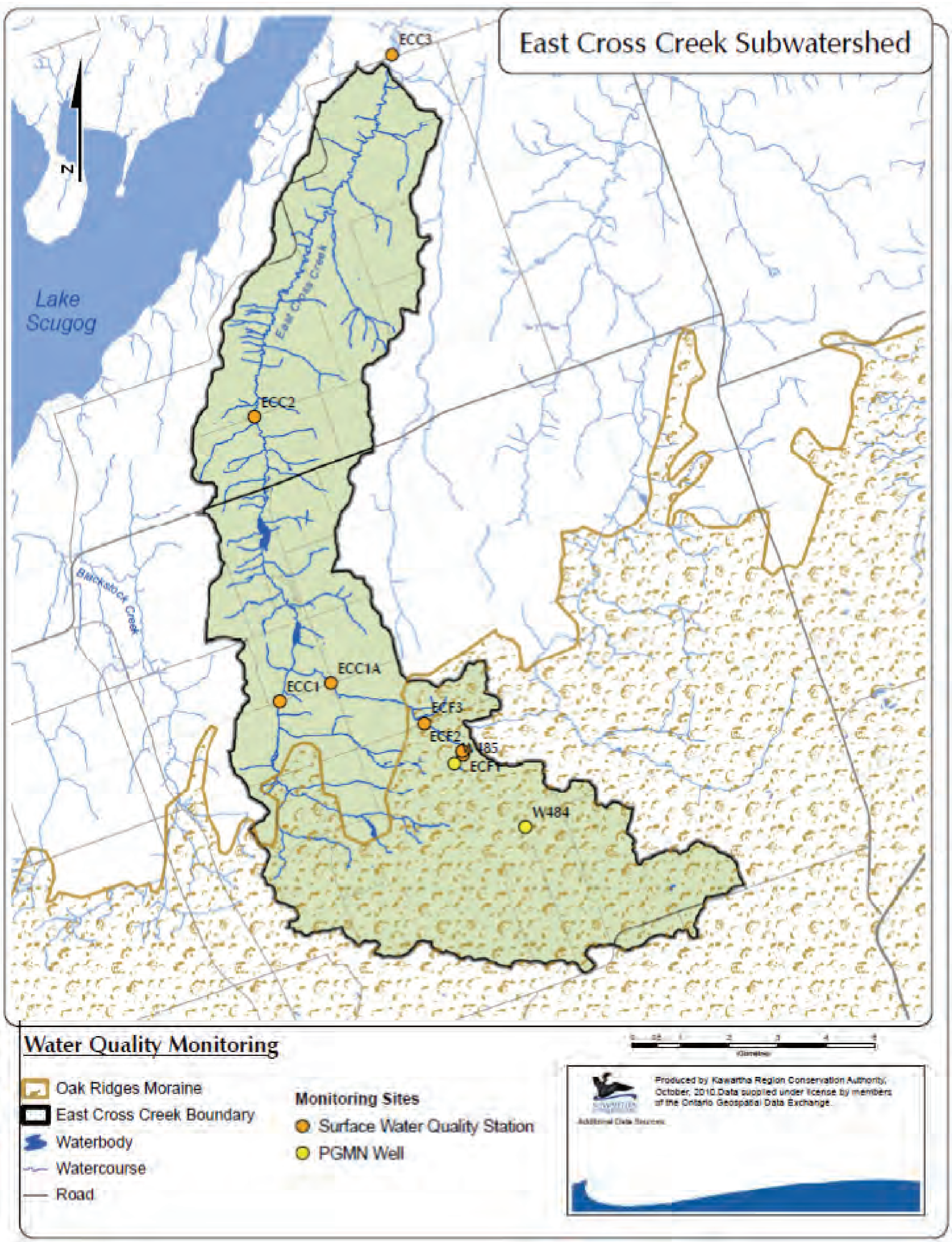


Figure 7.1: Water quality monitoring sites.

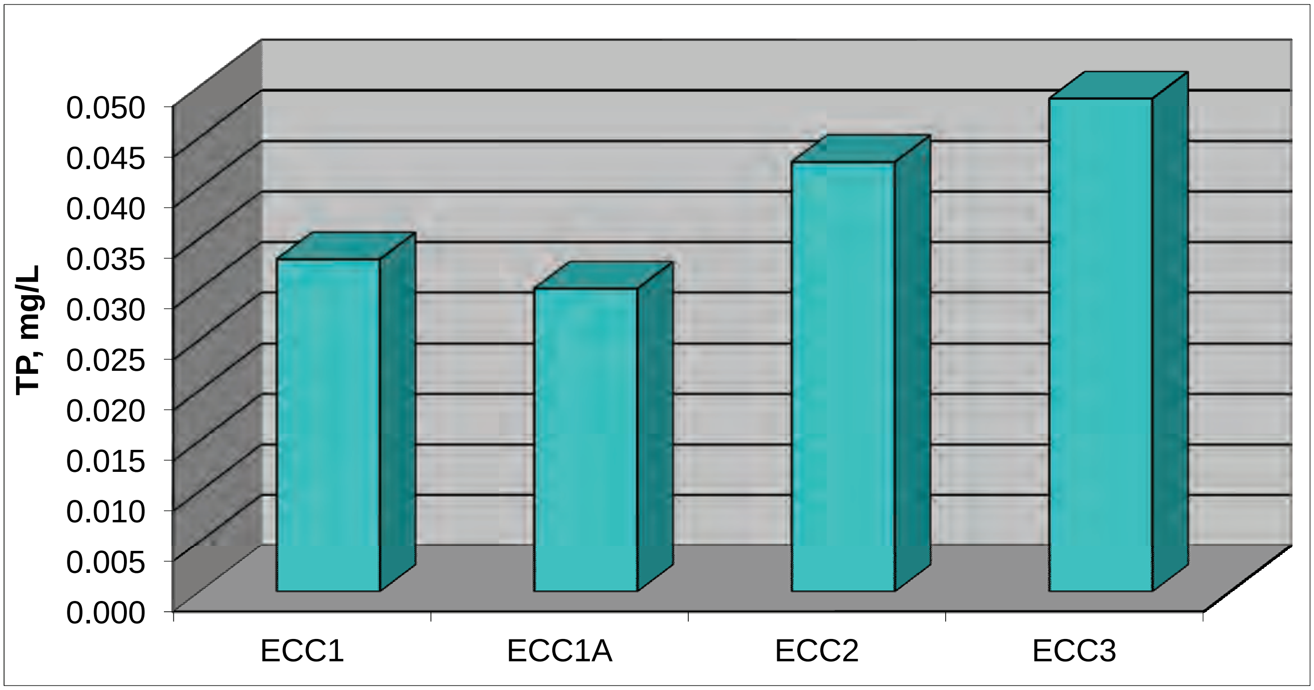


Figure 7.2: Average Phosphorus Concentrations at the East Cross Creek Monitoring Stations in 2006 – 2010 period.

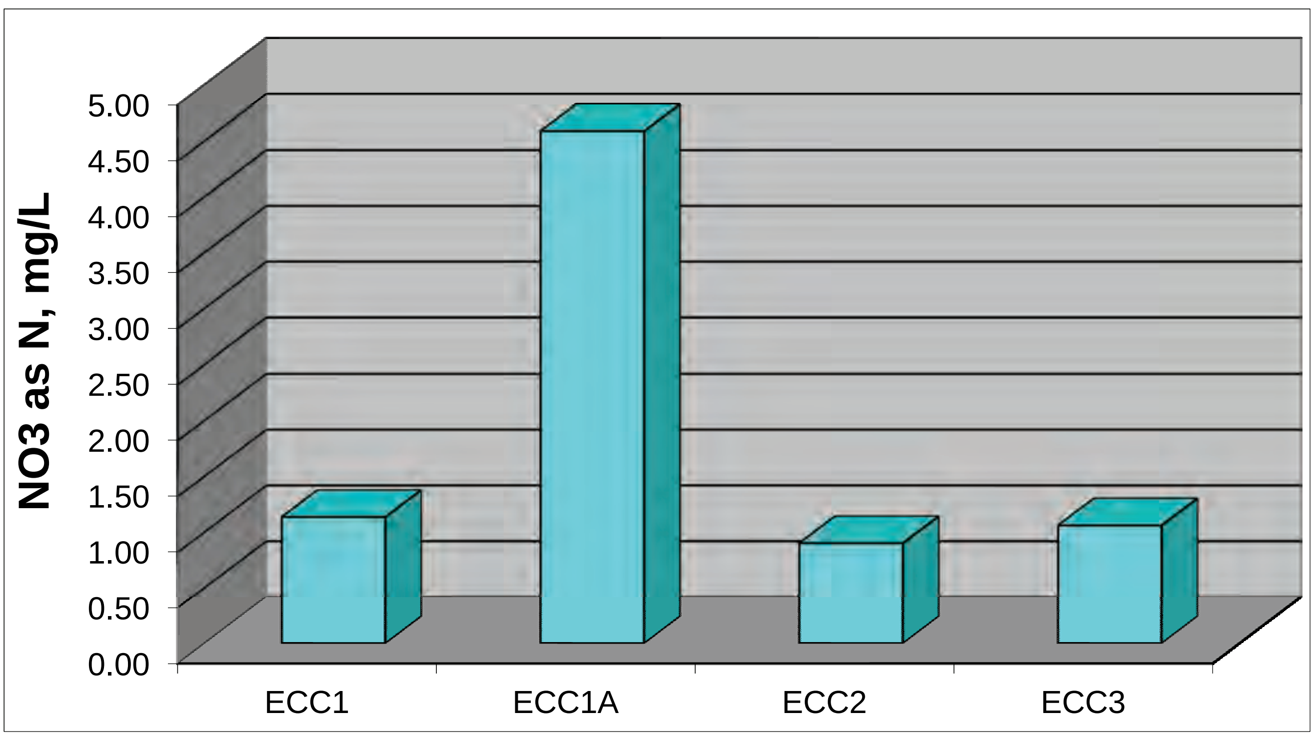


Figure 7.3: Average Nitrate Concentrations at the East Cross Creek Monitoring Stations in 2006 - 2010.

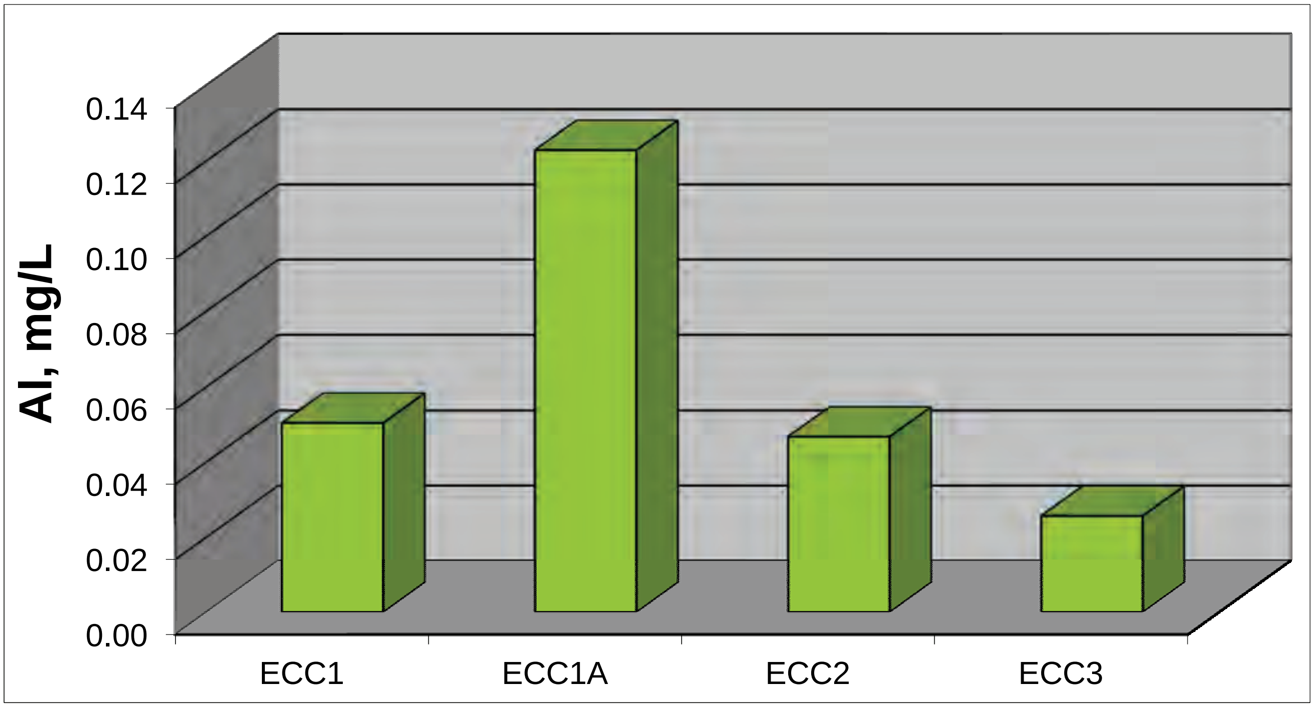


Figure 7.4: Average Aluminum Concentrations at the East Cross Creek Monitoring Stations in 2006 - 2010.

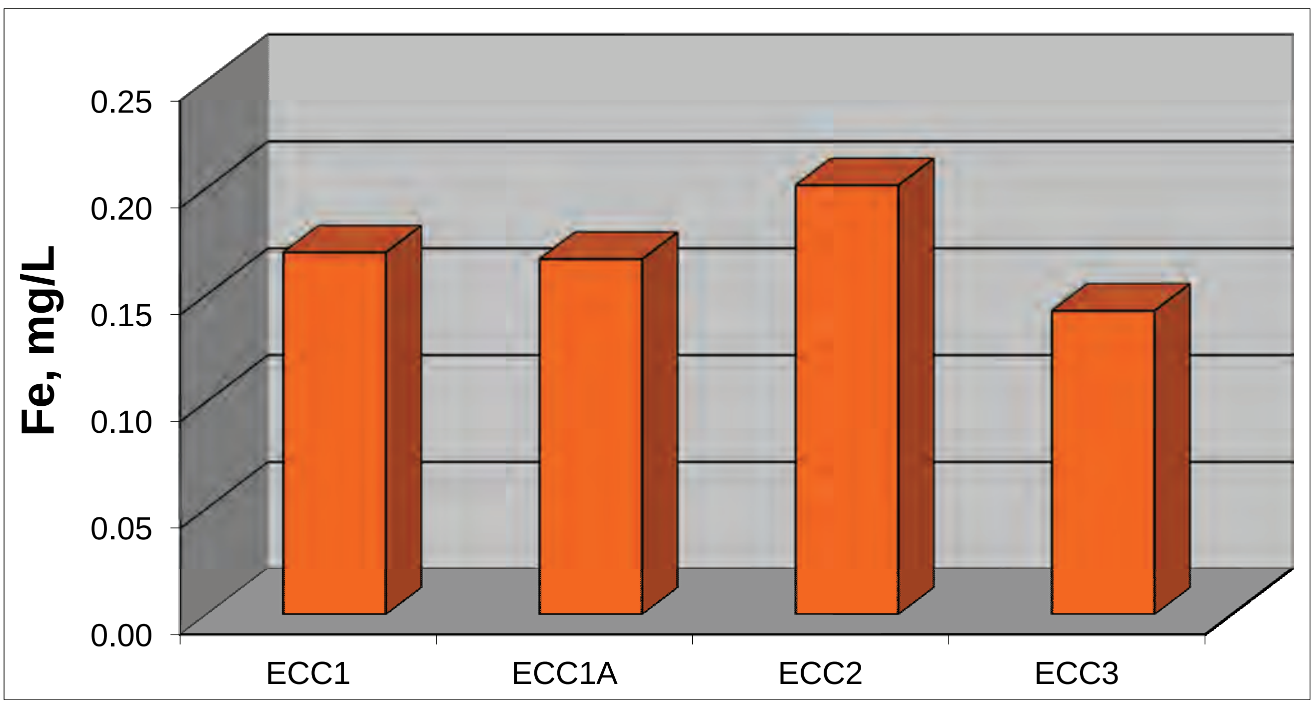


Figure 7.5: Average Iron Concentrations at East Cross Creek Monitoring Stations in 2006 - 2010.

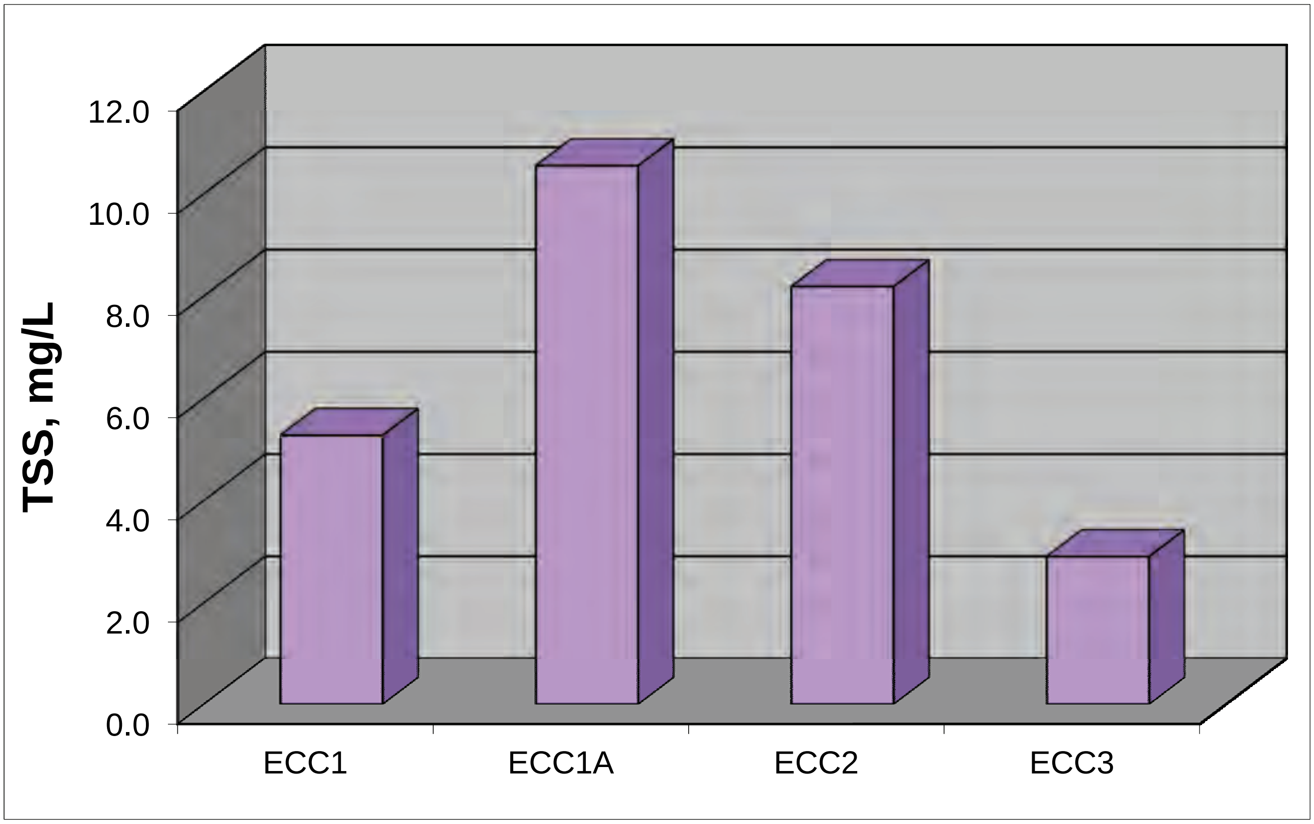


Figure 7.6: Average TSS Concentrations at East Cross Creek Monitoring Stations in 2006 - 2010.

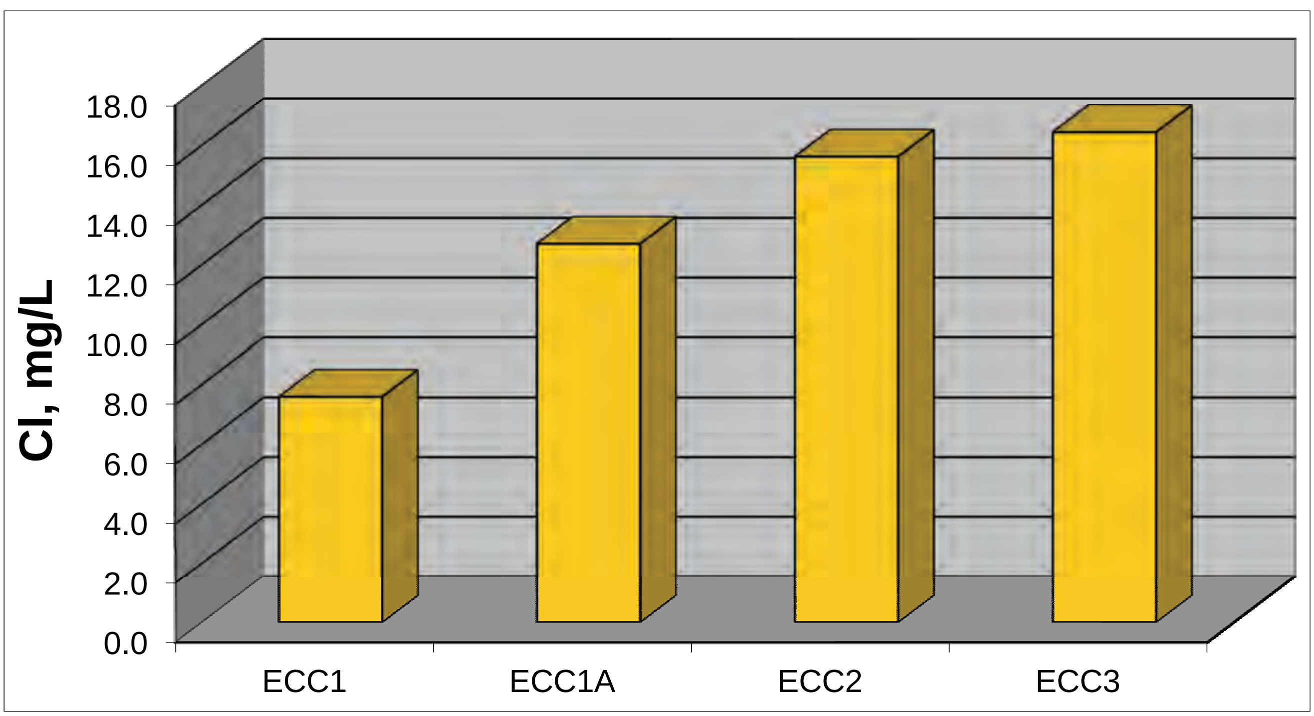


Figure 7.7: Average Chloride Concentrations at the East Cross Creek Monitoring Stations in 2006 - 2010.

8.0 Aquatic Resources

East Cross Creek, northwest of Cartwright East Quarter Line and McKee Road

8.1 Introduction

Aquatic resources include the aquatic species that occupy the watercourses flowing through the East Cross Creek subwatershed 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.

<u>Stream Order</u>

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. 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 characteristics of these lower-order streams make them much more dependent upon riparian vegetation for protection of natural ecological functions.

The East Cross Creek subwatershed supports a fourth-order watercourse before flowing into the southern sections of the greater East Cross Creek watershed (**Figure 8.1**, **Table 8.1**). First-order streams account for the majority of individual stream sections and comprise the majority (56%) of the entire watercourse length. Headwater streams account for over 95% of the entire length.

Table 8.1: Watercourse length by stream order.

	1st order	**2nd order**	**3rd order**	**4th order**
Stream Length (km)	57.4	21.3	18.9	4.5
Stream Length (%)	56.2	20.9	18.5	4.4

Substrate

Substrate refers to materials (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) stream 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 and caddisflies, for example, prefer stream reaches with coarse substrates, whereas aquatic worms and 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 East Cross Creek subwatershed, methods outlined in the Rapid Assessment Module of the Ontario Stream Assessment Protocol (Stanfield 2007) were applied at sample sites between 2006 and 2008. 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 15 sites sampled, 6 of these have substrates that fall within the gravel category and 9 have substrates that fall within the fines category (**Figure 8.2**). There were no sites with dominant cobble substrate. Sites exhibiting gravel substrates were only found in the southern portions of the watershed.

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 30 sites that were visited, 5 perched culverts were identified (**Figure 8.3**).

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 82 potential ponds located within the watershed (**Figure 8.3**). The most prominent ponds include Brown's Pond, located just north of Edgerton Road, and Fallis Pond, located just south of Highway 7A. The outlets of both of these ponds are verified instream barriers.

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 East Cross Creek subwatershed, 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 East Cross Creek subwatershed, the thermal regime at 15 sites was determined. Of these sites, 6 (40.0%) were classified as warmwater, 6 (40.0%) as coolwater, and 3 (20.0%) as coldwater (**Figure 8.5**). There are no coolwater or coldwater sites north of Highway 7A. There are three warmwater sites south of Brown's Pond. North of the pond, temperatures warm and are likely incapable of supporting coldwater fishes in the lower reaches. 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.

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 East Cross Creek subwatershed, 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 about 30 metres and narrower, the East Cross Creek subwatershed 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.

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)	20.1	22.0	25.1	31.9	41.4
Aggregate	0	<0.1	0.1	0.1	0.2
Natural	76.6	74.4	70.7	63.2	53.5
Development (rural and urban)	3.2	3.7	4.1	4.7	4.8
Manicured Open Space	0	<0.1	<0.1	0.1	<0.1

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	65.6	60.8	56.4	47.7	36.9
2nd order	88.3	83.6	78.5	67.0	51.4
3rd order	99.0	98.4	97.7	95.3	87.5
4th order	100.0	100.0	100.0	99.9	97.2

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 East Cross Creek subwatershed is limited; however, there are two known reports of significance. In 1983, IEC Beak Consultants Ltd. conducted a benthos survey at 4 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 East Cross Creek subwatershed ranked 4th when compared to sites within the Pigeon River, Fleetwood Creek, East Cross Creek, Nonquon River, and Layton River.

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 East Cross Creek subwatershed. 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 East Cross Creek Subwatershed, Kawartha Conservation collected benthos at 15 sites, between 2006 and 2008, following methodology outlined in the Ontario Benthos Biomonitoring Network protocol (Jones et al. 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 East Cross Creek subwatershed 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 (40%) are classified as having "fairly poor" water quality, no sites were found to have "excellent" or "very good" 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 2.3% to 53.1%. Within-and-around the Oak Ridges Moraine planning area, none of the sites matched the "reference composition" of 55% EPT. Sites within the south-eastern portion of the watershed tend to be more dominated by EPT than other sites.

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 (20)
5.01-5.75	Fair	Fairly substantial organic pollution likely	4 (27)
5.76-6.50	Fairly Poor	Substantial organic pollution likely	6 (40)
6.51-7.25	Poor	Very substantial organic pollution likely	2 (13)
7.26 - 10.00	Very Poor	Severe organic pollution likely	0 (0)

8.7 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 East Cross Creek subwatershed; however, there have been some inventory work. In 1975, the OMNR sampled six sites (**Figure 8.11**) and documented the presence of sixteen species, of which are considered to be native and common to streams in the area. Stocking records obtained from the OMNR indicate that Brown Trout and Brook Trout were released in the creek in the 1940's and Muskellunge in the 1980's.

To examine the existing fisheries communities within the East Cross Creek subwatershed, Kawartha Conservation sampled 29 sites between 2006 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 that would sampling 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 (15 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 (14 sites) hoop-nets were used to determine fish species composition. These sites were located within Brown's Pond, Fallis Pond, and immediately downstream of Fallis Pond because the Ontario Stream Assessment Protocol methodology was not suitable (i.e., non-wadeable substrate) within these sections of the watercourse.

A total of 24 fish species, represented 8 families, were captured during these recent sampling efforts. This included all of the historically-documented species except for Smallmouth Bass (**Table 8.4**). Species richness per site ranged from 1 to 11 (average of 4.4) for wadeable sites and from 1 to 13 (average of 6.6) for nonwadeable sites. Most of these fishes are common throughout watercourses within south-central Ontario;

there are no species of conservation concern. Common Carp is the only non-native (not naturally occurring) species within the watershed. These species are not native to the Great Lakes Basin, but have are considered naturalized, as they have existing within Ontario for over 100 years. This species was only found within Fallis Pond.

The East Cross Creek subwatershed contains both warmwater and coldwater fish communities. **Figure 8.12** shows the sites where coldwater fishes (Brook Trout and/or Mottled Sculpin) and where warmwater fishes (all other species) were captured, both during historical and recent sampling efforts. The distribution of warmwater fishes is widespread throughout the watershed, whereas coldwater fishes were only found at 7 sites, and restricted to the southern portion of the watershed. Brook Trout were found only upstream of Brown's Pond, however, historical sampling documented Brook Trout immediately downstream of the pond. Currently, Mottled Sculpin is the only coldwater fish occupying that site. 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 watershed 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 East Cross Creek subwatershed is extremely significant, as they have been introduced to many Oak Ridges Moraine tributaries.

Table 8.4: List of fish species.

Common Name	Scientific Name	Current Catch (2006-2008)	Historical Catch (1975)
Brook trout	*Salvelinus fontinalis*	x	x
Central mudminnow	*Umbra limi*	x	x
White sucker	*Catostomus commersonii*	x	x
Northern redbelly dace	*Phoxinus eos*	x	x
Brassy minnow	*Hybognathus hankinsoni*	x	x
Common shiner	*Luxilus cornutus*	x	x
Striped shiner	*Luxilus chrysocephalus*	x	
Golden shiner	*Notemigonus crysoleucas*	x	x
Common carp	*Cyprinus carpio*	x	
Spottail shiner	*Notropis hudsonius*	x	
Bluntnose minnow	*Pimephales notatus*	x	
Fathead minnow	*Pimephales promelas*	x	x
Blacknose dace	*Rhinichthys atratulus*	x	x
Longnose dace	*Rhinichthys cataractae*	x	x
Creek chub	*Semotilus atromaculatus*	x	x
Pearl dace	*Margariscus margarita*	x	
Brown bullhead	*Ameiurus nebulosus*	x	
Brook stickleback	*Culaea inconstans*	x	
Rock bass	*Ambloplites rupestris*	x	x
Pumpkinseed	*Lepomis gibbosus*	x	x
Smallmouth bass	*Micropterus dolomieu*		x
Largemouth bass	*Micropterus salmoides*	x	x

Yellow perch	*Perca flavescens*	x	x
Logperch	*Percina caprodes*	x	
Mottled sculpin	*Cottus bairdii*	x	
Total # of documented species		**24**	**16**

8.6 Key Observations and Issues

- The watershed supports diverse fish communities that are dominated by native species. Twenty-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. Common Carp are not native to the watershed, but are now widespread throughout the Kawartha Lakes and as such, are considered naturalized.
- 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 74%. However, these areas are just shy of meeting 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). 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.

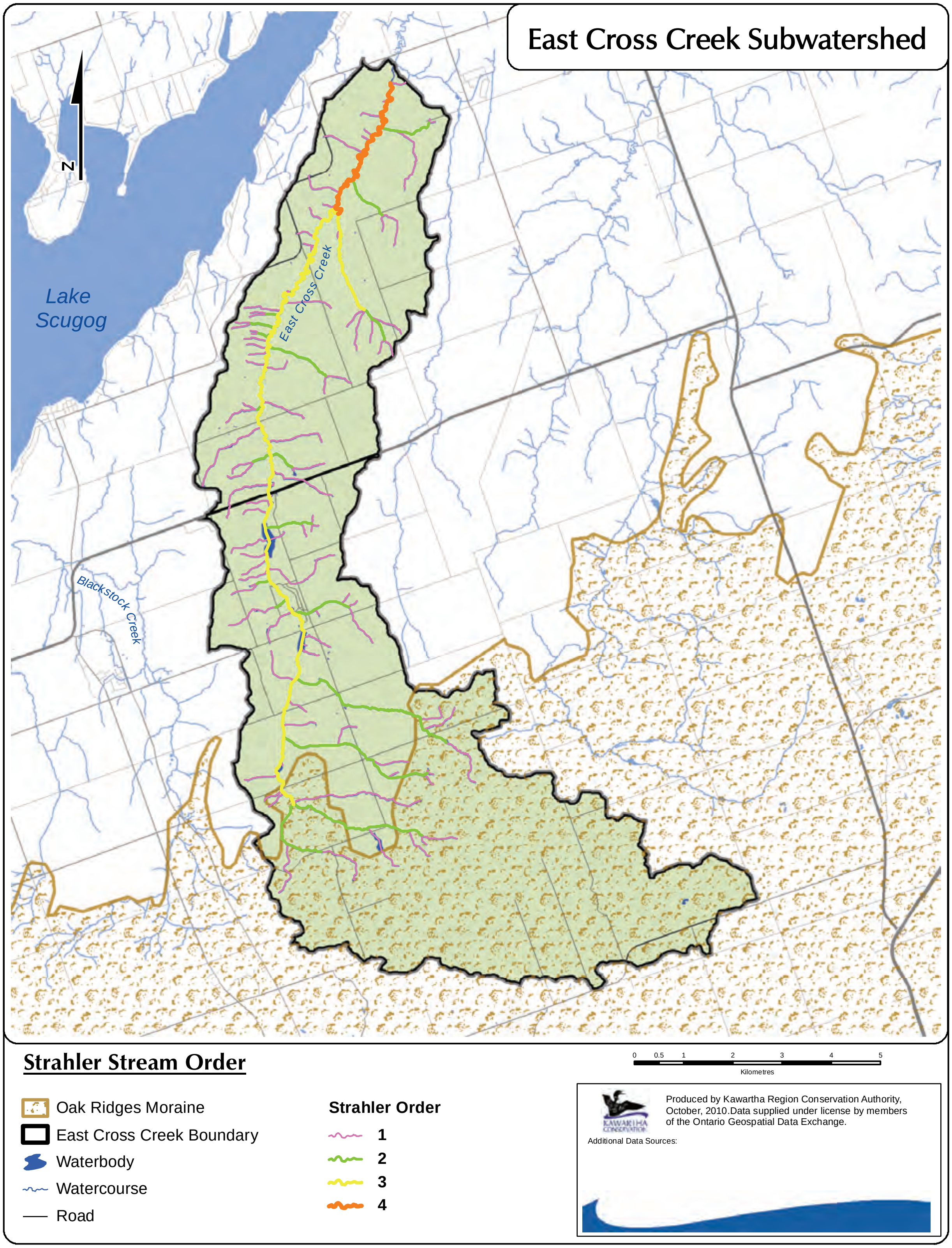


Figure 8.1: Stream order.

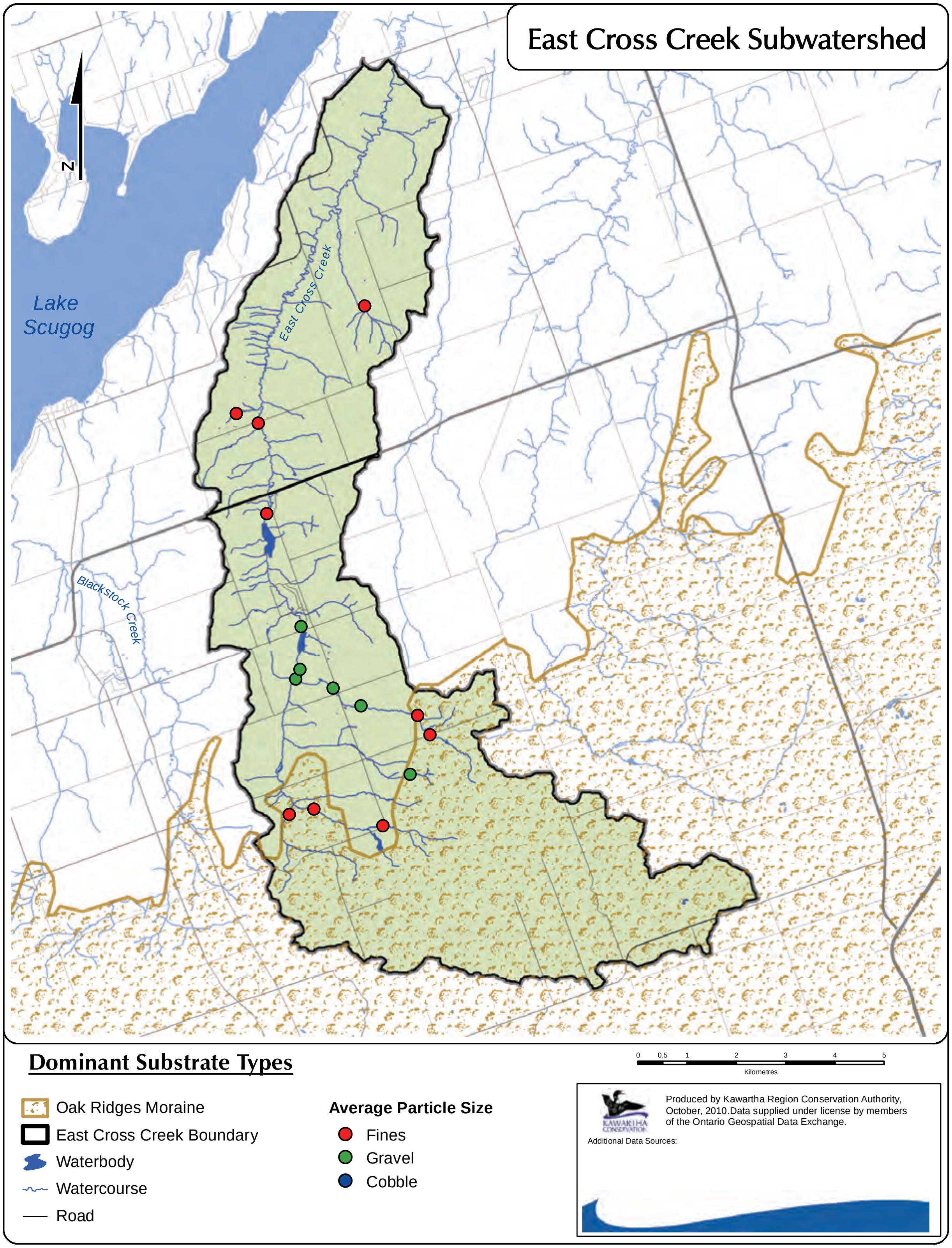


Figure 8.2: Dominant substrate types.

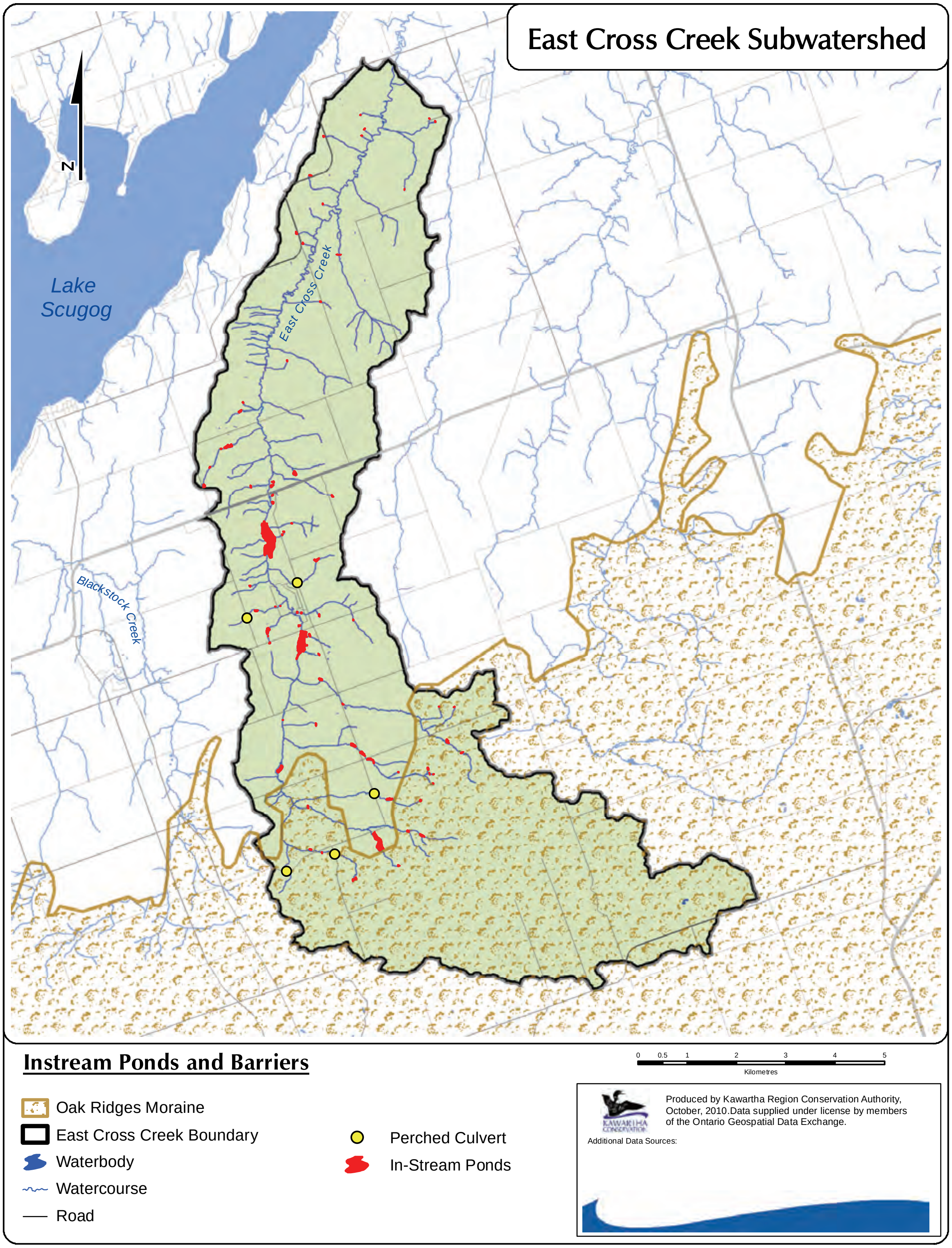
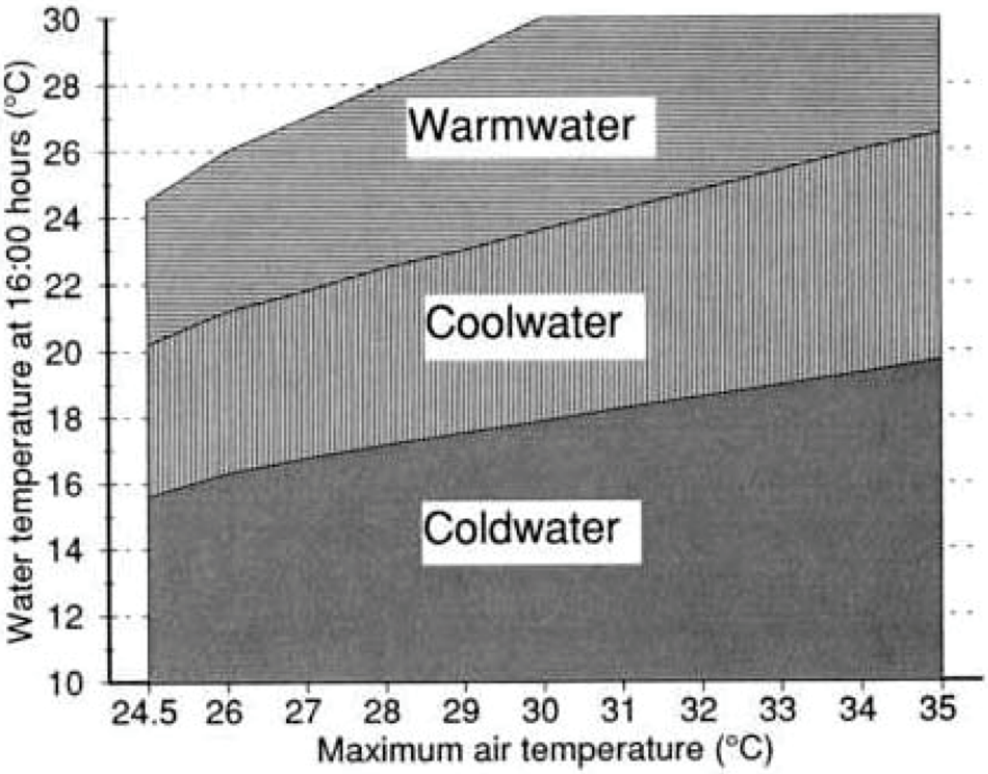


Figure 8.3: Instream barriers and ponds.



From Stoneman and Jones (1996)

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

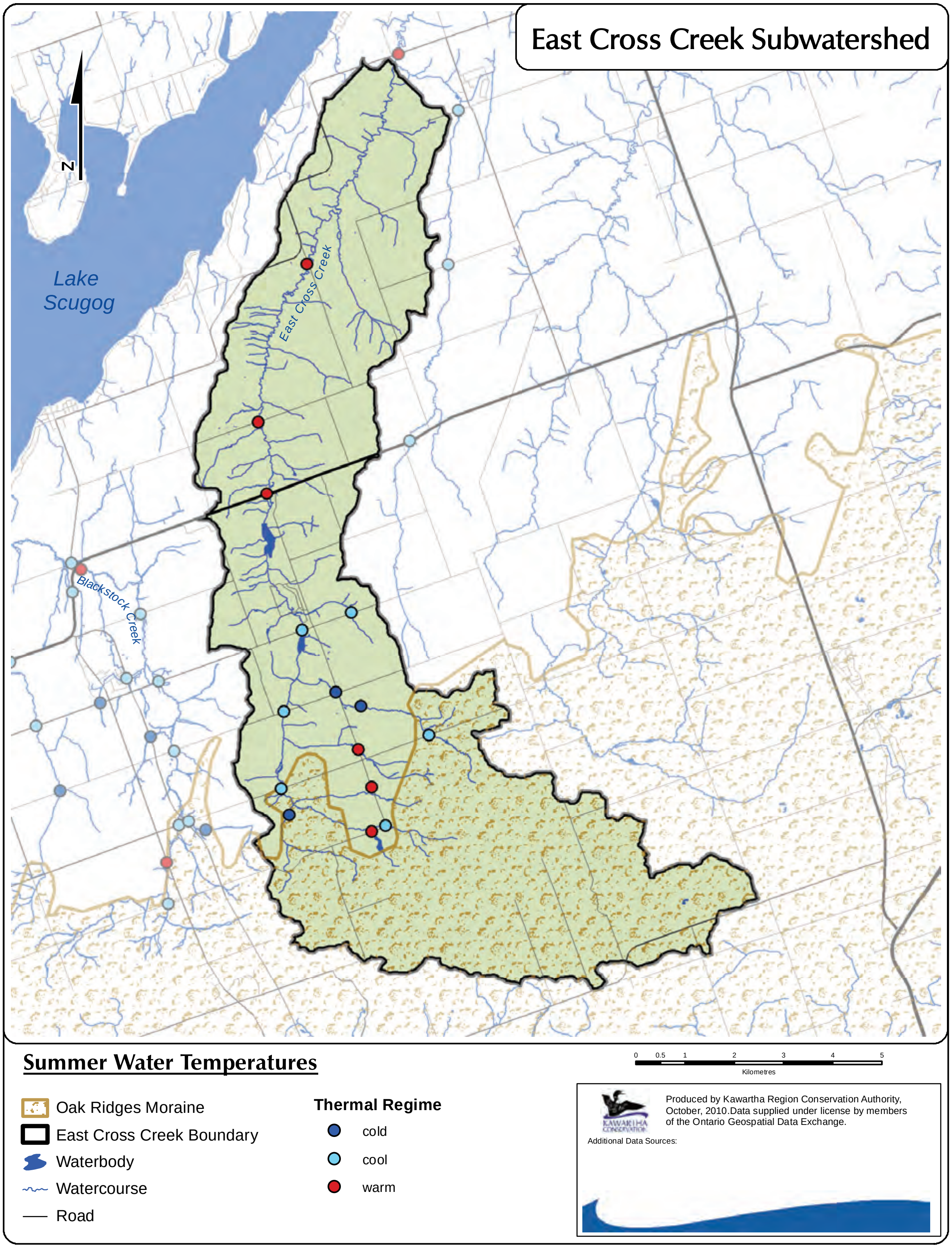
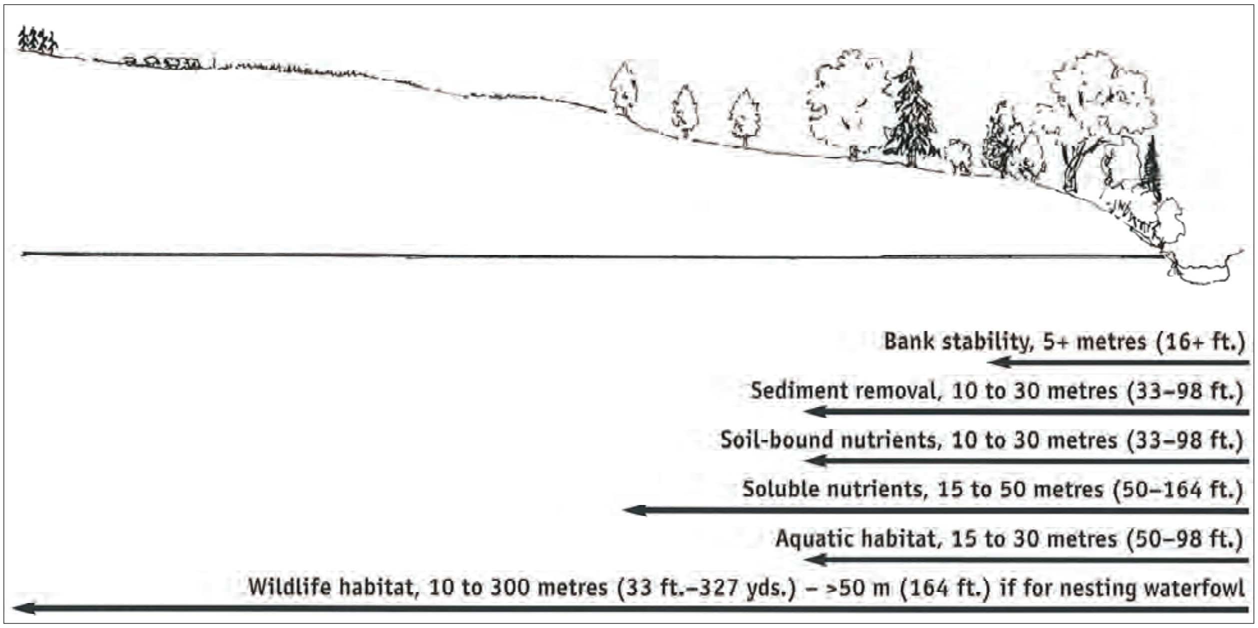


Figure 8.5: Thermal regime based on summer water temperatures.



From OMAFRA (2003)

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

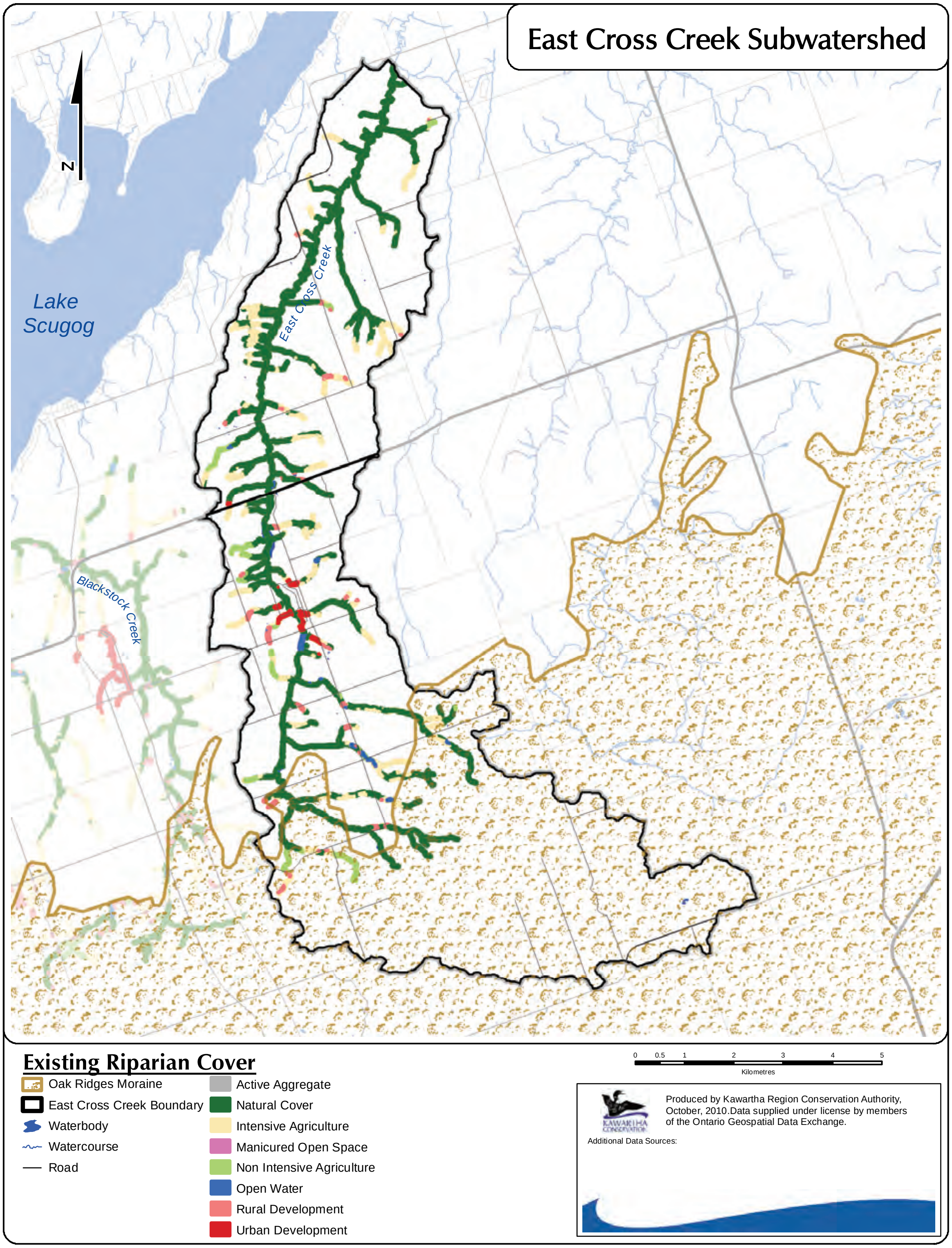
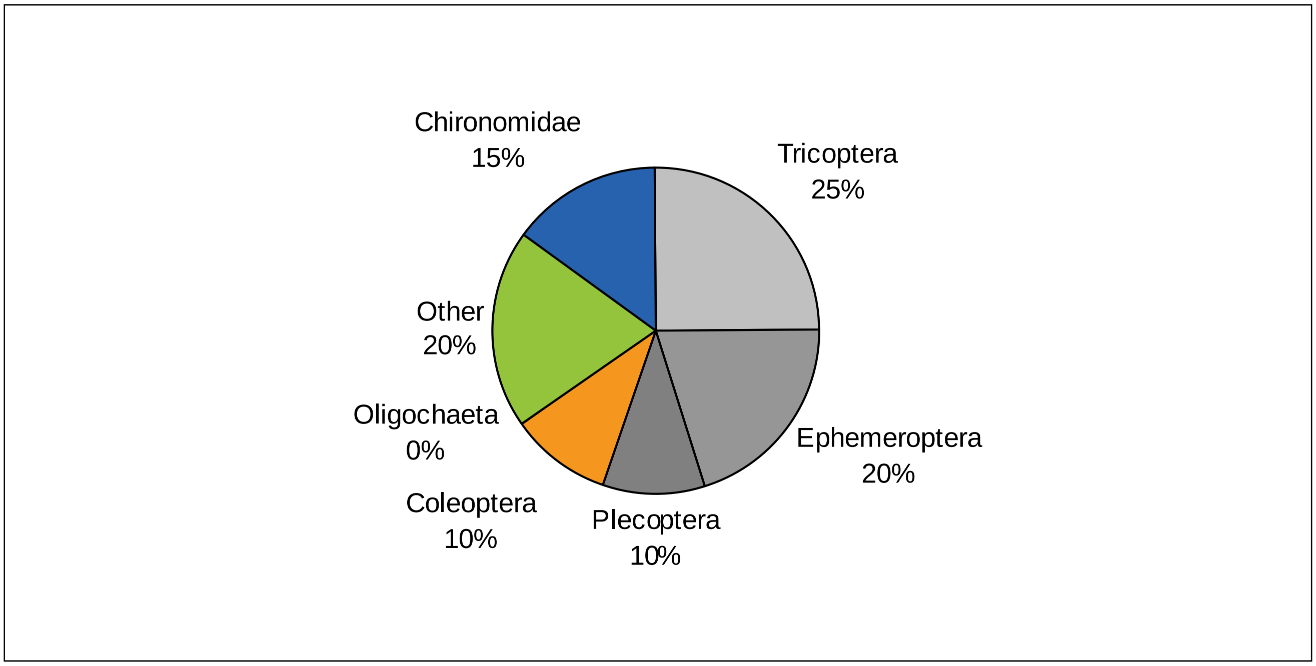


Figure 8.7: Existing riparian cover.



From Maude and Di Maio (1996)

Figure 8.8: Benthos community composition model.

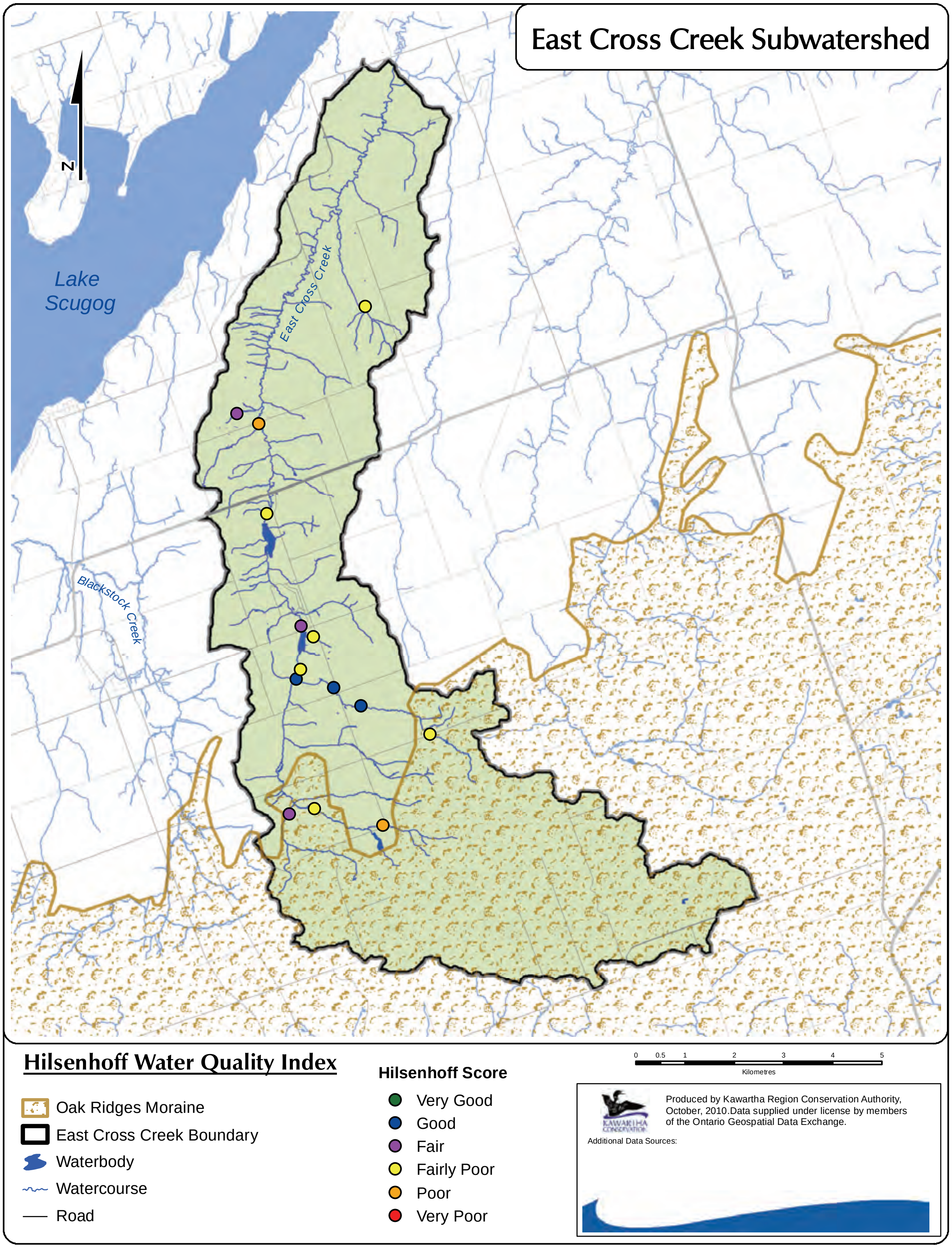


Figure 8.9: Hilsenhoff Index values.

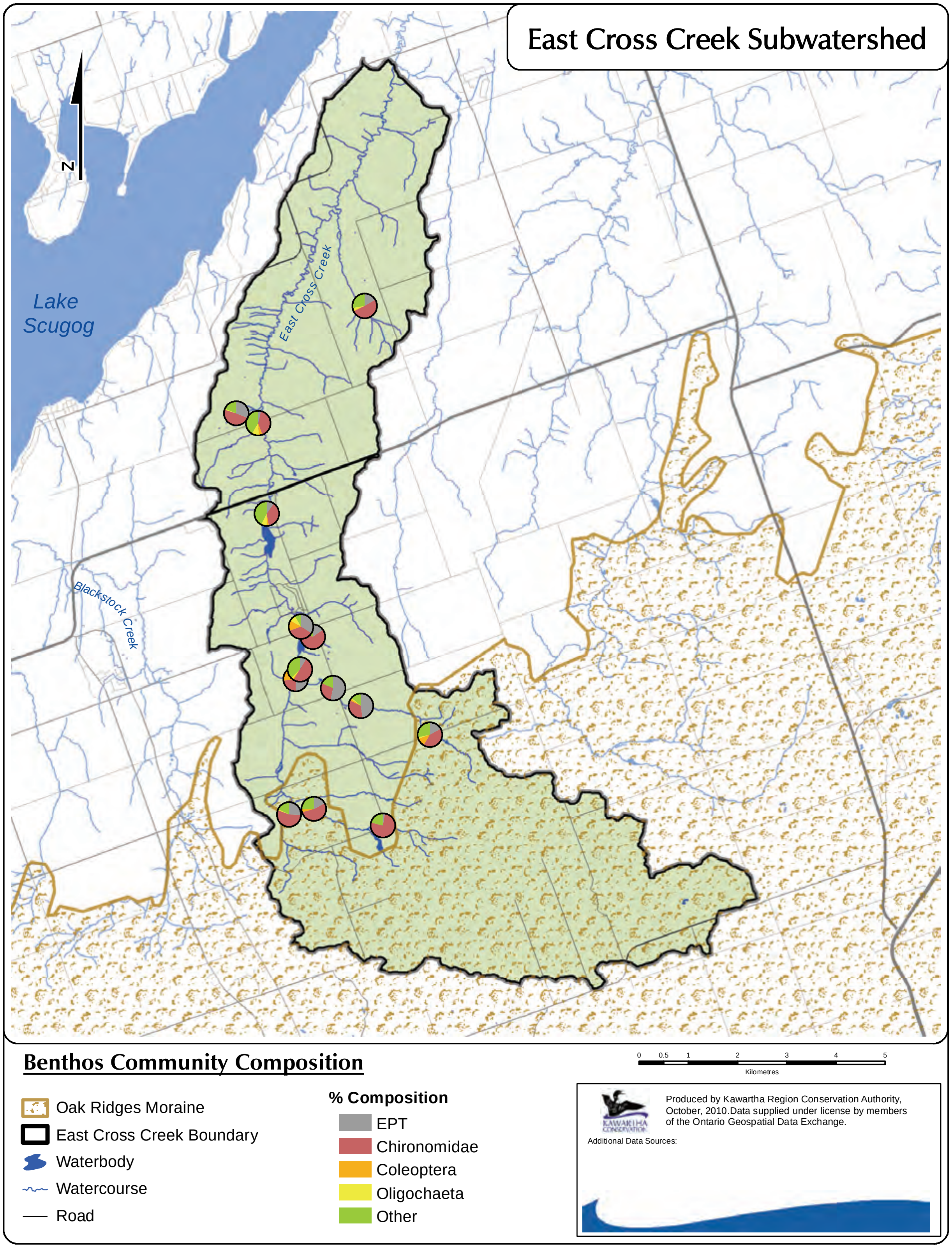


Figure 8.10: Benthos community composition.

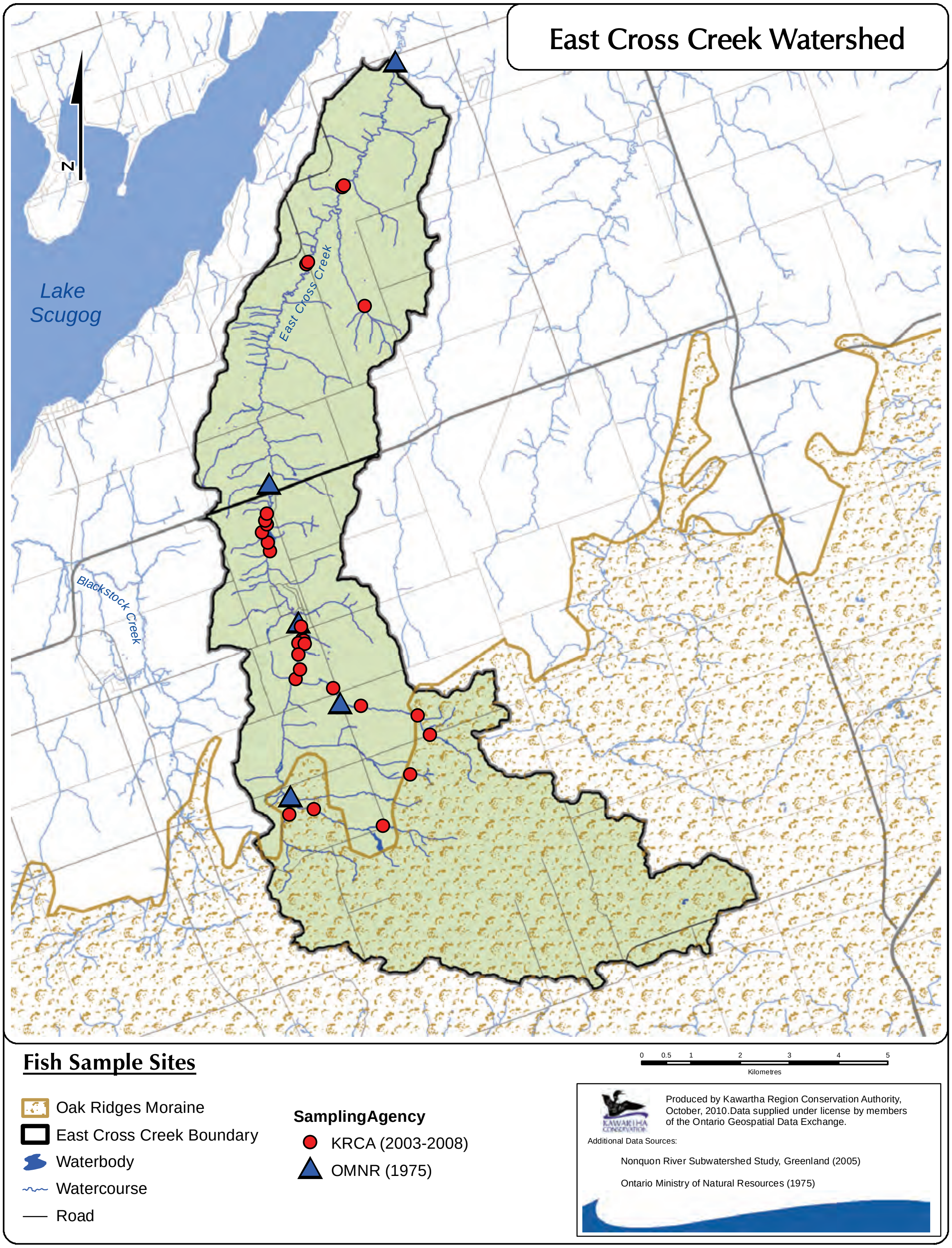


Figure 8.11: Fish samples sites.

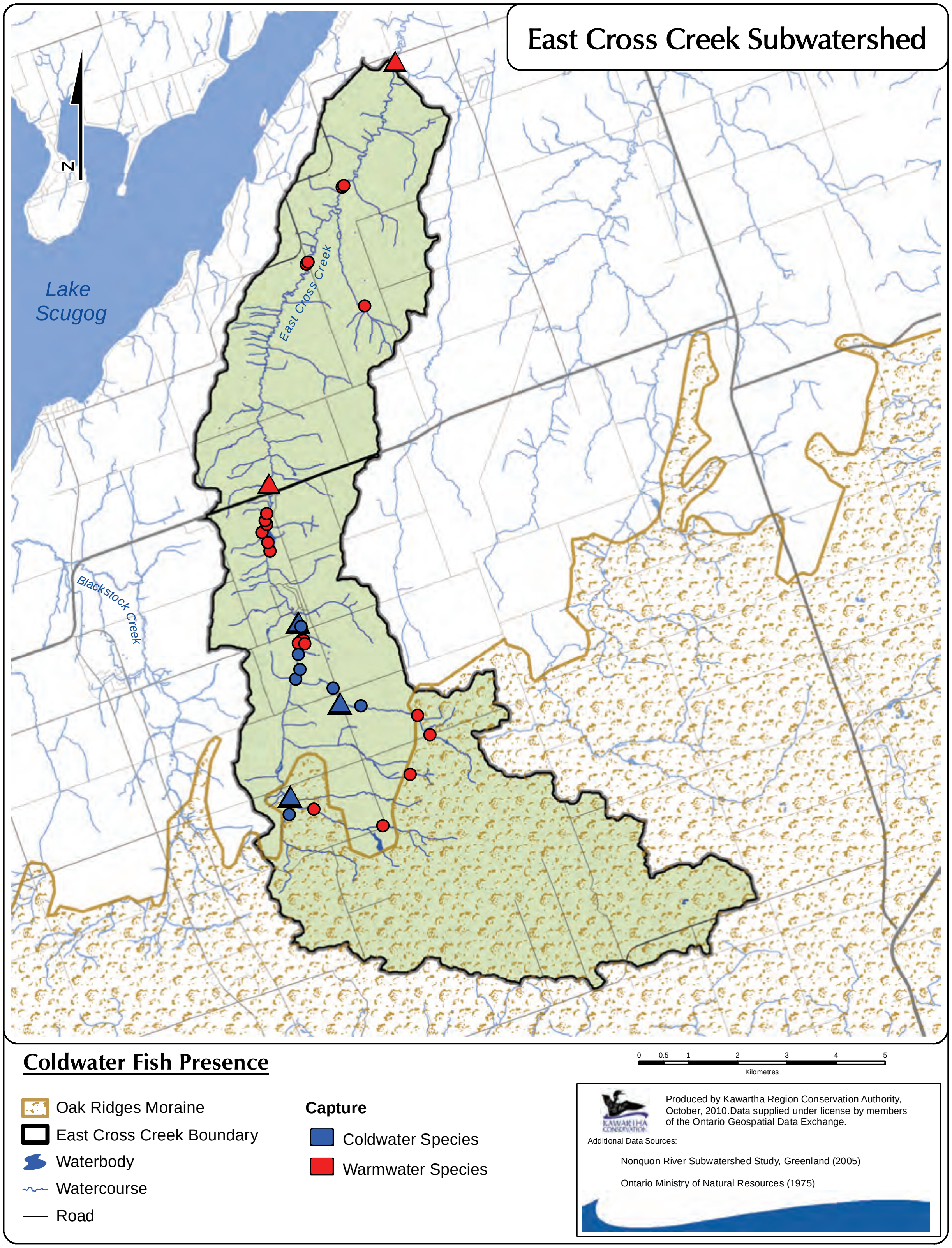


Figure 8.12: Coldwater fish captures.

9.0 Terrestrial Natural Heritage

East Cross Creek, north of Brown's Pond

9.1 Introduction

This section reports on the terrestrial natural heritage system within the East Cross Creek subwatershed 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 Subwatershed within the Surrounding Landscape

The East Cross Creek subwatershed 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 include Sugar Maple, American Beech, Basswood, Ash, Birch, Oak and occasionally Eastern Hemlock, White Pine and Balsam Fir. The species compositions of the East Cross Creek sub-watershed forests are typical of this forest region, with primarily mixed forest, and some pockets of coniferous and deciduous forest.

The subwatershed is located within the Scugog tertiary watershed, 2HG (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 East Cross Creek subwatershed is situated over two ecodistricts including the Peterborough Ecodistrict (6E-8) and the Uxbridge Ecodistrict (6E-7).

The northern portion of the sub-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 sub-watershed, is situated over scattered sands and the Schomberg Clay Plains, to the west of the sub-watershed. Within the subwatershed, the physiography is mainly sand plain with one area of clay plain and scattered drumlins. 1% 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.

The southern portion of the East Cross Creek subwatershed 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. 7% 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, savanna and alvar have been identified as high priority conservation targets for ecodistricts 6E-7 and 6E-8. Remnants of tallgrass prairie have been identified within this subwatershed.

The Oak Ridges Moraine, extending along the southern portion of the East Cross Creek subwatershed 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 East Cross Creek subwatershed 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 East Cross Creek subwatershed contains 41.3km^2 of natural cover, representing 52.3% of the total subwatershed 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 subwatershed, with 52.3% natural cover, exceeds related targets 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 sub-watershed contains 48% forest cover, well above target levels including: 30% forest cover for the Region of Durham, 25% - 35% forest cover for watersheds in Ontario, and 30% forest cover for area of concern watersheds within the great lakes basin.

Comparison of the amount of forest cover with target levels suggests that the East Cross Creek subwatershed is currently in a healthy state, however careful management is required for the future.

Table 9.1: Percentage of natural cover.

Land Use	Watershed Area (km^2)	Watershed Area (%)
Forest	28.9	36.6
Forested Wetland	8.7	11.1
Non-Forested Wetland	1.7	2.1
Meadow	1.6	2.1

9.4 Ecological Land Classification

Ecological Land Classification (ELC) is a method to further classify natural cover types into vegetation community types within the 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. 11 types of cultural areas and 12 types of natural areas (ELC community series) were identified for the subwatershed.

The subwatershed contains 9.1 % cultural vegetation community types, and 43.2% natural vegetation community types (**Table 9.2**). Mixed forests encompass the greatest area of the natural forest community types, accounting for 11.4%, and coniferous and deciduous forest amounts are fairly equal at 9.5% and 8.8% respectively. Seven different wetland types have been identified within the sub-watershed and account for 13.2% of the sub-watershed with mixed swamp, thicket swamp and coniferous swamp making up the majority of wetland area (**Figure 9.2**). There are nearly equal amounts of deciduous swamp, mixed shallow aquatic marsh, and shallow marsh, accounting for less than one percent of the sub-watershed area.

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	0.9	1.2

[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 (%)
	proportion of non-native plant species. These areas are characterized by a tree and shrub cover each of less than 25%.		
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%.	4.6	5.8
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%.	0.3	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%.	0.4	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%.	0.9	1.2
Natural Areas			
FOC – Coniferous Forest	Areas where tree cover is greater than 60%, and the canopy is comprised of greater than 75% coniferous tree species	7.5	9.5
FOD – Deciduous Forest	Areas where tree cover is greater than 60%, and the canopy is comprised of greater than 75% deciduous tree species	6.9	8.8
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	9.0	11.4
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.	0.3	0.4
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%.	<0.1	<0.1
OAO – Open Aquatic	Areas with water >2m deep. Plankton dominated with no macrophyte vegetation	0.1	0.2

Community Series (Code -Descriptive Name) [1]	Description of Community Series	Watershed Area (km^2)	Watershed Area (%)
	and no tree or shrub cover.		
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.	0.0	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.	0.1	0.2
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.	0.0	0.0
SBO – Open Sand Barren	Areas where bare sand substrates are covered by ≤25% tree cover and ≤25% shrub cover	0.2	0.3
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.	1.3	1.6
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 is greater than 5m, and deciduous tree species make up >75% of the canopy. Hydrophytic shrubs and herbs present.	0.2	0.2
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.	7.3	9.3
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%.	1.2	1.5
Cultural Areas		**7.2**	**9.1**
Natural Areas		**34.1**	**43.2**
Total Natural Cover		**41.3**	**52.3**

9.5 Terrestrial Biodiversity

The diversity of vegetation communities as well as the flora and fauna species that they support can provide an insight into the overall ecological health and condition of the subwatershed. 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 subwatershed.

Full flora and fauna lists have not been compiled for the sub-watershed, however significant species existing in the sub-watershed or with high potential to exist within the sub-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 subwatershed, including Red Shouldered Hawk and Black Tern (**Table 9.3** and **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 East Cross Creek Subwatershed	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.

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

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 East Cross Creek Subwatershed	Comments
						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 East Cross Creek Subwatershed	Comments
Juglans cinerea	Butternut	√	√			Mature deciduous forests. Species common, but Ontario populations undergoing rapid decline due to Butternut canker.
Panax quinquefolius	American Ginseng	√				Observed in relatively close proximity to the watershed.

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 East Cross Creek subwatershed.

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, dohwood (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 East Cross Creek subwatershed, replacing native trees and shrubs as pioneer species.

Upland Forests

There are basically two types of upland forests in the East Cross Creek subwatershed, 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 East Cross Creek subwatershed 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 East Cross Creek subwatershed. 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. 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 sub-watershed that is forest cover 100 meters or further from the forest edge should be greater than 10 %. The proportion of the sub-watershed that is forest cover 200 meters or further from the forest edge should be greater than 5%. The East Cross Creek subwatershed has 23% forest coverage that is >100 meter from edge and 13% forest coverage that is > 200 meter form edge. Therefore the East Cross Creek subwatershed is meeting or exceeding the federal guidelines for interior forest and deep interior forest, due to the conservation areas located at the headwaters of East Cross Creek. **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.

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 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. There is only one candidate ANSI located within the East Cross Creek Subwatershed, the Long Sault Forest, most of which is Conservation Area managed by Central Lake Ontario Conservation Authority.

Table 9.6: Candidate ANSI sites in the East Cross Creek Subwatershed.

Name	Type	Area (ha)	Description
Long Sault Forest	ANSI-lsc (Regional)	429.98	Currently the Long Sault Forests are designated as the Long Sault Conservation Area. Once part of the Agreement Forest program operated by the Ontario Ministry of Natural Resources, Long Sault Conservation Area now includes close to 400 ha of mature forest, plantation, wetland, meadow and prairie. The area is considered an important core wildlife area because of the diversity and size of habitats that it contains. This area also includes headwater tributaries that are an important part of the Bowmanville/Soper Creek Watershed.

Endangered, rare and threatened species habitat

Significant portions of the habitat of endangered, rare and threatened species exist within the sub-watershed. Current Ontario Ministry of Natural Resources mapping, based on 1km grid size, highlights the entire subwatershed as habitat of rare and threatened species. In order to effectively inform watershed management, a greater level of detail and prioritization of these areas is necessary.

Priority areas of habitat of endangered, rare and threatened species were identified by Kawartha Conservation staff as areas where: (1) there has been a documented observation of an endangered, rare or threatened species, and (2) the general habitat requirements of the observed species can reasonably be assumed to be met by the habitat available in that area.

Priority areas of habitat of endangered, rare and threatened species exclude any areas classified as Active Aggregate (AA), Inactive Aggregate (AI), Road (ROAD), Intensive Agriculture (IAG), Manicured Open Space (MOS), Urban Development (URB), and in some cases Rural Development (RD).

Priority areas of habitat of endangered, rare and threatened species identified for the East Cross Creek Subwatershed include East Cross Forest Conservation Area, East Cross Creek #15 provincially significant wetland, and Long Sault Conservation Area.

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 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 subwatershed 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. Remnants of these globally-imperiled vegetation communities have been identified within the East Cross Creek subwatershed and will be considered to be high priority conservation targets.

Field assessments of rare vegetation communities have not been completed specifically for the purposes of this report, however, 3 tallgrass prairie remnants have previously been documented within the southern portion of this sub-watershed. These areas include:

- Area within a Manvers Township road right-of-way on the western side of Manvers-Scugog Townline, a short distance south of Drum Rd. Because of the sparseness of the prairie species and small size of the site, the condition of this remnant is too poor to be feasibly restored (Trevelyan 2008).

- Area beneath hydro lines on the west side of Manvers-Darlington Townline, a few kms south of Drum Rd. This relatively large remnant prairie is partially owned by the Municipality of Clarington and is partially in private ownership. There is potential for successful restoration at this site. It is likely that regular hydro corridor maintenance has helped maintain this prairie site and will continue to do this into the future. Recommendations for restoration within the limitations of what is appropriate for a hydro corridor have been made for this site by Tallgrass Ontario including removal of woody stumps through hand removal and pesticide application as opposed to pulverizing by large machinery; and using mowing as a disturbance regime, as opposed to fire, in order to protect the electrical transmission lines in the corridor (Trevelyan 2008).

- Area on the west side of Murphy Rd, a short distance north of Reg. Rd. 20, under hydro lines. This area is privately-owned and significantly disturbed by soil alterations and non-native invasive species. There is potential for successful restoration at this site. Since it is also in a hydro corridor, the recommendations for restoration of this area are the same as recommended for the previously-discussed area. In addition, it was recommended that alteration of soils cease to allow for soil stabilization and gradual re-colonization of prairie species (Trevelyan 2008).

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, % 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.

Areas of natural cover within this subwatershed exist primarily as pockets of forest and wetland across the landscape. This lack of habitat connectivity highlights the need for increased and improved animal movement corridors within the sub-watershed. The largest and best connected area with potential to function as an animal movement corridor within the sub-watershed includes a mosaic of swamp, marsh and forest extending roughly north-south along the East Cross Creek riparian corridor, and the Durham East Cross Forest Conservation Area, which is adjacent to the Long Sault Conservation Area, both in the heart of the Oak Ridges Moraine.

Significant Woodlands

Significant woodlands were assessed for the subwatershed based on Oak Ridges Moraine Conservation Plan Technical Paper #7 (Province of Ontario 2007) and mapping provided by the Ontario Ministry of Natural Resources.

Significant woodlands are identified for conservation protection because of the features and functions that they provide. They 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 Key Natural Heritage Feature; or act as an ecological linkage between them.

There are 26.0km^2 of significant woodlands within the subwatershed. These areas are primarily clustered along the riparian corridor of East Cross Creek (**Figure 9.4**). There are also several areas of significant woodland in the southern-most part of the subwatershed on the Oak Ridges Moraine, which are part of the Durham East Cross Forest Conservation Area and the Long Sault Conservation Area.

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 sub-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. 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 occurrence begin to level off.

The East Cross Creek subwatershed contains approximately 10.4km^2 of wetland which represents 13.2% of the total sub-watershed area. The provincially significant East Cross Creek Wetland #15, covers 7.9km^2 (10%) of the total subwatershed area. This Provincially Significant Wetland located north of Highway 7A extending north east to Janetville. It is composed of four wetland types,1.0% bog, 9.0% fen, 82.0% swamp, and 8.0% marsh (NHIC 2011)

All Ontario Ministry of Natural Resources evaluated wetlands including provincially significant wetlands (PSWs) are illustrated on **Figure 9.5**. The wetland coverage in the East Cross Creek subwatershed is well above the guidelines set out by Environment Canada.

Wetlands have 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**.

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 52% of the total watershed area. Natural cover is comprised of forests, wetlands and meadows.

- Forested areas account for approximately 48% of the total watershed area, and are comprised of cultural plantations (6%), cultural woodlands (1%), coniferous forest (10%), deciduous forest (9%) mixed forest (11%) and forested wetlands (11%). Forested areas meet 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 23%, which meets 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 13%, which also meets the minimum ecological requirements of 5%.

- Wetland areas account for approximately 13% of the total watershed area, and are comprised of marshes (<1%), shallow open waters (<1%), and swamp (13%). 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 95%) 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.

- Two terrestrial species of conservation concern (i.e., species at risk) have been documented within the watershed. These include the Red Shouldered Hawk and Black Tern. Seven additional terrestrial species of conservation concern have a high potential to exist within the watershed.

- 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.

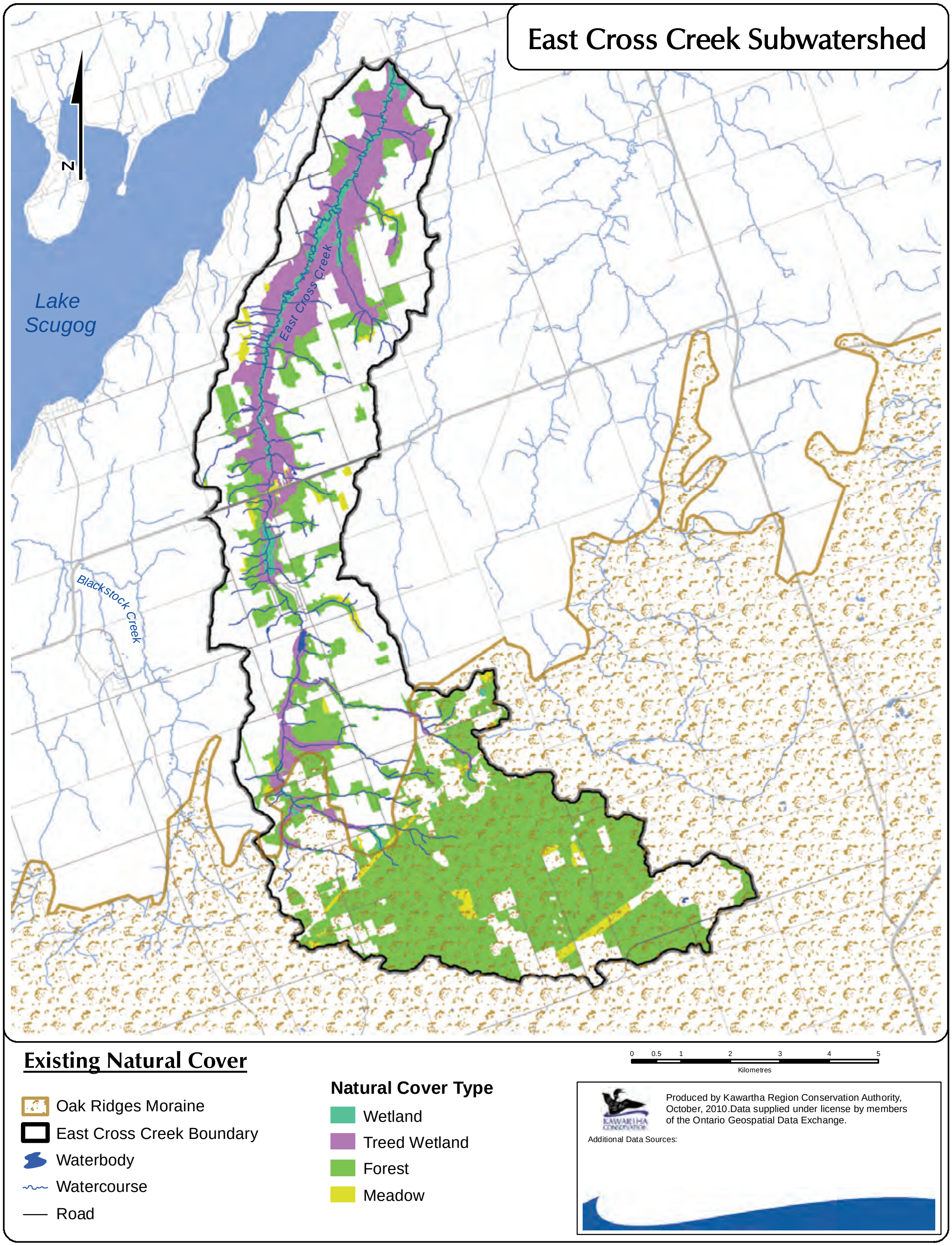


Figure 9.1: Existing natural cover.

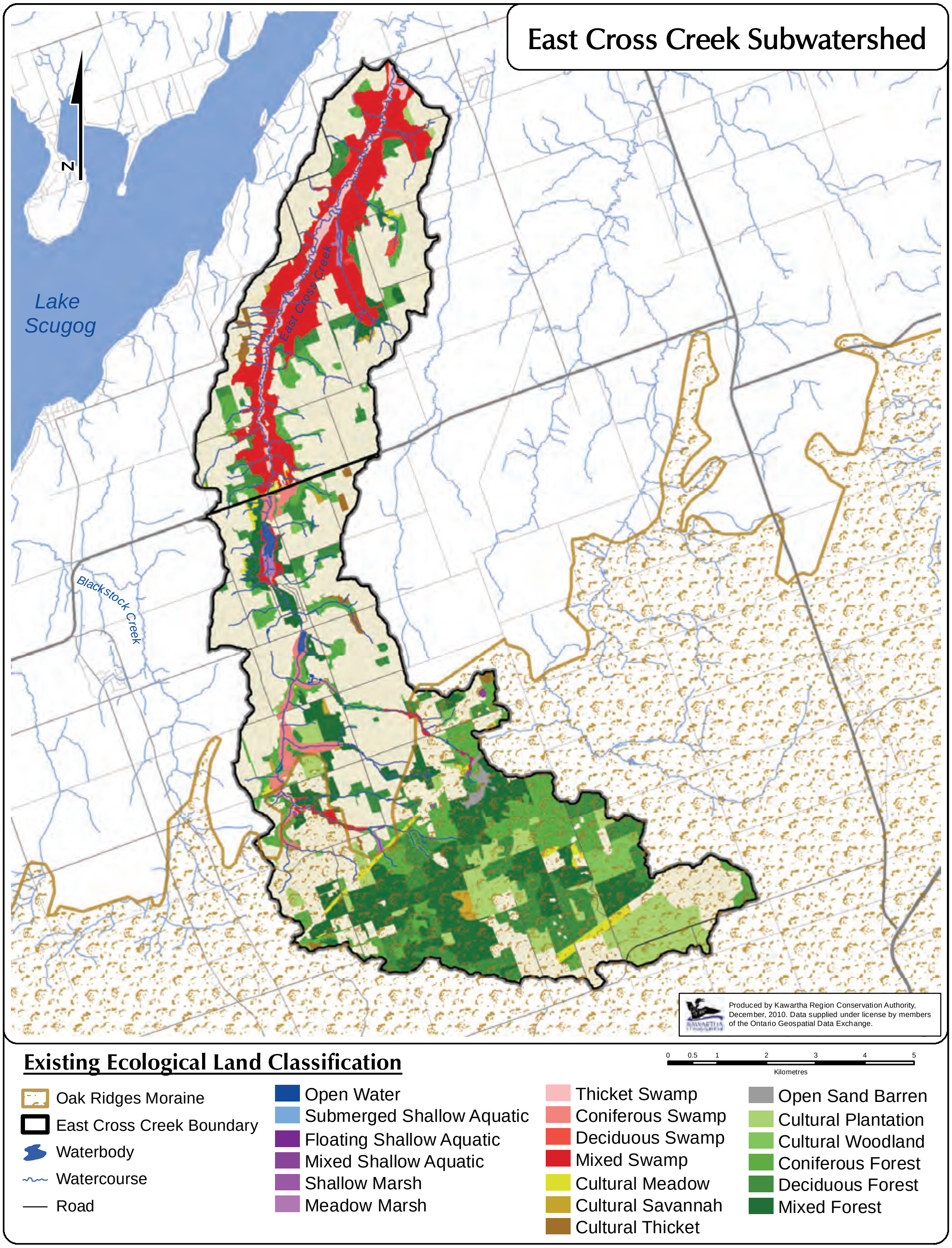


Figure 9.2: Existing ecological land classification.

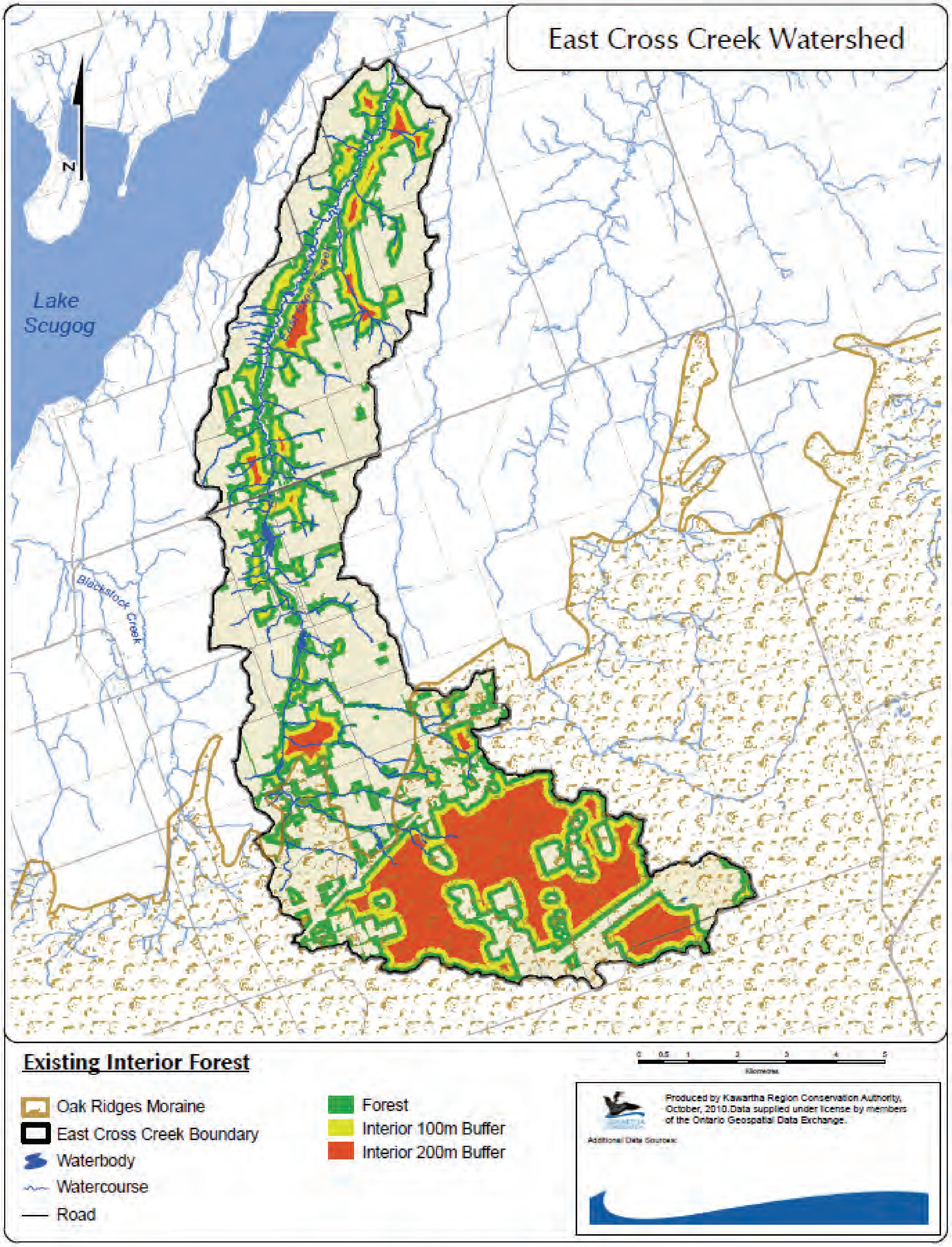


Figure 9.3: Existing interior forest.

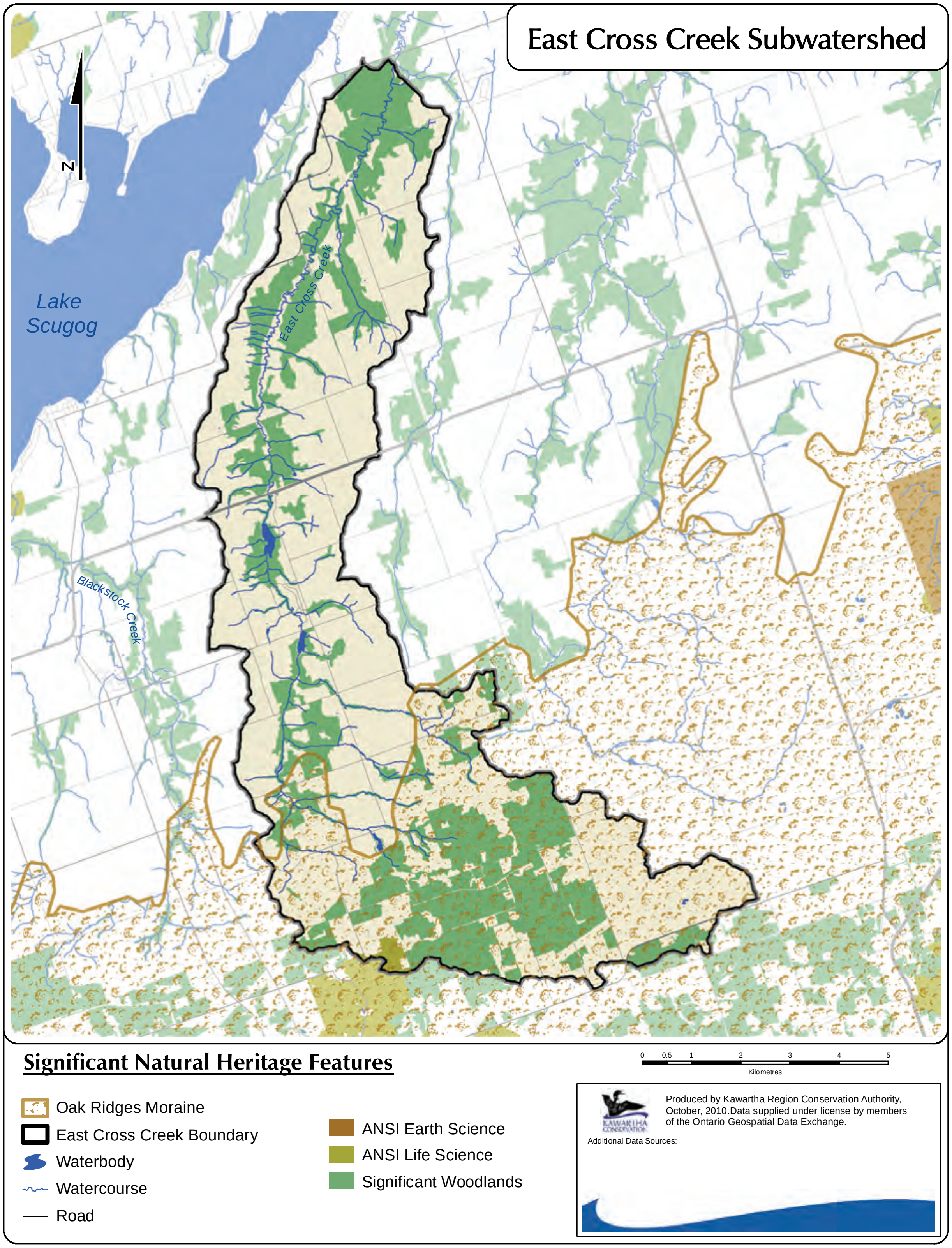


Figure 9.4: Significant natural heritage features.

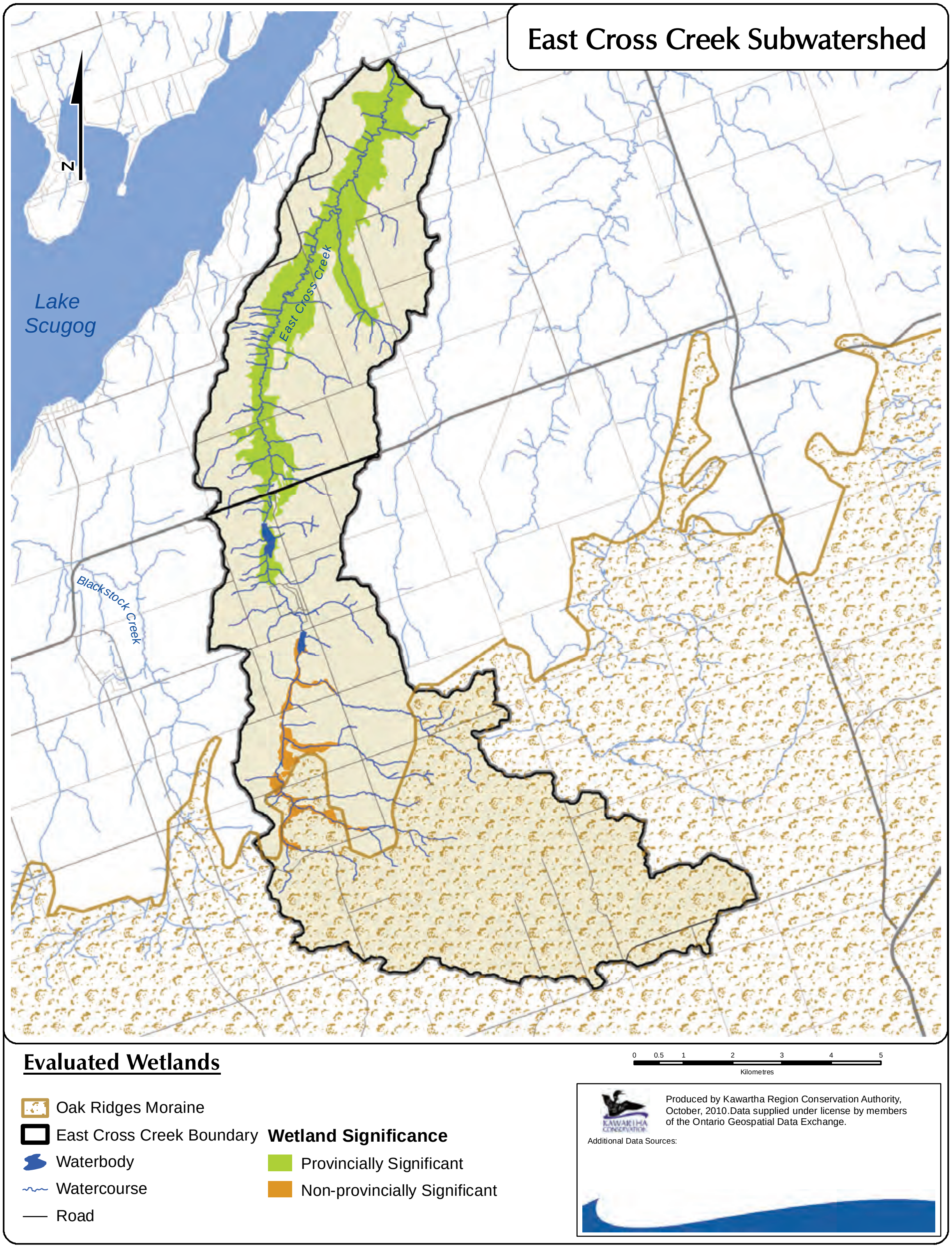


Figure 9.5: Evaluated wetlands.

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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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