Pigeon Lake Watershed Characterization Report

2018

KAWARTHA CONSERVATION

Discover · Protect · Restore

About Kawartha Conservation

Who we are

We are a watershed-based organization that uses planning, stewardship, science, and conservation lands management to protect and sustain outstanding water quality and quantity supported by healthy landscapes.

Why is watershed management important?

Abundant, clean water is the lifeblood of the Kawarthas. It is essential for our quality of life, health, and continued prosperity. It supplies our drinking water, maintains property values, sustains an agricultural industry, and contributes to a tourism-based economy that relies on recreational boating, fishing, and swimming. Our programs and services promote an integrated watershed approach that balance human, environmental, and economic needs.

The community we support

We focus our programs and services within the natural boundaries of the Kawartha watershed, which extend from Lake Scugog in the southwest and Pigeon Lake in the east, to Balsam Lake in the northwest and Crystal Lake in the northeast – a total of 2,563 square kilometers.

Our history and governance

In 1979, we were established by our municipal partners under the *Ontario Conservation Authorities Act*.

The natural boundaries of our watershed overlap the six municipalities that govern Kawartha Conservation through representation on our Board of Directors. Our municipal partners include the City of Kawartha Lakes, Region of Durham, Township of Scugog, Township of Brock, Municipality of Clarington, Municipality of Trent Lakes, and Township of Cavan Monaghan.

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Kawartha Conservation

277 Kenrei Road, Lindsay ON K9V 4R1

T: 705.328.2271 F: 705.328.2286

GenInfo@KawarthaConservation.com

KawarthaConservation.com

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City of KAWARTHA LAKES
Catch the Kawartha spirit

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Acronyms

CKL: City of Kawartha Lakes

CWQG: Canadian Water Quality Guideline

EC: Environment Canada

ELC: Ecological Land Classification

KLSA: Kawartha Lake Stewards Association

masl: Meters above sea level

MNR: Ontario Ministry of Natural Resources and Forestry

MOE: Ontario Ministry of the Environment and Climate Change

PGMN: Provincial Groundwater Monitoring Network

PLMP: Pigeon Lake Management Plan

PWQMN: Provincial Water Quality Monitoring Network

PWQO: Provincial Water Quality Objectives

SLMP: Sturgeon Lake Management Plan

TKN: Total Kjeldahl Nitrogen

TN: Total Nitrogen

TP: Total Phosphorus

TSS: Total Suspended Solids

TSW: Trent Severn Waterway

WSC: Water Survey Canada

Executive Summary

The purpose of the Pigeon Lake Watershed Characterization Report is to provide a technical, comprehensive report on the current state of Pigeon Lake and its subwatersheds that supports the development of a Pigeon Lake Management Plan. Emphasis has been placed on characterizing the immediate drainage area around Pigeon Lake (including the lake itself). This area is referred to as the 'core planning area'. Information within the core planning area is presented within several themes including: introduction, socio-economics, land use, physical characteristics, climate, water quantity, water quality, aquatic ecosystems, and terrestrial ecology. The following is a summary of the key observations, issues, and information gaps within each main theme.

Introduction

Pigeon Lake is a central lake within the chain of Kawartha Lakes, located downstream of Sturgeon Lake, and upstream of Buckhorn Lake. It is part of the Trent-Severn Waterway (TSW), a designated National Historic Site of Canada. Pigeon Lake is an elongated lake in a north-south orientation and, with a surface area of 51 km^2, is one of the largest of the Kawartha Lakes. The watershed draining into the lake is over 2500 km^2 and includes several large river systems such as Gull River, Burnt River, and Miskwaa Zibii River as well as the local subwatersheds of Balsam Lake, Cameron Lake, Lake Scugog, Scugog River, Sturgeon Lake, Little Bald, and Big Bald Lake. The core planning area is 711 km^2 which includes Pigeon Lake and its immediate subwatersheds of Pigeon River, Fleetwood Creek, Nogies Creek, Eels Creek, Reforestation Creek, Potash Creek, and other unnamed drainage areas into Pigeon Lake.

Socio-economics

Pigeon Lake provides high quality recreational opportunities, and is a desirable destination for seasonal and permanent settlement. Boaters have uninterrupted access to four adjoining lakes (Buckhorn, Chemong, Little Bald, and Big Bald) and Lock 32 in Bobcaygeon is one of the busiest on the TSW in terms of vessel traffic. The southern portion of the lake is not as conducive to recreation due to heavy growth of aquatic plants, particularly wild rice. Plant proliferation is a specific concern among several shoreline communities; however, local First Nations communities value these aquatic plants for traditional, ceremonial, and dietary purposes. Tourism is a key component of the local economy, and there are several attractions to this area including Emily Provincial Park, three public beaches, two sand bars, and high quality angling opportunities. Waterfront property along the Kawartha Lakes remains relatively affordable which puts shoreline reality in high demand. Agriculture is another key component of the local economy and the Pigeon Lake watershed is distinctly rural in nature, particularly in its southern subwatersheds. There has been a recent movement towards fewer, larger farms and increased cash cropping in recent years driven by market demand.

Land Use

The major land use types within the core planning area include natural areas, agriculture, open water, and development. Natural areas such as forests, wetlands, and meadows comprise 56% of the area, with large tracts existing in the northern subwatersheds of Nogies Creek and Eels Creek. Agriculture comprises 27% of the land area, with the majority found in the western unnamed subwatersheds, and southern subwatersheds of Reforestation Creek, Potash Creek, Fleetwood Creek and Pigeon River. Open water comprises 10% of the area and includes the surface area of Pigeon Lake, as well as Crystal Lake and Bass Lake which exist within Nogies Creek subwatershed. Development, which mainly includes urban and rural settlement areas, as well as aggregate operations, comprises 7% of the area. Dense development typically occurs within the settlement areas of Bobcaygeon and Omemee, and along shorelines which includes several waterfront communities (e.g., the Glen, Victoria Place, Windward Sands, etc.). The core planning area is situated within the following jurisdictions: municipal (City of Kawartha Lakes, County of Peterborough, Selwyn Township, and Municipality of Trent Lakes), First Nations (Williams Treaty First Nations, Treaty 20 area), provincial (Emily Provincial Park and several areas of isolated crown land), and federal (Ontario Waterways, water level regulation, and operation of major locks and dams).

Physical Characteristics

The physical geography of the core planning area varies considerably between the northern and southern sections. The northern subwatersheds are situated within the Canadian Shield and are characterized by areas of exposed granite or limestone bedrock and shallow soils. The southern subwatersheds are situated within the St. Lawrence Lowlands and are characterized by deep soils over limestone bedrock. The transitional area between the St. Lawrence Lowlands and Canadian Shield is a unique feature in this region and is referred to as the 'Land Between'. The Oak Ridges Moraine is another unique feature on the southern landscape, existing within Fleetwood Creek and Pigeon River subwatersheds.

Climate

The climate within the Pigeon Lake core planning area is characterized by warm summers with occasional hot and humid spells and cold winters with snowstorms, strong winds and cold air from Continental Polar or Arctic air masses. There are noticeable differences in air temperature and precipitation between the northern and southern portions of the watershed, with the north being colder and much wetter. Climate conditions are currently projected to change as a result of the global climate change process, shifting towards warmer air and water temperatures, changes in precipitation patterns, and more frequent and severe storms events.

Water Quantity

The water level regime of Pigeon Lake is regulated in accordance with the TSW management regime. Water levels remain relatively stable from May until October, are lowered throughout late fall and winter to accommodate high spring runoff, and raised in late spring to accommodate vessel traffic. Small, unregulated tributaries of Pigeon Lake exhibit a natural flow regime with well-defined seasonal flow patterns. High flows typically occur in spring, associated with snowmelt, and throughout the year following high volume precipitation events. Low flows are typically observed in the summer and winter months. Pigeon Lake, on average, receives 2.4 billion m^3 of water flow every year. Most of this water (89%) comes from Sturgeon Lake, which outlets at Bobcaygeon through the Big Bob and Little Bob Channels in the north-west end of the lake. The remaining water inputs include Pigeon River Subwatershed (3%, which includes Fleetwood Creek Subwatershed), Nogies Creek Subwatershed (3%), local surface inflow (2%, which includes Pigeon Lake Subwatershed, Eels Creek, and Reforestation Creek), direct precipitation (2%), Potash Creek (<1%), and septic systems around the lake (<0.1%). Water exits Pigeon Lake through Gannon's Narrows into Buckhorn Lake and continues in a general east-southeast direction through the Kawartha Lakes, eventually draining into Lake Ontario through the Trent River and the Bay of Quinte.

Water Quality

Pigeon Lake can be characterized as a mesotrophic (moderately productive) water body with fair water quality. Water quality, as indicated by nutrient concentrations, varies between the northern and southern portions of the lake. According to data from 2012-2015 phosphorus concentrations in Pigeon Lake average 14-19 ug/L, with the highest values observed in the summer months. Pigeon Lake occasionally has elevated phosphorus levels that exceed Provincial Water Quality Objectives (20 ug/L). This level can stimulate the proliferation of green and blue-green algae. The shallow southern section of Pigeon Lake has higher phosphorus and nitrogen concentrations compared to the northern section. Nitrogen concentrations in the lake fluctuate between 300-760 ug/L in the northern section, and between 540-950 ug/L in the southern section. Reforestation Creek exhibited the highest levels of phosphorus of all tributaries and routinely does not meet provincial objectives. Elevated *E.coli* levels have been often observed at the Omemee beach which has led to frequent postings in 2012, 2013 and 2014. Phosphorus loading data from 2012 to 2015 indicate that approximately 29,161 kg of phosphorus enters the lake every year. The majority of phosphorus enters the lake during the spring, when elevated runoff caused by snowmelt and precipitation carries large quantities of nutrients into the lake. Sturgeon Lake accounts for 80% (23,201 kg) of the total phosphorus inputs into the lake, Local Subwatersheds account for 19% (5,437 kg), and Atmospheric deposition accounts for 2% (523 kg).

Aquatic Ecosystems

Aquatic habitat conditions vary between the north and south sections of the lake, with the north end of Pigeon Lake (north of Gannons Narrows) characterized by relatively deep open water conditions consisting of steep and narrow nearshore areas with coarse substrates, and the south end characterized by relatively shallow broad nearshore areas dominated by large tracts of marsh wetlands and submerged aquatic plants. The fish community structure in the lake has changed over time and, at present, the large-bodied nearshore fish community in the lake consists of bluegill, black crappie, walleye, common carp, largemouth bass, smallmouth bass, pumpkinseed, muskellunge, yellow perch, brown bullhead, and rockbass. There have been recent changes to fish community composition, with an increase in the relative abundance of several panfish species, particularly bluegill and black crappie. Sensitive coldwater fish species have been documented in the deeper northern basin of Pigeon Lake and within the headwaters of several tributaries. Several key issues have been documented including the establishment of non-native and invasive species, loss and fragmentation of aquatic habitat, and potential impacts from climate change. Further, several key information gaps have been noted including: limited understanding of how stressors such as climate change, cumulative development and invasive species will impact the aquatic ecosystem, limited understanding of coldwater aquatic habitat and communities, limited understanding of small-bodied fish communities, and limited understanding of fish spawning habitat and recruitment dynamics.

Terrestrial Ecology

The core planning area contains approximately 396 km^2 of natural cover, representing 60% of the total terrestrial land cover. Areas of natural cover are more extensive in the northern part of the planning area than in the south. In the north, there are large uninterrupted tracts of natural cover corresponding with few urban and agricultural areas. Existing forest cover in the core planning area is 48% of the total terrestrial land cover, indicating that moderately healthy aquatic systems are likely to be supported. Nogies Creek and Eels Creek are the only subwatersheds to have over 50% forest cover, an amount at which most of the potential species and healthy aquatic systems are likely to be supported. Natural cover along streams within the core planning area is 83%, which meets the minimum recommended guidelines to maintain healthy stream systems. Streamside vegetation is lacking in the unnamed subwatersheds of Pigeon Lake, as well as Pigeon River and Reforestation Creek. Approximately 69% of the shoreline area around Pigeon Lake is considered natural cover, with shallow marshes as the dominant type. There are twelve provincially significant wetlands along the shoreline, several of which occur in the southern end of the lake. Existing natural areas provide habitat for several locally or provincially rare wildlife species including: barn swallow, black tern, bobolink, eastern meadowlark, Henslow's sparrow, least bittern, redheaded woodpecker, whip-poor-will, Blanding's turtle, eastern musk turtle, northern map turtle, spotted turtle, wood turtle, snapping turtle, eastern hog-nosed snake, milksnake, and five-lined skink.

1.0 Introduction

1.1 Project History

Pigeon Lake is centrally located in the chain of Kawartha Lakes. It is situated between Sturgeon Lake upstream and Buckhorn Lake downstream. Similar to other local lakes, for the most of the 20th century, the lake served as a vacation destination for residents of the southern Ontario and Greater Toronto Area (GTA). Over time, more and more people converted their seasonal cottages into year-round homes. Currently, Pigeon Lake supports many aspects of the local economy in the City of Kawartha Lakes, Municipality of Trent Lakes, Selwyn Township, and Peterborough County. For example, the multiple shoreline residences and small lakeside communities support many local businesses including landscaping, home renovation and property management, as well as commercial enterprises in the Bobcaygeon and Omemee areas.

In order to create the framework for the continuous management of the lake, Kawartha Conservation and the City of Kawartha Lakes initiated the development of the Pigeon Lake Management Plan (PLMP) as the third phase of the watershed-wide lake management initiative. The first phase of watershed-wide Lake Management Planning in the City of Kawartha Lakes was initiated in 2010. In that year, Kawartha Conservation and the City of Kawartha Lakes, recognizing the importance of the environmental health of Sturgeon Lake, and with support from multiple citizen groups and partner organizations, commenced the Sturgeon Lake Management Plan (SLMP). This plan was completed in 2014. In 2011, the Balsam and Cameron Lake Management Plan was started and completed in 2015.

The Watershed Characterization Report is an overview of the current state of the aquatic and terrestrial ecosystems within the Pigeon Lake core planning area. The core planning area includes all of the subwatersheds that drain directly into Pigeon Lake, excluding areas upstream of Bobcaygeon and Little Bald Lake. This report includes information on geology and physiography, climate and hydrology, terrestrial and aquatic ecology of the watershed, land use and economic activities within the watershed, as well as characterization of the current water quality in the lakes and their tributaries. It provides the findings from our scientific research and environmental monitoring for the three-year period from June 2012 to September 2015. Additionally, it includes information and data from previous studies dating back to the 1970s and 1980s.

The information gathered help to further understand the issues and stressors impacting the lake, provide an overview of watershed health, and ultimately to inform the Pigeon Lake Management Plan in terms of developing effective recommendations for protecting and enhancing lake health.

1.2 Study Area

Pigeon Lake is a central lake within the chain of Kawartha Lakes, located downstream of Sturgeon Lake, and upstream of Buckhorn Lake. It is part of the Trent-Severn Waterway (TSW), a designated National Historic Site of Canada. Pigeon Lake is an elongated lake in a north-south orientation and, with a surface area of 51 km^2, is one of the largest of the Kawartha Lakes. The watershed draining into the lake is over 2500 km^2 and includes several large river systems such as Gull River, Burnt River, and Miskwaa Zibii River as well as the local subwatersheds of Balsam Lake, Cameron Lake, Lake Scugog, Scugog River, Sturgeon Lake, Little Bald, and Big Bald Lake. The core planning area is 711 km^2 which includes Pigeon Lake and its immediate subwatersheds of Pigeon River, Fleetwood Creek, Nogies Creek, Eels Creek, Reforestation Creek, Potash Creek, and other unnamed drainage areas into Pigeon Lake (Figure 1.1).

The Village of Bobcaygeon, with a population of more than 3,000 residents (Statistics Canada, 2012), is the largest urban centre within the core planning area and is situated between Pigeon and Sturgeon lakes at the Sturgeon Lake outlet in the northern part of the study area. Another urban center is the Village of Omemee situated at the mouth of the Pigeon River. As well, about 10 villages, hamlets and subdivisions are situated within the lake's watershed. Many of these are located in areas adjacent to the lake's shoreline.

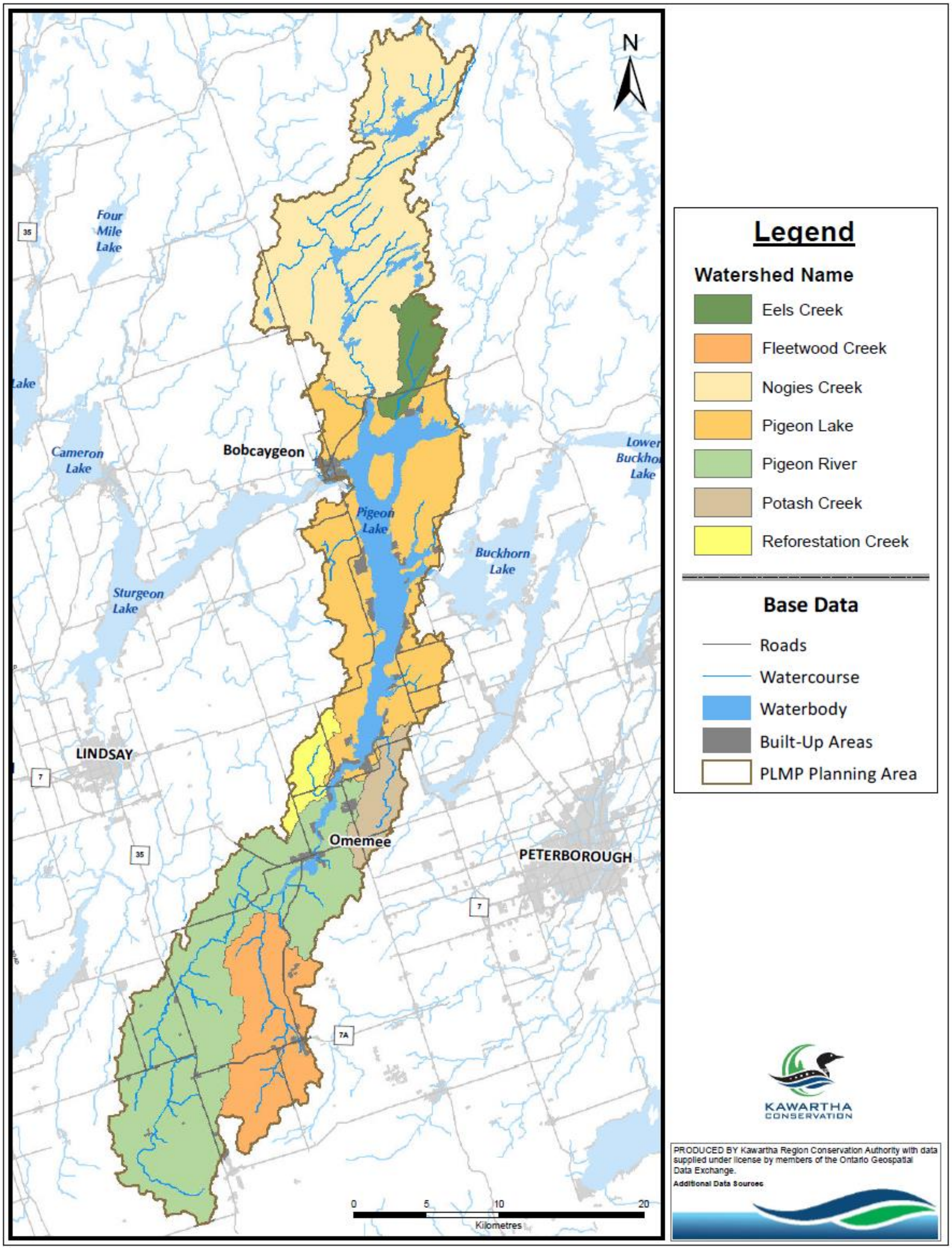

Figure 1.1. Pigeon Lake Study Area

2.0 Socio-Economic Characterization

2.1 Summary of Observations, Key Issues, and Information Gaps

OBSERVATIONS

- ***Seasonal population is expected to increase by 2031.*** Although data indicate that vessel traffic through the Trent-Severn Waterway has been decreasing over the last several years, the Village of Bobcaygeon is expected to incur an increase in population and seasonal residents. The affordability of the Kawartha Lakes area in comparison to the driving prices of cottages to the North will influence this population growth. This growth will affect the City of Kawartha Lakes region positively.

- ***Pigeon Lake provides ample opportunities for swimming, boating (power, canoe, and sailboat), fishing, and hunting, all of which are key recreational activities on the lake***. According to the City of Kawartha Lakes' Tourism Profile (2008), boating and fishing were ranked two of the top three activities of participation while visiting the Kawartha Lakes area. Recreational angling is particularly significant as a socio-economic resource of the Kawartha Lakes. A 2005 survey of recreational fishing in Ontario indicates that the Kawartha Lakes provide one of the largest recreational fisheries in Ontario in terms of number of days fished. Pigeon Lake was ranked as the 14th most-fished lake in Ontario in terms of number of days fished, and hosts numerous competitive fishing tournaments every year.

- ***First Nations have been in the Kawartha Lakes area for thousands of years***. First Nations communities have a long cultural presence within the region and have a deep connection to the Kawartha Lakes. The Curve Lake First Nations community residents have traditionally utilized Pigeon Lake and Nogies Creek watersheds for seasonal hunting and gathering activities. Their influence and management of the native grass species, *Zizania* spp. (wild rice or Manomin) has encouraged excellent fish and bird habitat. The cultural and traditional ecological knowledge of the Curve Lake First Nations is highly regarded.

KEY ISSUES

- ***The proliferation of Zizania spp. (wild rice or Manomin) is an important topic of debate among the First Nations and shoreline owners on Pigeon Lake*.** There have been recent discussions regarding the presence of wild rice on Pigeon Lake and its distribution in the southern portion of the lake. Controversy over the prolific growth of Manomin (wild rice) has begun to emerge and includes recent discussions with respect to traditional growing and harvesting methods of this native species and concerns regarding boat access in the southern area of the lake. The conversation will continue at the Federal Government level in hopes that a resolution can be achieved.

- ***The boat traffic through Lock 32 in Bobcaygeon contributes greatly to the economy of the local municipality*.** The number of vessels visiting and travelling through the lock at Bobcaygeon is significant and could be contributing up to the overall $3,091,500 in direct expenditures to the City of Kawartha Lakes.

- ***Agriculture is a significant economic contributor to the region.*** The agricultural industry is a key contributor to local economies. The agricultural sector is comprised of 46% of the entire Kawartha Lakes watershed. It is also the largest land user within the city boundaries and in the Pigeon Lake watershed. Recently there has been a shift, driven by market demand, to convert pasture land and marginal lands into intensive cropland production. Agriculture practices have the potential to negatively impact lake water quality by contributing excess sediment and nutrients without proper management.

INFORMATION GAPS

- ***There is a lack of data on the number of visitors to the City of Kawartha Lakes area during the winter months.*** Current City of Kawartha Lakes data supports summer tourism contributions to the economy, but little to no data exists for winter tourism. The City of Kawartha Lakes area is full of winter recreational opportunities such as snowmobiling, winter hiking and ice fishing.

- ***There is currently a lack of research on the effects of the Zizania spp. proliferation within the southern portion of Pigeon Lake.*** How does the proliferation of *Zizania* spp. influence the socioeconomic sphere of Pigeon Lake within the larger watershed? Is the proliferation decreasing access to the southern portion of Pigeon Lake by TSW users? How is the *Zizania* spp. growth affecting angler hours and yield of various fish species? Is the abundant growth area an opportunity for eco- tourism and a potential contributor to the economy?

2.2 Brief History

First Nation Peoples have lived in the Kawartha Lakes area for thousands years before the Europeans arrived in the beginning of 19^{th} century. The area we know as the City of Kawartha Lakes (CKL, formally known as Victoria County) was settled when the Government of Canada put forward the land for sale in 1821. It was one of the first municipalities in the province to be established, in 1863. The County of Victoria was composed of the Town of Lindsay, the Villages of Bobcaygeon, Fenelon Falls, Omemee, Sturgeon Point, Woodville, the Townships of Bexley, Carden, Dalton, Eldon, Emily, Fenelon, Manvers, Mariposa, Ops, Somerville, Verulam and the United Townships of Laxton, Digby and Longford (CKL, 2010). This collection of towns and villages remained physically unchanged until 1974 when the Regional Municipality of Durham was established and Manvers Township was added to the County of Victoria. The City of Kawartha Lakes was created on January 1, 2001 by the amalgamation of municipalities formed within the County of Victoria (CKL, 2010).

The history of Bobcaygeon began in the early 1800s and became incorporated in 1876. When the first white settlers arrived, they heard the Mississaugas of the Anishnaabeg Nation, calling Bobcaygeon 'Bobcajewonunk' meaning "shallow rapids" or "swirling rivers around islands" (CKL 2016). French explorer Samuel de Champlain referred to Bobcaygeon as “Beaubocage” meaning beautiful farmland (Kawartha Living, 2012). Today, Bobcaygeon is a popular attraction for tourists and travelers making their way through the locks between Pigeon and Sturgeon Lakes (Kawartha Living, 2012). Bobcaygeon is a series of islands that are separated by channels and connected by a series of 6 bridges. Its population is 3533, but increases dramatically in the summer during peak tourism season due to visitors of the Trent Severn Water Way and the seasonal cottager population (Kawartha Living, 2012).

2.3 Trent-Severn Waterway

One of the most unique features of the CKL area is the Trent-Severn Waterway (TSW), which has federal designation and is managed by Parks Canada. This series of lakes and rivers, which is 382 kilometeres long and includes 45 locks, allows boaters to navigate from Lake Ontario to Georgian Bay.

Lock 32 is located on the Big Bob channel in Bobcaygeon and provides passage between Sturgeon and Pigeon Lakes. In 2013, a total of 6183 vessels used the lock (Table 2.1). Boaters create positive economic impacts to the local economy.

Parks Canada estimated that the average annual boating related expenditure per seasonal household in 2006 for resident boaters, assuming a 10-week season, was $180 per week, for a total of $1,800 per year (Parks Canada, 2009). For transient boaters (those that do not live on the waterway) the average annual direct expenditure per boat transient slip was estimated at $5,000. Parks Canada estimates that the Kawartha Lakes have approximately 3,436 single detached homes (not including seasonal dwellings) that face onto waterway areas in the TSW corridor (TCI Management Consulting and EDP Consulting, 2007). If even half of those homeowners in the Kawartha Lakes owned boats, they could be contributing up to $3,091,500 in direct expenditures to the CKL.

Table 2.1. Number of Vessels through the Bobcaygeon Lock 32 in 2013

Lock	Station	May	June	July	Aug	Sept	Oct	Total
32	Bobcaygeon	222	901	1921	2314	724	101	6183

Source: Parks Canada, 2013

2.4 Population and Housing

According to the Canadian Business Analyst which is based on the most recent Canadian Census numbers, the permanent population of the City of Kawartha Lakes was 88,158, which was a small decrease of 1.0% from the 2008 population of 88,615 (ESRI 2013) (Table 2.2). The CKL has an aging population that is similar to many other areas in Ontario. The median age was 48.4 in 2011, while the median age for the province was only 40.4. There were 35,044 private households in 2013, with the average household size of 2.2. The City of Kawartha Lakes has a low population density with only 23.7 persons per square kilometre as a result of the predominantly rural area. Approximately 65% of the population lives in rural areas (CKL, 2009) with the remainder living in the larger towns of Lindsay, Bobcaygeon and Fenelon Falls (Richard Fortin Associates, 2012). The City's Growth Management Strategy predicts a fairly moderate increase in population households through 2031 (MHBC Planning Inc., 2011).

Table 2.2. Population and Housing Statistics for the City of Kawartha Lakes.

Variable	Census Year	
	2008	2013
Population (year round)	88,615	88,158
Households (Permanent Residences)	34,393	35,044

Source: ESRI Canada 2013

More specifically the 2 major urban centres within the Pigeon Lake Watershed include, Bobcaygeon and Omemee which have an estimated year round population of 3,639 and 1,233 (2013), respectively (ESRI 2016). Seasonal residents and visitors to this area increase greatly during the summer months adding increased pressure to the total watershed and a positive impact on the economy.

Seasonal Population

The CKL has a significant seasonal population due to its many cottages and vacation properties. In 2011, the seasonal population was estimated at 32,000 (MHBC Planning Inc., 2011). Current projections of the seasonal population could reach approximately 37,000 by 2031 (Table 2.3). As a significant number of the cottager population retire an observed recent growing trend is the conversion of seasonal properties, such as cottages, to larger permanent residences. This trend is expected to increase as our large portion of our population reaches the age of retirement. It is predicted that 17.9% of the seasonal residents will convert to permanent residency by 2031 (Tim Welsh Consulting and Lapoint Consulting, 2013). This boost in population will increase pressures to the lakes. A higher population means more lake usage with a greater impact to the lake from increased pleasure crafts, fishing, waterfront property construction, and road expansions etc. An increase in waterfront homes also means a higher installation and usage of septic systems which are known to contribute large amounts of excess nutrients to lakes if not managed properly (Whitehead et al., 2011).

Table 2.3. CKL Projections for Seasonal Population and Conversions of Seasonal Residences to Permanent Residences (2001-2031).

Variable	2001	2006	2011	2021	2026	2031
Seasonal Population	29,000	31,000	32,000	35,000	36,000	37,000
Seasonal Conversions	NA	NA	480	1,580	2,030	2,330

Source: Reprinted from Tim Welsh Consulting and Lapoint Consulting, 2013.

Table 2.4. Residential Demographics of Pigeon Lake.

2013 Total Population	12,484
2013 Households	4,905
Owned Dwellings	4,440
Rented Dwellings	465
Band Dwelling	0
Average Household Income (2013)	$83,370
Median Age (2013)	47.70

Source: ESRI Canada, 2013.

Real Estate

It is estimated that 16,437 single detached homes (not including seasonal dwellings) face onto (i.e. have frontage on) waterway areas in the TSW corridor communities. A large portion of these properties are located in the area from Lakefield to Lake Simcoe, accounting for 6,871 properties, and over half of them are located within the Kawartha Lakes area (TCI Management Consulting and EDP Consulting, 2007).

According to Royal LePage's Recreational Property Report (2013), in the Kawartha Lakes, a standard waterfront property, with land-access, is priced at approximately $325,000. This price is low compared to neighbouring cottage country, Muskoka, where average cottage prices are $700,000. Due to affordable list prices, waterfront property is in high demand in the Kawartha Lakes and is expected to increase. The main buyers moving to the area are families who plan to use the property, rather than investors (Royal LePage, 2013). Currently in the City of Kawartha Lakes, within the Bobcaygeon area, property taxes average 0.97%. An increase in the development in the area would instigate an increase in property across the City of Kawartha Lakes (CKL, 2014). The average value of waterfront properties depends on the water quality of the local lakes and overall watershed. The development around the Pigeon Lake has focussed in the urban centres of Bobcaygeon and Omemee. Pigeon Lake currently supports 1270 buildings (Table 2.5) with a density of 8.7 which is the number of buildings within a kilometre distance (Table 2.5).

Table 2.5. Building Parameters for Pigeon Lake

Lake	Building Count	Lake Area (ha)	Shoreline (km)	Density (bldgs/km)	Average Frontage	Density (Bldgs/ha)
Pigeon Lake	1270	5349	145.2	8.7	114.3	0.24

Source: City of Kawartha Lakes, 2002.

In order to accommodate the projected population growth by 2031 to 100,000 people, the City of Kawartha Lakes has included designated land to be developed within their growth plan. There are a total of 1,216 units in Draft Approved and Registered Plans in the Designated Greenfield Areas of Lindsay (730), Bobcaygeon (427), and Fenelon Falls (65 units) as of 2010. The housing demand analysis indicates a need for 10,681 new units from 2006 to 2031 averaging 428 units per year (Table 2.6). CKL staff indicates that there has been an average of approximately 338 new units built per year over the last 10 years (1999-2008). This slower growth approach allows for careful planning and better management strategies to ensure the highest protection of Kawartha Lakes including Pigeon Lake.

Table 2.6. Estimated Total Residence type (Projected for 2031).

	Single Detached	Semi Detached	Townhouses	Apartments	Seniors	TOTAL
Lindsay	13,171	194	3,815	1,951	442	19,572
Fenelon Falls	1,451	21	486	83	66	2,107
Bobcaygeon	5,395	52	539	781		6,767
Omemee	1,533		183			1,716
Sub-total	21,550	267	5,023	2,815	508	30,162
Hamlets	3,285					3,285
Conversions	6,105	0	0	0	0	6,105
TOTAL	30,940	267	5,023	2,815	508	39,552
Average persons per unit (in	2.62	2.62	1.78	1.51	1.2	

2031)							

Source: City of Kawartha Lakes

2.5 Industry and Employment

The main industries in the CKL include retail, manufacturing, agriculture, and tourism, as shown in Table 2.7 below.

Table 2.7. CKL Economic Contributions by Industry in 2007

Industry	Economic Contribution (2007)
Manufacturing	$340 million
Agriculture	$243 million
Retail	$600 million
Tourism	$100 million

Source: Reprinted from CKL, 2010.

Agriculture

Agriculture is one of the largest economic contributors to the City of Kawartha Lakes (Table 2.7). This industry supports a number of year round and seasonal jobs and businesses while contributing largely to the economic development of the CKL (CKL, 2010). The total number of people employed within the agricultural sector is approximately 15,558 (OMAFRA, 2013). The agricultural sector is the largest land user within the city boundaries and the Pigeon Lake watershed. A total of 53,446 ha represents the total land area used for farming which is composed of approximately 1366 individual farms (OMAFRA, 2013). Approximately 69% (26,645 ha) of the total farmland area is cropland and an additional 31% (11, 828 ha) represents natural lands used for pasture (Figure 2.1). Table 2.9 demonstrates the economic contribution of agricultural income derived from the land usage is well supported as oilseed and grain farming represented the highest gross income of all farming activities. Dairy and cattle farms demonstrated significant economic returns, however similar to cropland farming they have the ability to contribute substantial amounts of nutrients to water bodies if not managed properly.

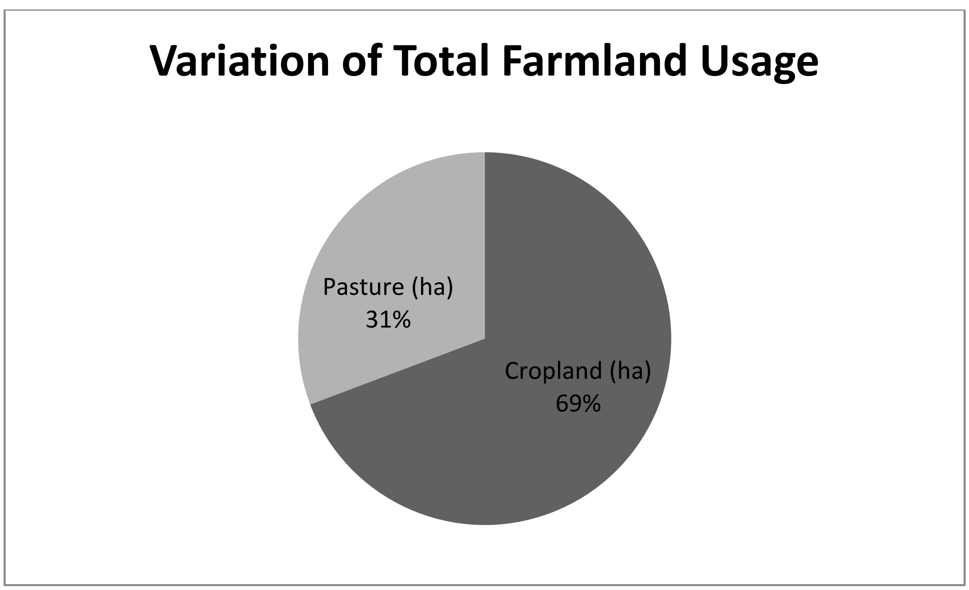

Figure 1.2. Farmland area (ha) delineated by usage for the City of Kawartha Lakes (OMAFRA, 2013).

Table 2.9. The Number of Farms by Industry in the City of Kawartha Lakes according to Gross Income.

Farms by Industry Group	Number of Farms	Gross Income, $
Oilseed and grain farming	146	29,000,000
Dairy cattle and milk	64	21,400,000
Beef cattle ranching	411	20,400,000
Hog and pig production	3	2,700,000
Greenhouse, nursery and floriculture	31	4,500,000
Vegetable and melon farming	19	2,700,000
Sheep and goat farming	56	-
Poultry and egg production	14	-
Other animal production	246	-
Fruit and tree nut farming	10	-
Other crop farming	366	-

Source: OMAFRA 2013.

Within the Pigeon Lake watershed agriculture occupies 28% of land. Even though it is mostly concentrated in the southern portion of the watersheds, the movement of nutrients from manure and fertilizers via lake tributaries can have whole lake impacts and thus supports ongoing water quality monitoring programs and an overall lake management plan.

Recreation and Tourism

The CKL, including the areas around Pigeon Lake, offers a wide variety of recreational opportunities. Healthy local lakes encourage tourism, which in turn strengthen the job market within tourism industry. Seasonal and permanent residences around the lakes have resulted in the growth of property management businesses, food services, and other support industries. Due to the large number of navigable lakes and waterways, the main recreation attractions tend to be seasonal outdoor activities. Some of the key recreation activities available around Pigeon Lake include:

- The navigable waterways of the TSW system,
- Emily Provincial Park near the mouth of Pigeon River,
- Seasonally used areas such as private cottages, campsites and trailer parks,
- Fishing (ice fishing included), including leisure, and competitive tournaments, and
- Local parks and beaches (The Tourism Company and CKL, 2008).

Tourism is extremely important to the regional economy of the CKL, contributing $100 million in 2012. The projected industrial growth in CKL will be in the commercial sector with the focus on tourists and seasonal and permanent residents (Dillon Consulting, 2012).

In 2012, it was estimated that there were close to 1 million visits to CKL which generated 101,841,825 million dollars in visitor spending (CKL 2016). Figure 2.3 illustrates the percentage of person visits to various recreational activities. The highest person visits corresponded with Outdoor and Sports Activities category (Figure 2.3). Most of the visitors to the area were travelling for pleasure or visiting friends or relatives. The most popular times of the year for people to visit the area were January through March and July through September.

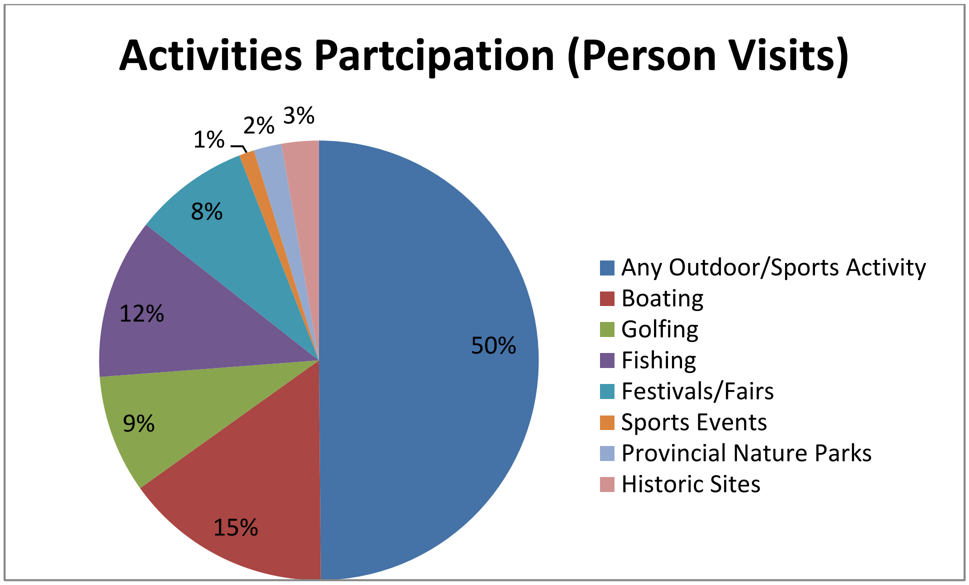

Figure 1.3. The distribution of person visits varies among several categories of activities participated in. Outdoor/ Sports activities comprised 50% or person visits during 2012 (CKL 2016).

Pigeon Lake supports excellent recreational fishing in both winter and summer. Many fishing guides and online fishing forums refer to Pigeon Lake as a hot spot for muskellunge fishing. The Ministry of Natural Resources and Forestry dedicates a weekend in February and July as Ontario Family Fishing Weekends which are license free events correlating with the most popular times of year for visitors to the CKL area meant to encourage new members to the angler community.

Emily Provincial Park, on the eastern bank of the Pigeon River, received over 81,000 visitors in 2010 (Ontario Parks, 2015). This park offers opportunities for camping, hiking, wildlife viewing, swimming, paddling, and biking. The attraction of over 81,000 visitors impacts the economy positively; however it also has the potential to impact the Pigeon Lake watershed in a variety of including a human pathway for invasive species introduction if management strategies are not considered (Ontario Invasive Plant Council 2016).

There are many private businesses in the vicinity of Pigeon Lake that support the tourist industry and water-based recreation. Boating and fishing accounted for 15% and 12%, respectively of the total person visits to the Kawartha Lakes Region (Figure 2.3). These businesses benefit from the recreation opportunities the lakes provide, and help re-circulate money into the local economy.

Bobcaygeon is located at the northern portion of the lake and is home to one of the busiest locks along the TSW, Lock 32. The downtown is filled with mainly locally owned shops and restaurants which contribute to the overall 101,841,825 million dollars in visitor spending (CKL 2016). It offers a variety of events throughout the year including numerous fishing tournaments, opening of the lock festivities, plant and flower sales, home and garden shows and tours, Canada Day parade and fireworks, Jeep jamborees, Ontario Open Fiddle & Step Dance Competition, antique and classic car show, a fall fair, Festival of Trees, Christmas Galas and more. The Globus Theatre at the Lakeview Arts Barn hosts performances throughout the year. In the winter, there are opportunities for public skating and many trails for skiing and snowmobiling.

Wild Rice

The region around Pigeon Lake was historically occupied by First Nations peoples including the Mississaugas of the Anishnaabeg Nation who likely had very little environmental impact. *Zizania* spp. also known as Wild rice or Manomin is an emergent aquatic plant which is native to Pigeon Lake and other local lakes. It is of particular importance to First Nations Anishinabek, who relies on its environmental, ceremonial, and dietary benefits to sustain their traditional cultural heritage. First Nations have been active in the Kawartha Lakes region for centuries and wild rice has always been a staple food source in their community. The recent proliferation of wild rice in southern Pigeon Lake is considered a significant harvesting opportunity for First Nations, which they have a constitutional right to harvest.

Over the last several years, wild rice growth has increased significantly across southern Pigeon Lake. The exact reason(s) for its proliferation has not been scientifically characterized, but is likely due to a combination of factors including changes to the aquatic ecosystem (e.g., increased water clarity and growing conditions), and human use (e.g., direct planting and harvesting). From an ecological perspective wild rice has phosphorus sequestration ability while the dense patches of wild rice acts as a food source for many birds and water fowl coupled with a nursery effect for juvenile fish can be considered ecologically significant. The proliferation of growth is observed in 5 distinct areas of the southern portion of Pigeon Lake (Figure 2.1). The plants have been providing excellent yields for harvesting by First Nations and thus harvesting is encouraged within their communities. There have been recent controversial discussions about the population of wild rice on Pigeon Lake in the southern portion of the lake including shoreline property owners and their concerns of restricted boat access as a result of the dense patches of rice. Current ongoing attempts are being made to unite both parties to work towards a solution on how to live harmoniously with the native wild rice.

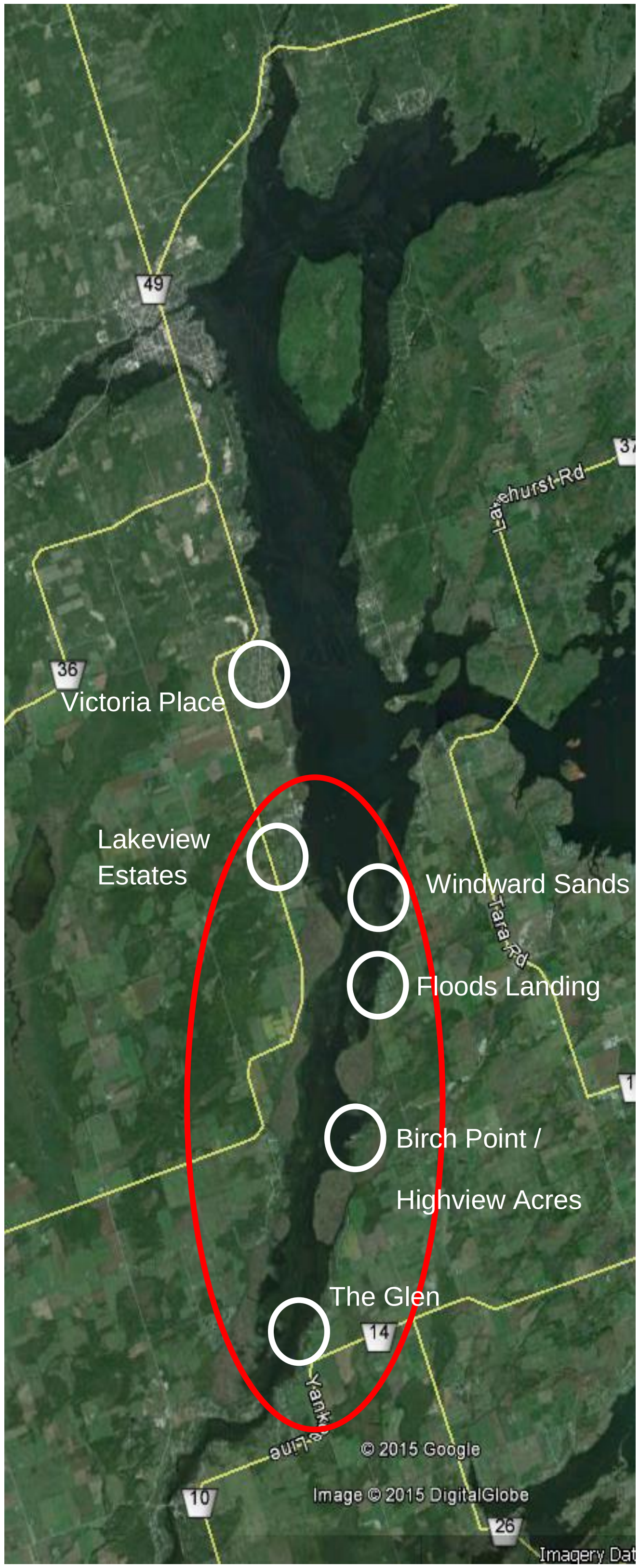

Figure 2.1: Map showing locations of nuisance aquatic plants. The areas circled in white indicate specific shoreline communities that have expressed concern. Red indicates the general location (southern Pigeon Lake) of heavy aquatic plant growth.

3.0 Land Use

Land use within the Pigeon Lake watershed has been delineated, using the Ecological Land Classification (ELC) system for Southern Ontario, with the aid of air photography and Geographic Information System (GIS) software by the GIS technicians of Kawartha Conservation. The watershed land use has been subdivided into the following categories: agriculture (cropland and pasture), forest, wetland and treed wetland, meadow, urban areas, rural development, manicured open space, and transportation (roads) (Figure 3.1).

3.1 Summary of Observations, Key Issues, and Information Gaps

OBSERVATIONS

- ***28% of the watershed land area is utilized for agricultural activities***. The production of alfalfa and soybeans were identified as the dominating cash crops within the City of Kawartha Lakes, with beef cattle representing the largest portion of livestock.

- ***40% of the study area is forest-covered*.** This is above the provincial guideline recommendation of 30% for maintaining ecological integrity.

- ***Almost 15% of the study area is wetlands including marshland and treed wetland***. This value is above the recommended guideline of 10%. Much of the wetland area is located in the northern part of the watershed where there is less development and farmland.

- ***Urban development in Pigeon Lake planning area is concentrated within Bobcaygeon, Omemee, and along shoreline areas*.** The shoreline of Pigeon Lake is approximately 147 kilometres (km) in length and as of 2013, approximately 69% of the shoreline on Pigeon Lake has been developed within a 30-metre distance from shore.

KEY ISSUES

- ***The implications of agricultural activities and rural residential development on sensitive ecosystems*.** Certain farming practices have been linked to water quality degradation, and when paired with the continued development of the landscape, especially along shorelines, these issues may be compounded.

- ***Urban growth within Bobcaygeon and Omemee***. As infrastructure continues to develop in these populated areas, there will be an increase in impervious surfaces within the watershed, having negative impacts on the adjacent terrestrial and aquatic ecosystems.

- ***Agriculture is one of the largest economic contributors to the City of Kawartha Lakes*.** The agriculture industry is a strong contributor to the local economy and also plays a significant role in employment over the entire watershed. However, agricultural practices can negatively impact the lake by contributing excess nutrients through various processes. This is discussed in more detail in the Water Quality section.

INFORMATION GAPS

- ***Recreational trail use within the Kawartha Lakes watershed has little to no data available.*** It is important to consider possible other land uses in order to have effective management strategies. What is the percentage of trails being used for recreational use? Is there environmental impact as a result of ATVs and other motorized vehicles? Has invasive species been mapped in these areas?

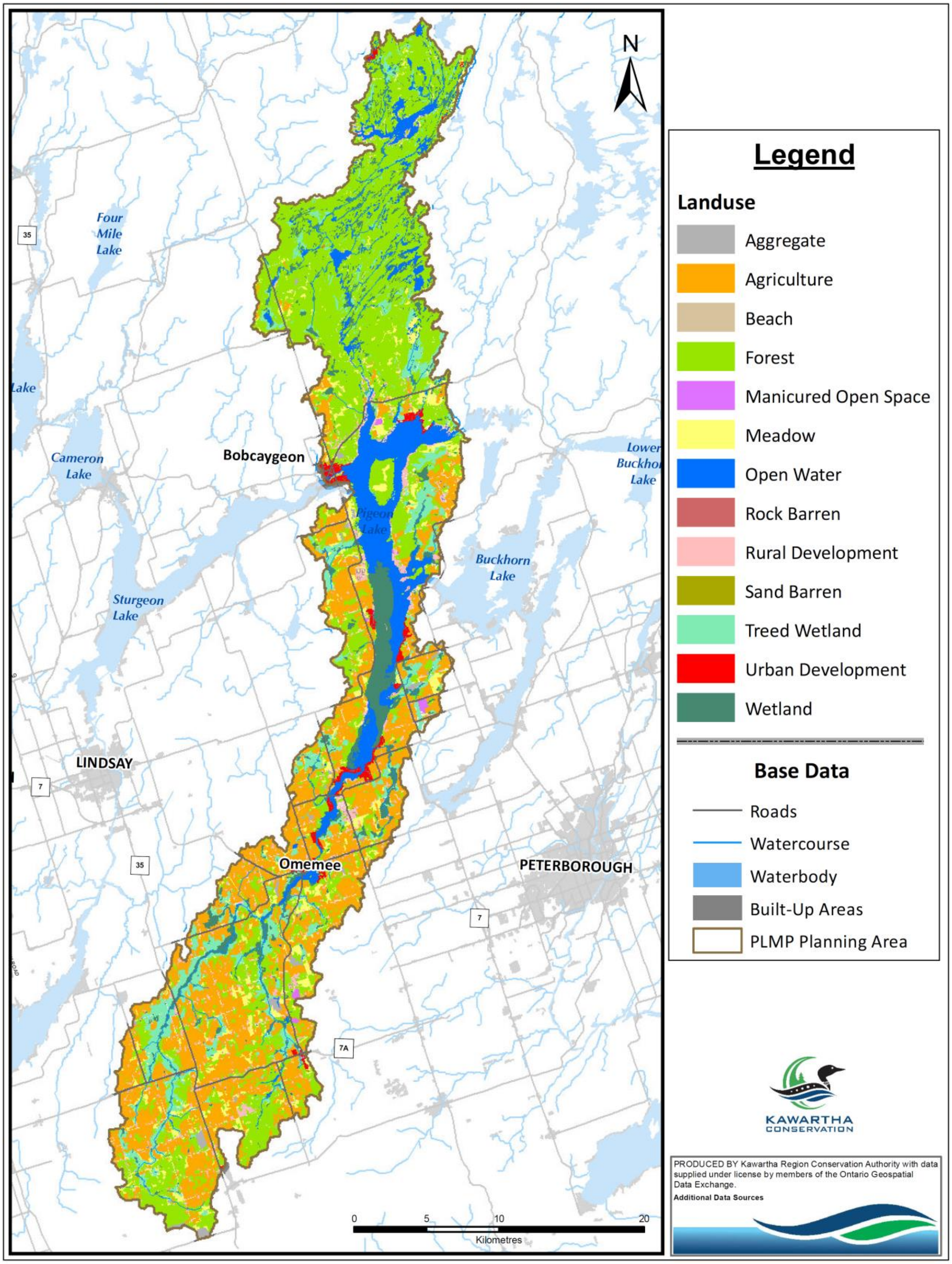

Figure 3.1. Land Use in the Pigeon Lake Watershed.

3.2 Human Use Areas

Agricultural Lands

Land use delineation of Pigeon Lake watershed identified 28%, or 190 km^2 of the total area, supporting agricultural practices. The subwatersheds, including Potash creek and Reforestation Creek (aka Chatten's Creek or White's Creek) contribute the largest portion of agricultural land use within the overall Pigeon Lake watershed encompassing 55% and 52% respectively, of the area (Table 3.1).

According to the 2011 Census data, the major crop production in the City of Kawartha Lakes includes (in descending order); alfalfa and alfalfa mixtures (226 km^2), soybeans (118 km^2), corn (99 km^2), hay and fodder crops (84 km^2), and wheat (74 km^2) (Statistics Canada, 2011). As the proximity of Pigeon Lake is central to the CKL area is assumed with confidence that the same crops dominate within the study area.

Table 3.1. Major Land Use Within the Pigeon Lake Watershed.

			Aggregate		Agriculture		Forest		Meadow		Treed Wetland		Wetland		Urban Development		Rural Development	
	Total Ha	**Total %**	**Ha**	**%**	**Ha**	**%**	**Ha**	**%**	**Ha**	**%**	**Ha**	**%**	**Ha**	**%**	**Ha**	**%**	**Ha**	**%**
Eels Creek Subwatershed	**1932**	**2.9%**	6.4	0.3	120.1	6.2	1087.12	56.28	135.15	7.00	391.77	20.28	69.67	3.61	3.92	0.20	27.10	1.40
Fleetwood Creek Subwatershed	**7290**	**11.1%**	88.1	1.2	2565.5	35.2	2760.31	37.87	512.38	7.03	510.03	7.00	299.51	4.11	40.96	0.56	314.30	4.31
Nogies Creek Subwatershed	**18489**	**28.1%**	10.2	0.1	137.8	0.8	13708.20	74.14	399.33	2.16	893.15	4.83	1304.33	7.05	0.00	0.00	226.50	1.23
Pigeon Lake Excluding the Lake	**14366**	**21.8%**	120.9	0.8	4583.5	31.9	4204.82	29.27	1082.68	7.54	1471.30	10.24	820.69	5.71	546.30	3.80	927.03	6.45
Pigeon River Subwatershed	**20103**	**30.5%**	228.6	1.1	9647.0	47.9	4112.39	20.46	1205.13	5.99	2320.86	11.54	804.66	4.00	187.61	0.93	885.01	4.40
Potash Creek Subwatershed	**2176**	**3.3%**	9.6	0.4	1199.9	55.2	269.36	12.38	136.99	6.30	285.71	13.13	125.73	5.78	3.88	0.18	107.41	4.94
Reforestation Creek (Chatten`s Creek) Subwatershed	**1533**	**2.3%**	10.8	0.7	797.6	52.0	291.78	19.04	68.81	4.49	208.20	13.58	74.09	4.83	4.27	0.28	51.45	3.36
Grand Total	**65888**	**100%**	474.6	0.7	19051.5	28.9	26433.98	40.12	3540.45	5.37	6081.01	9.23	3498.68	5.31	786.94	1.19	2538.8	3.85

Livestock production is dominated by beef cattle, with 13,712 head of cows present in the City of Kawartha Lakes (Statistics Canada, 2012). There are also 4,632 dairy cattle. Additionally, the total number of swine in the City is approximately 6,149 (Statistics Canada, 2012). A large number of farms within the watershed use various forms of soil conservation practices including, but not limited to, crop rotation, minimum or no-till (28% of all cultivated lands), crop residue retention on the surface (42%), as well as permanent grass cover and grassed waterways. 30% of crop lands are still prepared for seeding with use of conventional tillage (Statistics Canada, 2012).

Over 138 km^2 or 21% of agricultural land in the City of Kawartha Lakes receives manure application as fertilizer (Statistics Canada, 2012). Farmers apply manure by several methods, via the incorporation into the soil in a solid or liquid form, as well as surface application without mechanically incorporation into the fields. Furthermore, commercial fertilizers are applied to 348 km^2 or 53% of agricultural lands or 89% of all seeded lands in the City of Kawartha Lakes (Statistics Canada, 2012).

Transportation

The road network within the study area is quite intensive. It includes provincial highways (Hwy 35 & 7), regional roads (County Roads 8, 24, 49 and 35) and numerous local roads, drives and lanes, both paved and unpaved. According to ELC calculations less than 1% of the watershed is covered by the transportation network. Natural areas for wildlife can be interrupted and habitat segmentation can occur. Additionally, the development of roads and the increase in traffic can accelerate the road mortality of turtles and other animals therefore supporting the need for a multi-perspective management plan.

Road salt is an emerging contaminant to local water ways and can have a great impact on primary and secondary producers as well as lake chemistry as a whole. A baseline study is needed in the CKL to quantify concentrations within the Pigeon Lake watershed and the Kawartha Lakes Watershed as a whole.

Rural Residential Developments

Rural residential developments are closely related to agricultural land use as many farm households are categorized under this same agricultural land use. Furthermore, rural residential development land use includes a number of recently developed small residential settlements throughout the study area, including those situated along lake shorelines, but not part of the urban centres. Some older villages and hamlets that exist in the watershed also fall under this land use criteria. According to the 2008 ELC data rural developments occupy approximately 35 km^2 or 7.42% of the Pigeon Lake watershed (Table 3.1).

Urban Development

The major urban centre within the Pigeon Lake watershed is Bobcaygeon, located in the northern portion of Pigeon Lake. According to the City of Kawartha Lakes Official Plan, a large part of future growth is expected within the Bobcaygeon designated urban area (City of Kawartha Lakes, 2010). A less populated urban centre, Omemee, is located in the southern portion of the lake and is also is part of the secondary growth plan. The current trend of urban development results in an increased proportion of impervious surfaces (concrete, asphalt, etc.) and associated urban stormwater runoff with high concentrations of various pollutants, a greater demand on water supplies, and an increase in waste (both landfill items and sewage) all of which have a direct impact on adjacent water bodies.

Lakeshore Areas

The shoreline area of the lake is already highly impacted by human activities. According to aerial photo interpretation using Ecological Land Classification methodology (Lee et al., 1998), currently 29% of the Pigeon Lake shoreline is developed within 30 m of the lake. In summer 2015, Kawartha Conservation conducted a rapid shoreline classification project along the entire shoreline of Pigeon Lake. This study was conducted by travelling along the shoreline in a boat and documenting the major types of land use along the shore-water interface. In total, 142.2 km of shoreline was characterized. Results from the data indicate that approximately 57% (80.7 km) of the shore-water interface is occupied by natural vegetation, 26% (37.4 km) is occupied by natural non-vegetated lands, and 17% (24.1 km) is occupied by artificial installations (Tables 3.2, 3.3 and 3.4).

The good water quality in Pigeon Lake, particularly in the north end, is an attractive feature to both landowners and visitors. As a result, the population of the lakeshore areas is growing. More and more cottages are being converted into permanent residences.

Within a 30 m buffer of Pigeon Lake, 12.0% of the area is occupied by urban development and 17.4% by rural development. Lakeshore areas with a considerable density of residential properties are located along mid-eastern, and northern shore of the lake.

Many of houses along shorelines were initially built as summer cottages but later converted to permanent residences. Furthermore, the majority of the waterfront residences have altered shorelines that tend to lack the buffering capacity and habitat-producing aspects of a natural shoreline. These residences usually have private septic systems and private wells for water use. A number of trailer parks and camps exist on the shoreline of Pigeon Lake. They concentrate human activities and place additional burdens on the lakes' water quality. It is anticipated that shoreline development will increase as recreational opportunities attract more tourists to the watershed, and as shoreline cottages continue to be transformed into year-round homes. More nearshore subdivisions and houses in backlots will also be built.

Table 3.2. Length and Percentage of the Surveyed Pigeon Lake Shoreline Occupied by Categories of Natural Vegetation

Shoreline Category	Length (km)	Percentage of Total Shoreline (%)
Marsh	49.3	34.7
Forest	22.5	15.9
Swamp	5.2	3.6
Meadow	3.7	2.6
Other	0.02	<0.1
Bog	0	0
Fen	0	0
TOTAL	**80.7**	**56.8**

Table 3.3. Length and Percentage of the Surveyed Pigeon Lake Shoreline Occupied by Categories of Natural, Non-vegetation

Shoreline Category	Length (km)	Percentage of Total Shoreline (%)
Cobble	23.9	16.8
Boulder	8.6	6.1
Bedrock	1.8	1.2
Open Water	1.7	1.2
Gravel	0.7	0.5
Sand	0.7	0.5
Other	0	0
TOTAL	**37.4**	**26.3**

Table 3.4. Length and Percentage of the Surveyed Pigeon Lake Shoreline Occupied by Artificial Installations

Shoreline Category	Length (km)	Percentage of Total Shoreline (%)
Armourstone	6.1	4.3
Manicured Lawn	5.4	3.8
Concrete	4.1	2.9
Wooden	3.2	2.3
Steel	1.6	1.1
Beach	1.4	1.0
Riprap	1.1	0.8
Flagstone	0.6	0.4
Gabion Baskets	0.5	0.4
Other	0.2	0.1
Rubber	<0.1	<0.1
TOTAL	**24.1**	**16.9**

3.3 Natural Areas

Forests

A detailed forest characterization is given in Chapter 9. In this section forests are described only as a category of land use.

Prior to the arrival of European settlers, most of the study area was forested, locally interspersed with lakes, wetlands and rock barrens. On the better drained loamy soils, sandy and more gravelly soils, the forests were dominated by sugar maple, American beech, American basswood, white ash, red, white and bur oak, red pine, white spruce and scattered white pine. In locations where the soil has more moisture, the dominant forest cover shifted to American and white elm, poplar or aspen, black ash and eastern white cedar (Helleiner et al., 2009). Drier sites tend to host white and red pine and red oak (Ecological and Stratification Working Group, 1995).

As of 2008, ELC calculations indicate that the Pigeon Lake watershed contains 264 km^2 of forest, representing 40% of the total land area (Table 3.1). The forest cover in each individual subwatershed varies from 12% in the Potash Creek subwatershed to 74% in the Nogies Creek subwatershed. The amount of forest cover has a direct effect on water quality and ecological integrity. The forest cover in the Pigeon Lake watershed is above the provincial guideline recommendation of 30% for maintaining ecological integrity.

Meadows

Meadow ecosystems describe a community type in which herbaceous plants such as grasses, sedges, and forbs (wildflowers) dominate over woody plants (they are treeless or nearly treeless), typically occurring on deep soils (Rodger, 1998). Meadows are important habitat for many local and migrating pollinators in addition to many bird species.

The Pigeon Lake watershed contains of 35 km^2 of meadow, representing 5% of the total watershed area (Table 3.1). The proportion of meadow in each subwatershed varies from 1.3km^2 in Eels Creek to 12km^2 in the Pigeon Lake subwatershed.

Protected Areas

Protected areas within the Pigeon Lake watershed include provincial and conservation authority owned or operated lands. The provincial designate, Ontario Parks has the responsibility of ensuring that Ontario's Provincial Parks protect significant natural, cultural and recreational environments. The sole Provincial Park located within the Pigeon Lake watershed is Emily Provincial Park located in the southern portion of the lake. The park is 83 hectares and offers opportunities for camping, hiking, wildlife viewing, paddling, and biking. It has nice long beach for swimming. It received 81,198 visitors in 2010 (Ontario Parks, 2011).

Wetlands

A detailed wetland characterization is given in Chapter 9. In this section wetlands are described only as a category of land use.

A wetland is land that is saturated with water for a sufficient period of time to promote wetland or aquatic processes as indicated by poorly drained soils, hydrophytic vegetation (plants adapted to grow in water), and biological activities which are adapted to a wet environment (NWWG, 1988).

The Pigeon Lake watershed contains 34km^2 of wetland (5% of the watershed) (Table 3.1). Wetland cover for the subwatersheds varies from 4.54% for the Fleetwood Creek subwatershed up to 8.20% for the Nogies Creek subwatershed. There are approximately eight evaluated and designated Provincially Significant Wetlands in the Pigeon Lake watershed, occupying 54 km^2 of the study area (Figure 9.8, Chapter 9).

Provincially Significant Wetlands (PSWs) are those that have been evaluated and scored using a point-based system known as the Ontario Wetland Evaluation System (OWES), developed by the Ministry of Natural Resources (MNR, 2011). Wetlands are evaluated based on four different criteria. The first, the biological component, measures the productivity and habitat diversity of the wetland. The second, the social component, grades the direct human uses of wetlands including economic products, recreational and educational activities. The third, the hydrological component assesses water-related values, including contributions to groundwater recharge, improvements to water quality, and minimizing flooding. The last, the special features component is focused on the rarity of wetlands in the area, the occurrence of rare or species at risk, habitat quality and the age of the ecosystem, amongst other variables (MNR, 2011). A wetland is deemed significant if it gets a total of 600 or more points (to a maximum of 1000) or 200 or more points in either the Biological Component or the Special Features Component.

4.0 Physical Characteristics

4.1 Summary of Observations, Key Issues, and Information Gaps

OBSERVATIONS

- **The Pigeon Lake watershed is part of a transition zone between the Canadian Shield granite formation and limestone formation.** It encompasses the Canadian Shield to the north and the Oak Ridges Moraine in the south. This area is a geological significant area.

- **The most prominent soil type is till plain and moraine**. The till plain soil is found mostly to the south where farming is more popular and the till moraine is found mostly central to the lake.

- **Bobcaygeon is a major aggregate source in south-central Ontario useful for asphalt**.

KEY ISSUES

- **Aggregate mining is intensified in the northern area of Pigeon Lake.** Its environmental impacts are great and long lasting. Mining also contributes positively to the local economy. The 5.07 million tons extracted in 2012 ranks the municipality second in the province in licensed aggregate extraction and represented approximately 10% of the total provincial production of 50 million tons in 2012.

- ***Natural Influences on Native aquatic vegetation.*** Are the natural flora and fauna changing as a result of natural influences such as climate change? Are there areas within the watershed that need better management strategies for protection/ mitigation for native aquatic vegetation?

INFORMATION GAPS

- ***Residual effects of historical mining may still exist.*** As mining practices have improved greatly over the past decade are there any residual effects of historical mining impacts in the Pigeon Lake watershed? Have any comparison studies been performed in the recent past?

- ***Environmental monitoring on inactive mining sites.*** Does monitoring data exist on inactive mines in the local area? Is there a potential or need to implement an environmental monitoring program as shifts to the landscapes occur through more intense storms and erosion?

- ***The only nutrient data analyzed is nitrogen and phosphorous.*** There is no data on how the chemistry of the lake changes with the shift in rock and soil formations from the southern portion of the watershed to the north. This data could be helpful when determining mitigation measures in areas where there are issues.

4.2 Geology

An estimated 480 to 460 million years ago, the Gulf of St. Lawrence in Eastern Ontario and the Michigan Basin to the south, flooded a large proportion of the North American Continent. The marine submergence lasted less than 20 million years in the vicinity of the Kawartha Lakes (Ecclestone & Cogley, 2009). The sediment deposited during this time began as a coarse grained conglomerate (reflecting proximity to shoreline) and eventually changed to a lime mud (similar to material deposited in shallow seas today that lack sediment input from rivers). Over time, this was compacted and cemented to form limestone, which makes up much of the Kawartha Lakes watershed today (Ecclestone & Cogley, 2009).

The Wisconsinan advance, the most recent glaciation, receded from the region approximately 12,000 years ago. Many of the surficial deposits from the glacier's advance were transported to the watershed (Ecclestone & Cogley, 2009). As the glaciers ceased their advancement, this facilitated the ponding of melt-water and resulted in pro-glacial lakes (Larsen, 1987). As they retreated the glaciers deposited material which represents the sand and clay till plains found today in the Kawartha Conservation watershed (Figure 4.1).

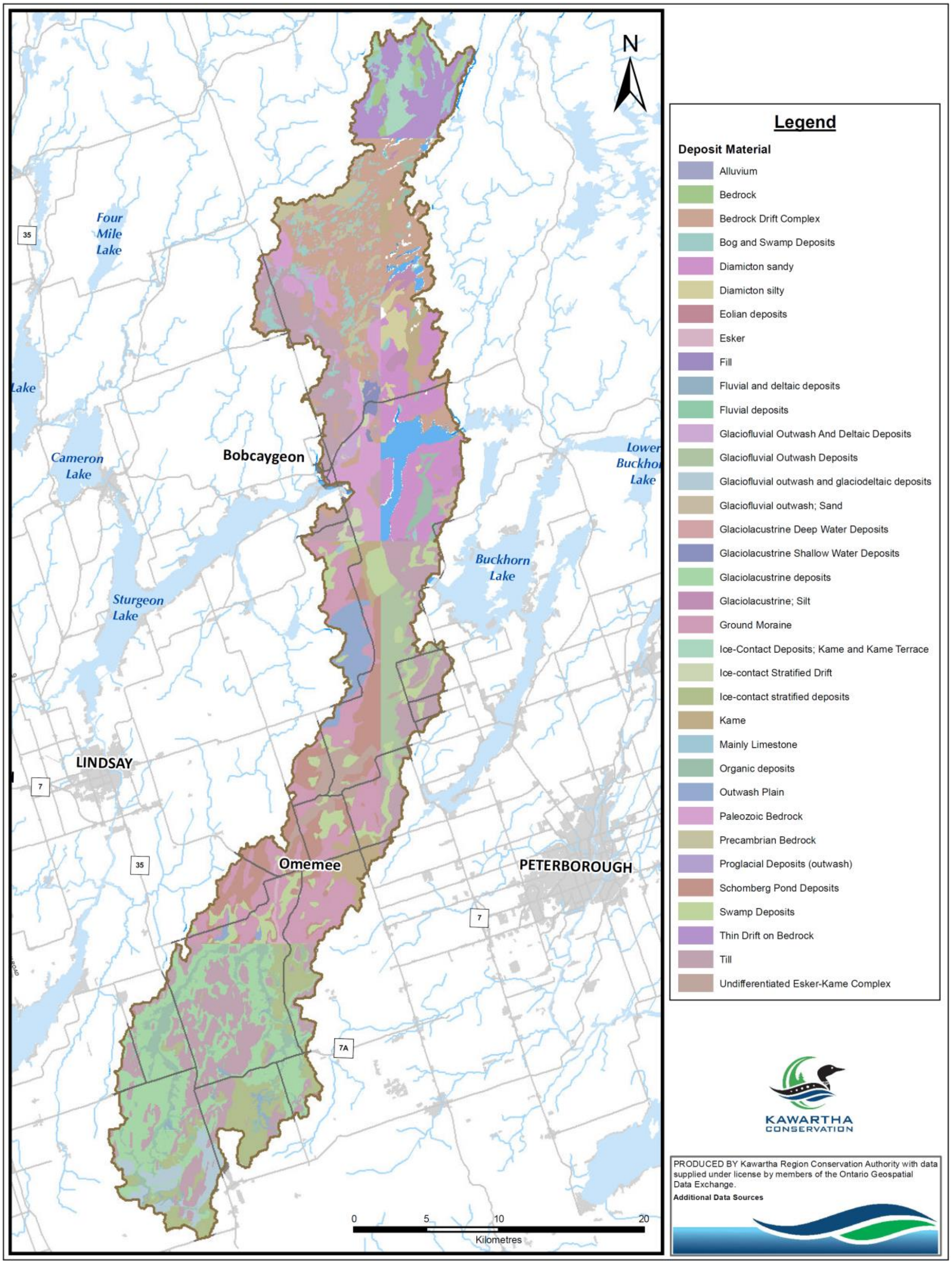

Figure 4.1. Surficial Geology of the Pigeon Lake Watershed.

4.3 Physiography and Topography

The Pigeon Lake watershed is unique as it spans a wide range of physiographic regions and topographies (Figure 4.2). This is due to the elongated shape of the watershed, which encompasses the Canadian Shield to the north and the Oak Ridges Moraine in the south. Formed during the Pleistocene epoch, the distinct differences in landscape within this watershed are still quite obvious today. Within the study area, there are eleven physiographic regions. Most noteworthy are the Bare Rock Ridges and Limestone Plain regions in the northern portion of the watershed and the Till Plains, Drumlins, and Karne Moraine regions found in the south (Barnett et al., 1998). The Pigeon River and Fleetwood Creek Subwatersheds in particular are characterized by their well-defined channels and higher gradients which originate from the Oak Ridges Moraine and provide an important source of fresh water to the surrounding areas.

The Omemee esker is one of the larger eskers in the area. It has a length of approximately 115km, extending from the south end of Pigeon Lake southward through Emily township, crossing Highway 7 one and a half miles west of Omemee. It extends a further 10km into Manvers Township. West of Omemee the esker forms a prominent 20 to 30m ridge, locally known as the "Hogsback". The road down the Manvers-Emily town ship line runs along the crest of the esker for almost two kilometres. A branch of esker from Downeyville joins the main esker just a mile north of Highway 7 (Hewitt, 1966).

The current surface topography and landscape of the study area is a direct result of Pleistocene glacial activity that impacted the area through deposition and meltwater. The topography of Pigeon Lake varies in elevation from 398.34 (masl) to 239.78 (masl) throughout the watershed (Figure 4.3).

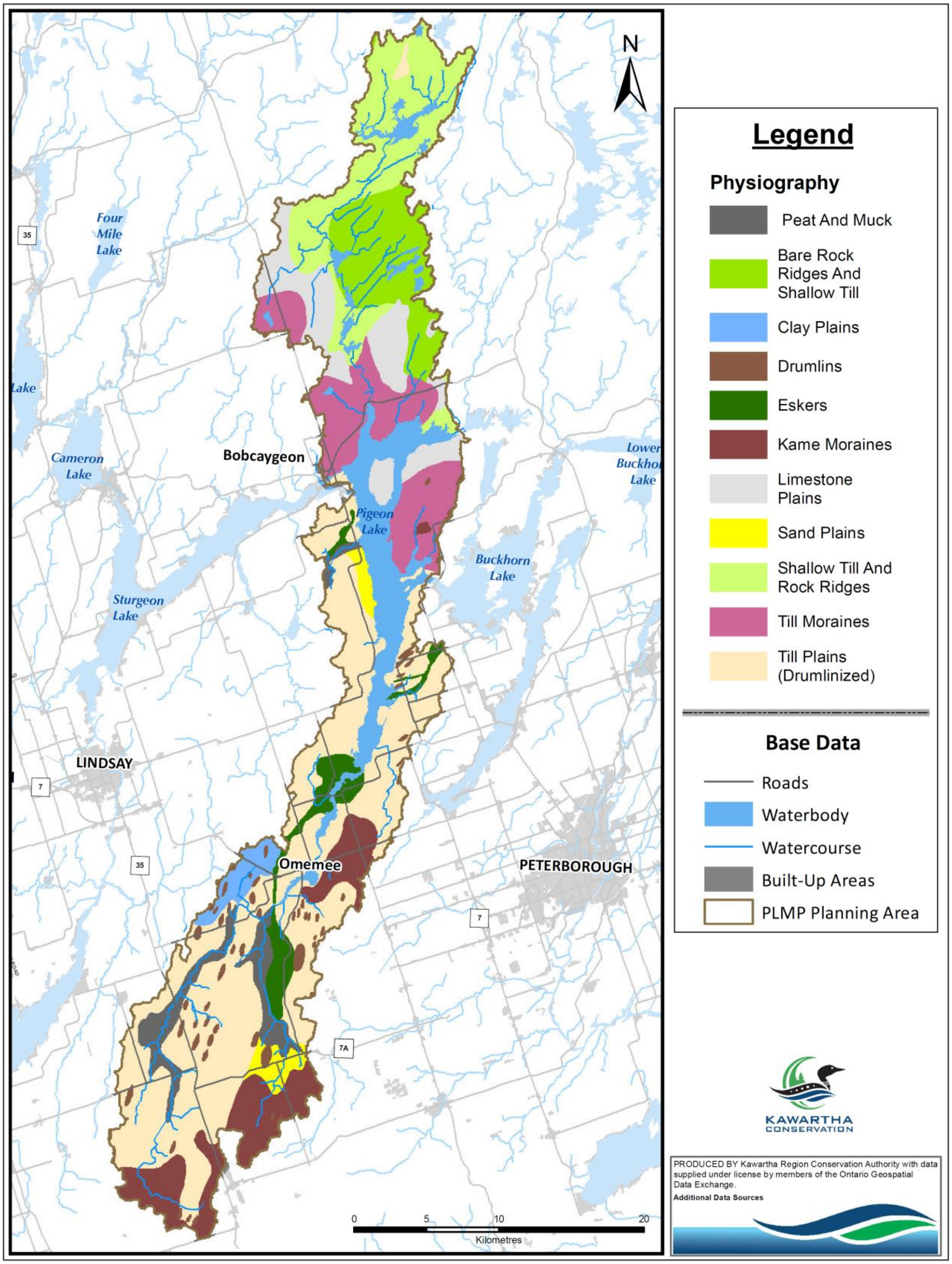

Figure 4.2. Physiography of the Pigeon Lake Watershed

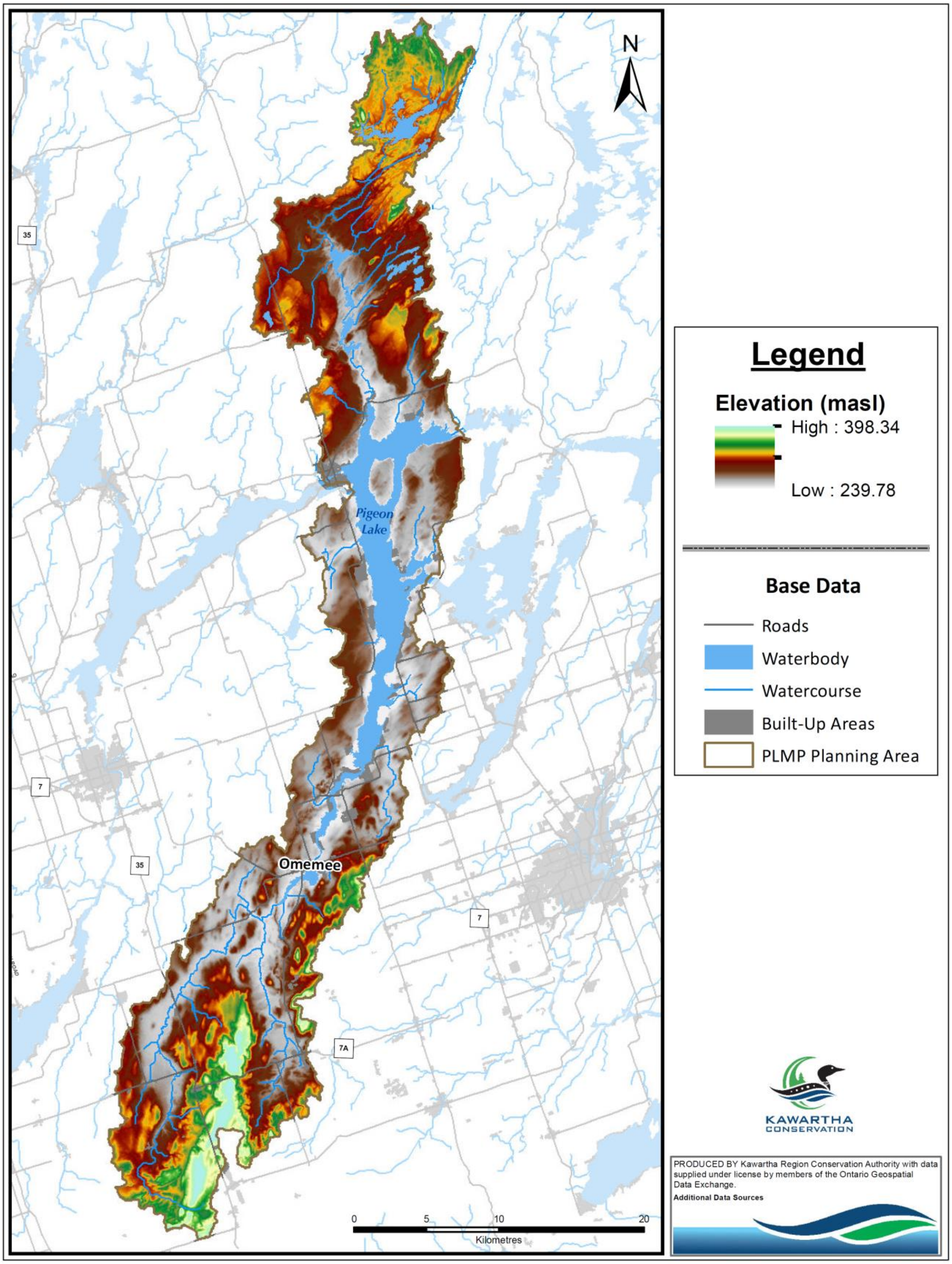

Figure 4.3 Topography of the Pigeon Lake Watershed

4.4 Soils

The landscapes, and by association the soils, differ greatly between the northern and the southern areas of the watershed. The transition zone closely mimics the major geological/physiographic boundary between the Canadian Shield and Great Lakes-St. Lawrence Lowland (Figure 4.4). On and adjacent to the Canadian Shield, the soils are frequently too thin to support successful agricultural activities and as a result, large areas of land have reverted back to modified forest cover (Helleiner et al., 2009). In fact, much of the higher ground on the Canadian Shield is exposed bedrock devoid of soil, as the glaciers removed and transported the soil that existed in the past (Helleiner et al., 2009).

The majority of the Pigeon Lake Watershed is Till Plain as classified by Chapman and Putnam (1984; 2007). A till plain is an extensive flat plain of glacial till that forms when a sheet of ice becomes detached from the main body of a glacier and melts in place, depositing the sediments it carried. Ground moraines are formed when the till melts out of the glacier in irregular heaps, forming rolling hills. The northern area of the watershed is described as Till Morraine due to the limestone transitioning into granite moving north. Agriculture is significantly decreased in this area due to the rocky nature of the soil.

4.5 Aggregate

Quaternary sources of mineral aggregate (sand, gravel etc.) include glaciofluvial ice-contact and outwash sediments, and glaciolacustrine and glaciomarine beach and delta deposits (Barnett, 1992). Outwash deposits are ideal for mineral aggregates as they occur as sheets that can be thick and extensive, with fairly uniform grain size and generally a lack of large boulders (Barnett, 1992). Sand and gravel extraction in the City of Kawartha Lakes is primarily concentrated in Manvers, Emily, Mariposa and Fenelon Townships. Licensed pits are typically located in large ice-contact and esker complexes, subaqueous fans and outwash deposits (Rowell, 2000). In the study area, the Omemee (Hogsback) Esker has many operational aggregate pits extracting material. The outwash deposits of the watershed have not been exploited to the same degree as the esker (ice-contact) deposits (Finamore and Bajc, 1983).

Quarries are concentrated in the northern portion of the Pigeon Lake Watershed, in which Paleozoic limestones, dolostones, and dolomitic limestones are extracted for crushed and decorative stone. The soft, friable siltstones and sandstone of the lowermost Shadow Lake Formation are considered unsuitable for most aggregate needs. The Gull River formation yields crushed stone that is used in southern Ontario variously for concrete, asphalt and granular base. Furthermore, the Bobcaygeon formation is a major aggregate source in south-central Ontario, with the upper and lower parts useful for concrete (not the middle), and with the entire formation useful for asphalt and granular base. The Bobcaygeon formation has been quarried elsewhere in the Province for lime and cement manufacturing, but the stone is susceptible to abrasion and is therefore less appealing for road building and construction aggregate. The Lindsay formation limestones are used for the manufacture of cement, but have a high clay content causing expansive properties, making them unsuitable for the production of concrete (Rowell, 2000).

Overall, the Kawartha Watershed contains significant aggregate deposits. In 2012, 5,070,923 metric tons of aggregate was licensed for extraction in the City of Kawartha Lakes. The 5.07 million tons ranks the municipality second in the province in licensed aggregate extraction and represented approximately 10% of the total provincial production of 50 million tons in 2012 (TOARC, 2012). This is an increase in production from to 4.7 million metric tons of aggregate licensed for extraction in 2011. The City of Kawartha Lakes has been in the top three aggregate producing municipalities for the five years period prior to the current production statistics released (2005-2009). ELC calculations indicate that aggregate land use (active and inactive) in the Pigeon Lake Watershed represents 1% of the total study area.

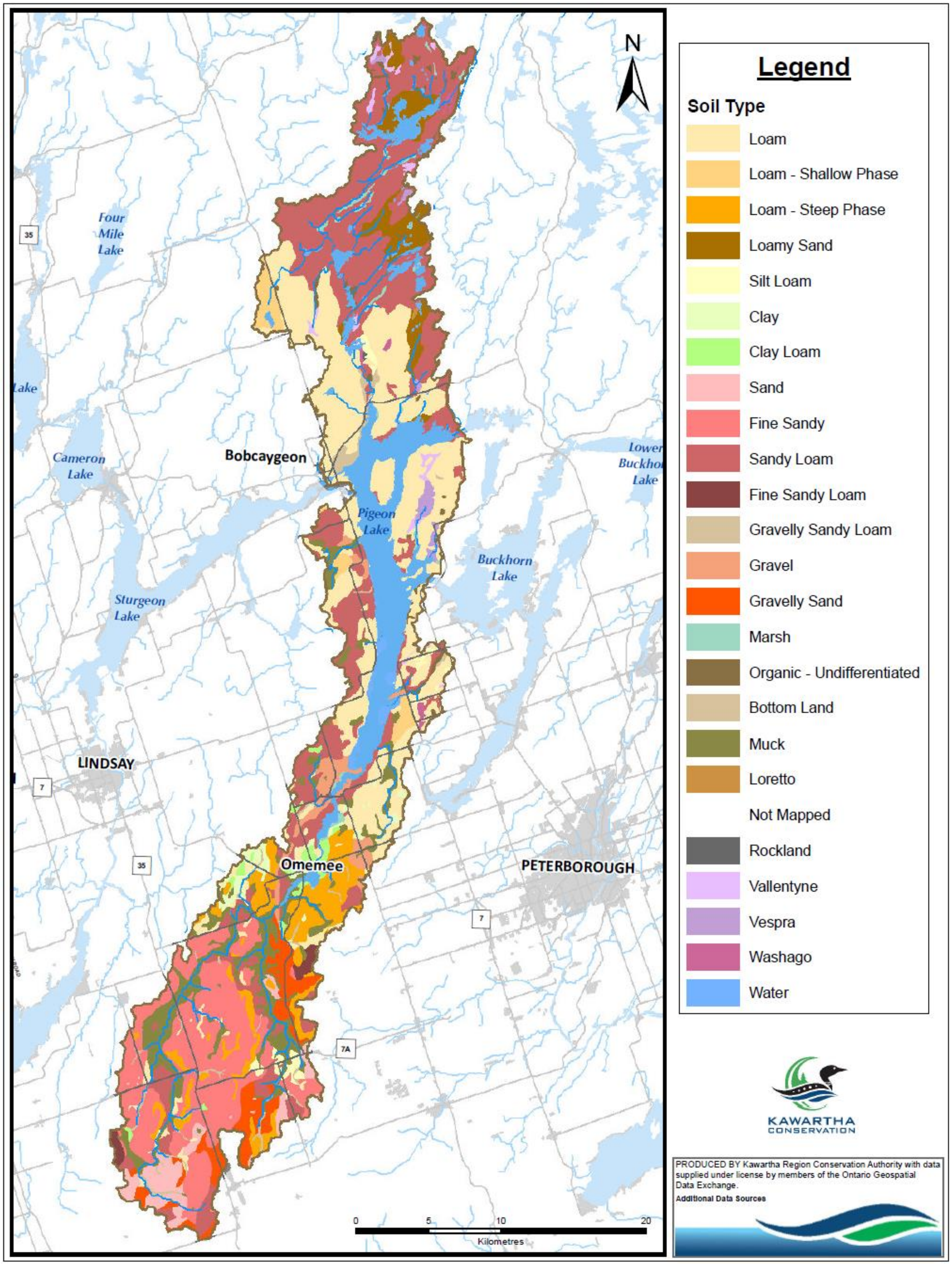

Figure 4.4. Soils in the Pigeon Lake Watershed

5.0 Climate

5.1 Summary of Observations, Key Issues, and Information Gaps

OBSERVATIONS

- **Climate within the Pigeon Lake planning area is described as moist continental, mid-latitude**; characterized by warm summers with occasional hot and humid spells and cold winters with snowstorms, strong winds and cold air from Continental Polar or Arctic air masses. Precipitation is fairly equally distributed through the year.

- **There are noticeable differences in air temperature and precipitation between the northern and southern portions of the watershed because of its longitudinal positioning**. The northern region is colder and much wetter.

KEY ISSUES

- **Climate conditions are currently projected to change as a part of the global climate change process.** Some of the possible changes to the weather are:
    - Higher temperatures in all seasons, especially in winter;
    - More variable precipitation with increases in both the incidence of drought and intense precipitation;
    - Decreased snow cover and increased amounts of rain in winter;
    - More violent storms and higher wind speeds.

- **Changes in climate may bring changes to the lake ecosystem that requires advance preparation and planning.**

INFORMATION GAPS

- **Current data on evaporation and evapotranspiration for the study area is not available**.

5.2 Introduction

Climate is a pattern or cycle of weather conditions including temperature, precipitation, wind, humidity and cloud movement over a given region, averaged over many years. The climate of a region is affected by its location on the planet, topography, as well as nearby water bodies and the respective currents.

The climate conditions of the Pigeon Lake core planning area is classified as a moist continental mid-latitude climate (Dfb climate category) with warm to cool summers and cold winters, as categorized by the Köppen Climate Classification System. The Köppen Climate Classification System is one of the most widely used climate classification systems (Strahler and Strahler, 1979). The system was developed by German climatologist

Wladimir Köppen (1846-1940), who divided the world's climates into six major categories based upon general air temperature and precipitation profiles in relation to latitude.

The Köppen system classifies a location's climate using mainly annual and monthly averages of temperature and precipitation ("normals"). The length of record required to determine climate normals for any particular location is 30 years, as defined by the World Meteorological Organization (WMO). For Canada, the normals are computed every 10 years by Environment Canada, utilizing all qualified monitoring stations. The current 30-year normals are determined from the weather data obtained during the 30-year period of 1981-2010.

According to the Köppen classification, the moist continental mid-latitude climate (Dfb climate category) is characterized by the average temperature of the warmest month greater than 10°C, while the coldest month is below -3°C. Also, no month has an average temperature over 22°C; precipitation is equally distributed across the year. Summers are warm with occasional hot and humid spells and winters are rather severe with snowstorms, strong winds and bitter cold from Continental Polar or Arctic air masses. This climate prevails in most of east-central Ontario with only little variability throughout the region (Figure 5.1).

For the reason that the core planning area of Pigeon Lake extends from north to south for more than 80 km, differences in local climate at different parts of the watershed are expected. Three Environment Canada climate monitoring stations in close proximity to the watershed are used to highlight those differences. Monitoring station in Janetville (station ID 6153853) describes climate conditions of the southern portion Pigeon Lake watershed; Lindsay location (Lindsay Frost, station ID 6164433) characterizes its central portion while Minden station (station ID 6165195) describes the northern portion.

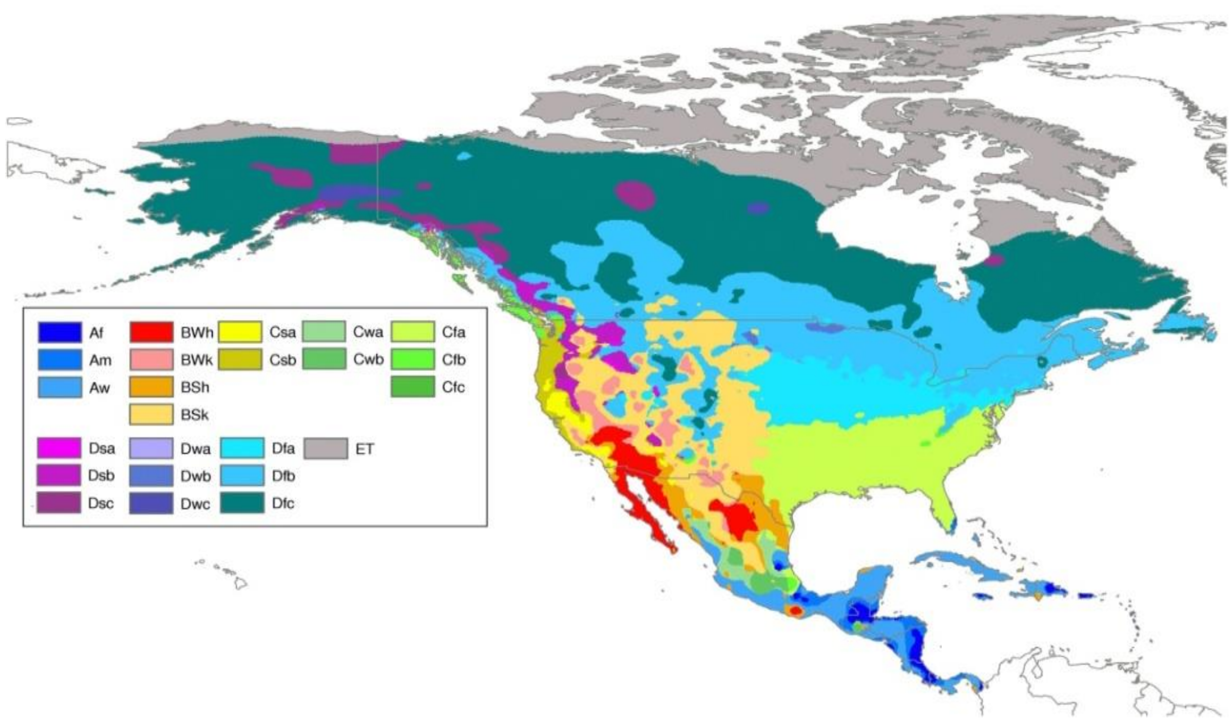

Figure 5.1. The Köppen Climate Classification System for North America
Source: http://www.eoearth.org

Average monthly temperatures and precipitation values for all monitoring locations are shown in Table 5.1 and Table 5.2, and Figure 5.2 and Figure 5.3. These data confirm the study area as belonging to the moist continental mid-latitude climate category. At the same time the variances in temperature and precipitation are noticeable. The south portion of the watershed (the Pigeon River subwatershed) is the warmest with average yearly temperature 6.7°C, while the Nogies Creek subwatershed that forms northern portion of the Pigeon Lake watershed, experiences average yearly air temperatures of only 5.6°C.

5.3 Air Temperature

As demonstrated in the Table 5.1, the difference in average monthly temperatures for the northern and southern portions of the watershed reaches up to 2°C. The average monthly air temperature in January, which is the coldest month of the year, ranges from -7.7°C as measured at Janetville climate station to -9.4°C observed in Minden (Table 5.1).

July is the warmest month with an average monthly temperature up to 20.3°C in the central portion of the watershed (Figure 5.2). August is the second warmest month, with an average temperature of about 19.0°C, while the average temperature in June ranges from 16.8°C to 17.5°C.

According to climate observation records, an extreme minimum temperature of -41.1°C was observed in January 1881 in Minden. For Janetville and Lindsay monitoring locations, the lowest recorded air temperature is not as cold, reaching -35.0°C and -36.5°C respectively. July 7, 1988 was the hottest day on record in the southern and central portions of the Pigeon Lake watershed, with a temperature of 36.5°C. For its northern portion that is represented by the Minden monitoring location, the highest temperature 35°C was recorded on July 1, 2002.

5.4 Precipitation

Due to its prolonged shape, there are notable differences in amount of precipitation throughout the watershed. Overall, its central portion, represented by the Lindsay climate monitoring station, is drier comparing to its north and southern edges. The long-term average amount of precipitation (snow and rain) recorded in Lindsay is 897 mm, Janetville is 949 mm, and Minden is 1056 mm in an average year (Figure 5.3). Approximately 20% of precipitation (170-230 mm) comes in the form of snow.

Precipitation is fairly evenly distributed throughout the year, with January-April being slightly drier than the rest of the year. The driest month of the year is February, which has on average approximately 6% of the total annual amount of precipitation. The largest average monthly precipitation for all three monitoring locations is observed in November and is approximately 10% of the total annual amount. The highest daily rainfall observed at climate monitoring locations ranged from 92.4 mm (Lindsay) to 110 mm (Janetville), all recorded in 1980.

Table 5.1. Average Monthly and Daily Extreme Values of Air Temperature and Precipitation for the Environment Canada Climate Monitoring Stations Janetville (6153853), Lindsay Frost (6164433) and Minden (6165195)

Characteristic	Location	Month												
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Air Temperature														
Daily Average (°C)	Janetville	-7.7	-6.5	-1.6	6	12.1	17.5	20.1	19.1	14.8	8.4	2.1	-4.5	**6.7**
	Lindsay	-8.4	-6.8	-1.8	6	12.5	17.7	20.3	19.2	14.8	8.2	2	-4.4	**6.6**
	Minden	-9.7	-7.8	-2.7	5.1	11.8	16.8	19.3	18.2	13.8	7.3	1	-5.6	**5.6**
Extreme Maximum (°C)	Janetville	13	13	24.5	30.5	33	34	**36.5**	36	33	27.5	21	18.5	
	Lindsay	11.5	11.5	24	29.5	32	34	**36.5**	36.5	32.5	27	21.1	17.5	
	Minden	11	13	23	30.5	34	34	**35.5**	35	33	28	23.3	17	
Extreme Minimum (°C)	Janetville	**-35**	-31	-31.5	-15	-5	-2	4	-0.5	-4	-9.5	-18.5	-33	
	Lindsay	**-36.5**	-35	-30.5	-14	-4	-2.5	5	1.7	-3.5	-9.4	-18.5	-34	
	Minden	**-41.1**	-39.4	-36.5	-24.4	-10	-3.9	-0.6	-3.3	-9.4	-13.9	-27.2	-40	
Precipitation														
Rainfall (mm)	Janetville	25.2	21.3	32.8	64.3	88.6	84	73.7	89.2	97.2	78.6	77.8	30.3	763
	Lindsay	22.4	22.2	30.4	57.5	87.3	82.6	75.8	85.7	88.2	74.9	72.3	29.4	728.6
	Minden	30.9	25.4	38.7	67.9	97.6	90.6	82.2	78	100.2	93.8	84.3	34.4	824
Snowfall (mm)	Janetville	47.2	34	29.4	10.3	0.1	0	0	0	0	2.1	21.2	42.3	186.4
	Lindsay	44.4	32.7	25.3	7.7	0	0	0	0	0	1.7	17.5	39	168.3
	Minden	58.8	41	32.5	10.9	0.2	0	0	0	0	3.4	25	60.3	232.1
Total Precipitation (mm)	Janetville	72.3	55.3	61.7	74.6	88.7	84	73.7	89.2	97.2	80.7	99	72.7	949
	Lindsay	66.8	54.9	55.7	65.2	87.3	82.6	75.8	85.7	88.2	76.6	89.8	68.5	896.9
	Minden	89.8	66.4	71.1	78.7	97.8	90.6	82.2	78	100.2	97.2	109.3	94.7	1056

Source: http://climate.weather.gc.ca/climate_normals

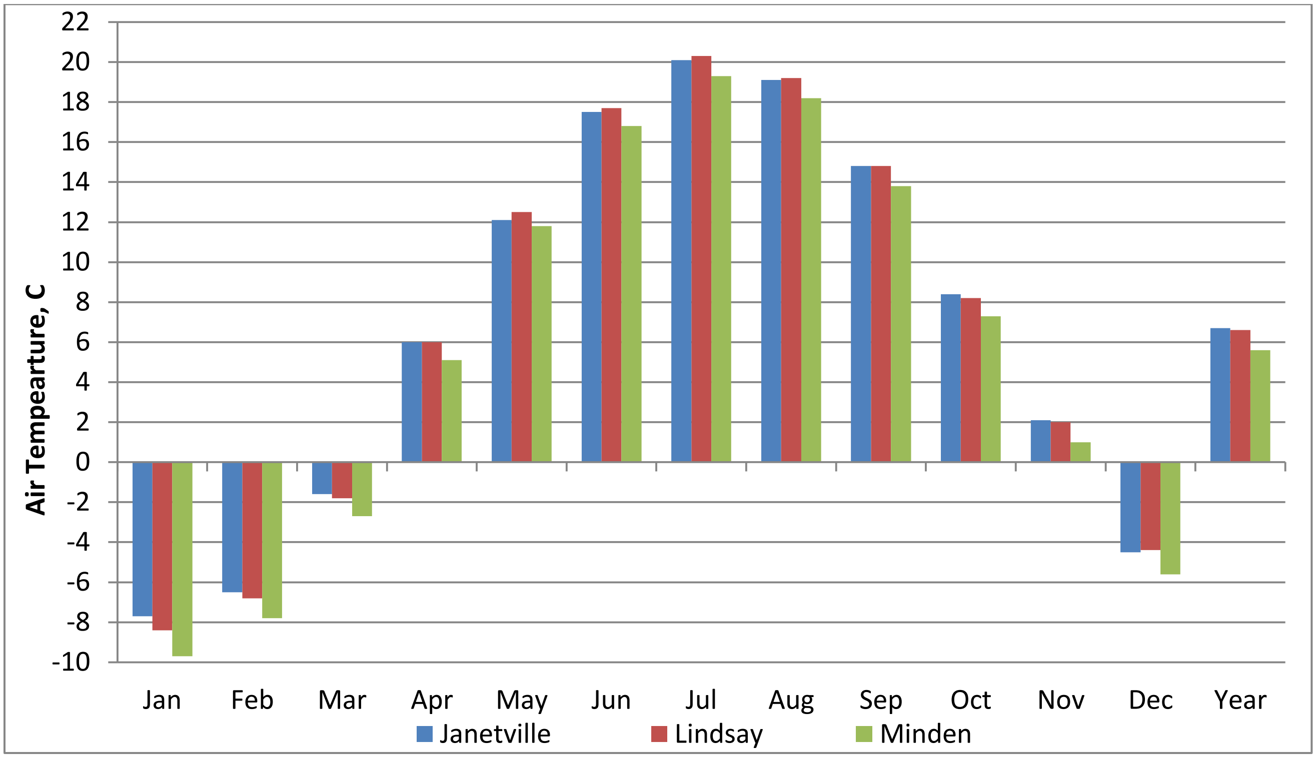

Figure 5.2. Monthly Air Temperature Normals for the Environment Canada Climate Monitoring Stations: Janetville (6153853), Lindsay Frost (6164433) and Minden (6165195)

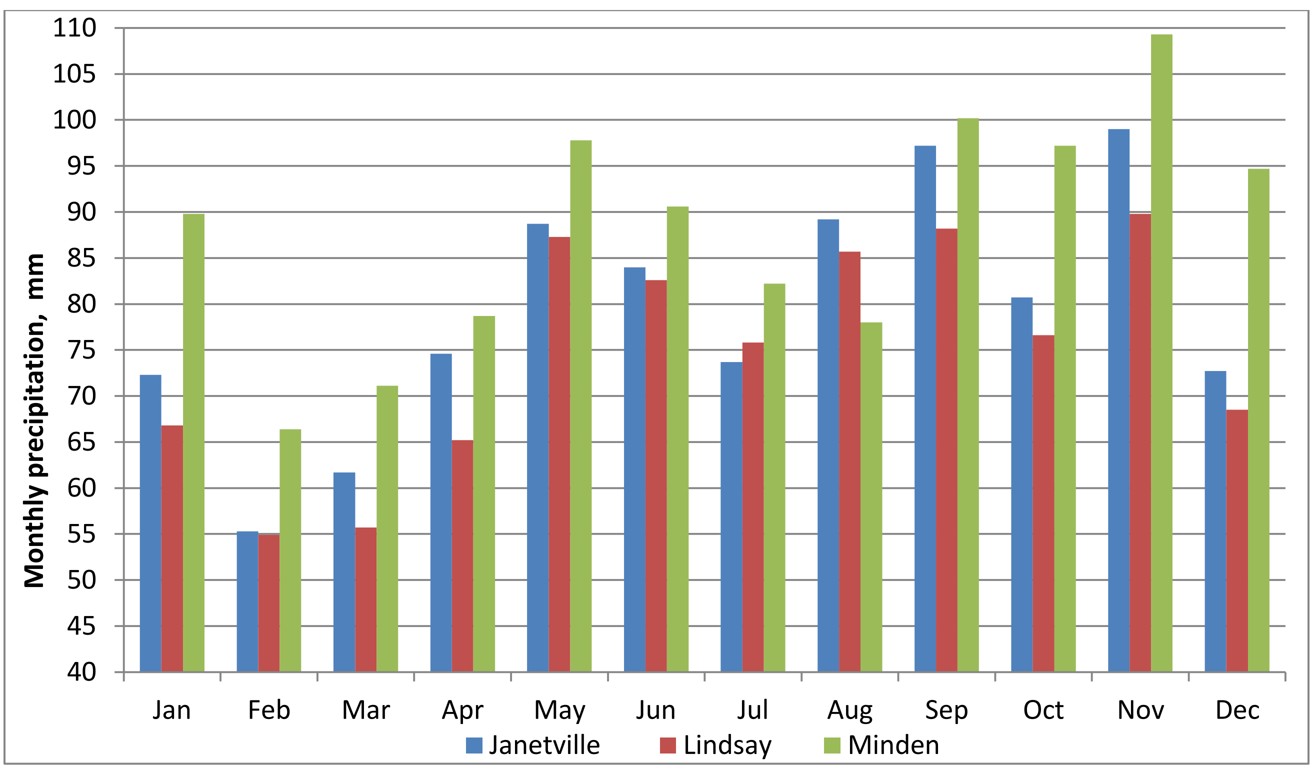

Figure 5.3. Monthly Precipitation Normals for the Environment Canada Climate Monitoring Stations: Janetville (6153853), Lindsay Frost (6164433) and Minden (6165195)

Currently, there is one active precipitation monitoring location within the Pigeon Lake watershed that was installed and maintained by Kawartha Conservation. It is located near the Potash Creek mouth and was installed in 2012 for the purposes of the Pigeon Lake Management Plan monitoring. Data from another station near the mouth of Hawkers Creek (west of the study area), was used to determine precipitation amounts. This station was installed in 2010 initially for the purposes of the Sturgeon Lake Management Plan monitoring.

Both monitoring locations are equipped with manual accumulative gauges that collect and store precipitation until a reading is taken. Precipitation amounts for the monitoring locations at Potash and Hawkers Creeks are shown in Table 5.2.

Table 5.2. Precipitation Amounts for Potash Creek and Hawkers Creek Precipitation Monitoring Stations Presented by Hydrologic Year

Year, hydrologic	2012-2013		2013-2014		2014-2015	
	Potash Creek	Hawkers Creek	Potash Creek	Hawkers Creek	Potash Creek	Hawkers Creek
June	123.5	112.3	83.1	86.0	59.1	81.7
July	56.7	35.9	20.4	52.1	80.9	73.1
August	55.8	39.5	101.7	143.4	56.2	88.7
September	133.0	103.9	81.5	71.3	89.8	90.1
October	124.8	116.3	145.3	165.9	101.1	105.0
November	21.2	36.4	47.2	53.8	72.3	80.1
December	74.4	87.2	58.8	76.1	30.6	55.1
January	63.5	79.9	31.9	64.5	28.9	32.2
February	69.2	75.8	35.9	40.6	17.0	28.1
March	7.8	11.3	26.9	52.2	14.6	20.8
April	89.2	104.7	132.9	102.4	63.4	68.1
May	80.2	59.7	60.2	48.5	70.7	68.9
Total	**899.3**	**862.9**	**825.8**	**956.4**	**684.6**	**791.9**

The total annual amount of precipitation, observed at both locations, was close to the long-term average value recorded for the Lindsay climate monitoring station that is the closest to both locations. However, variations in monthly amounts of precipitation of up to 25%, were observed (Table 5.2). The variation is greatest within the months of June, July and August. This can be explained by the effect of convectional precipitation that occurs during the warm period of the year and very often is unevenly distributed. Precipitation amounts recorded in both locations demonstrate that the 2014-2015 hydrologic year was considerably lower in precipitation comparing to average values. For example, precipitation in December 2014 – March 2015 measured by the

Potash Creek monitoring gauge was only 91.1 mm, representing 37% of long-term amount for this period (246 mm) recorded at Lindsay climate monitoring station.

There are two additional precipitation gauges within the study area: in the headwaters of the Pigeon River and near the mouth of Nogies Creek. Unfortunately, both of those gauges do not have ability to measure winter precipitation and cannot provide total annual precipitation amounts.

5.5 Evapotranspiration

Evapotranspiration (ET) is the combination of two simultaneous processes: evaporation and transpiration, both of which release moisture into the air. Evapotranspiration is a major component of the water balance equation. During evaporation, water is converted from liquid to vapour and evaporates from ground and surface water. During transpiration, water that was drawn up from the soil by the roots evaporates from the leaves (Figure 5.4).

Rates of evapotranspiration vary considerably both spatially and seasonally. Seasonal trends of evapotranspiration within a given climatic region follow the seasonal declination of solar radiation and the resulting air temperatures. Minimum evapotranspiration rates generally occur during the coldest months of the year. Maximum rates generally coincide with the summer season.

Measuring evapotranspiration is a complex and costly process. Because of that, ET is commonly computed from weather data, such as air temperature, daily precipitation and wind speed. A large number of empirical or semi-empirical equations have been developed for assessing evapotranspiration from meteorological data. Numerous studies have been done to analyze the performance of the various calculation methods for different locations. The Penman-Monteith method is now recommended as the standard method for the definition and computation of the reference evapotranspiration by the United Nations. The National Atlas of Canada, published in 1974 includes a coarse-scale map of the potential evapotranspiration (PET) for Canada (Figure 5.5). According to that map, PET value for the area that encompasses the Pigeon Lake watershed is about 560 mm (22 inches).

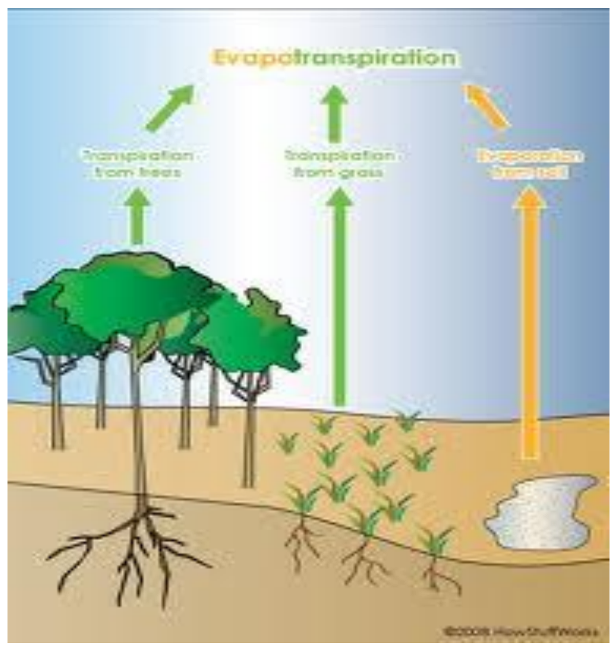

Figure 5.4. Process of Evapotranspiration
Source: http://science.howstuffworks.com

More recent data are available from the National Soil Database (Soil Classification Working Group, 1998). This database provides climate normals, including evapotranspiration for area units that are called Ecodistricts. Each Ecodistrict is characterized by relatively homogeneous biophysical and climatic conditions including: regional landform, local surface form, permafrost distribution, soil development, textural group, vegetation cover/land use classes, range of annual precipitation, and mean temperature. Average monthly and annual potential evapotranspiration values, available in the database, were estimated from monthly climatic normals for each Ecodistrict using the Penman empirical method.

According to this classification, the northern portion of the Pigeon Lake watershed (headwaters and middle portion of the Nogies Creek subwatershed) is located within the Algonquin Lake-Nipissing Ecoregion, Boreal Shield Ecozone (ecodistrict 413). The central and southern portions of the watershed belong to the Manitoulin-Lake Simcoe Mixwood Plains Ecoregion within Mixed Plains Ecozone (ecodistricts 552-554). Estimated values of the potential evapotranspiration for those ecoregions are shown in Table 5.3.

Since ET values follow the trend of the air temperature, the maximum values for both regions are observed during the summer months: July, June and August. Evapotranspiration in March and November is very low, less than 12 mm, declining to 0 mm in the winter season. The average annual evapotranspiration between the two ecoregions is 622 mm.

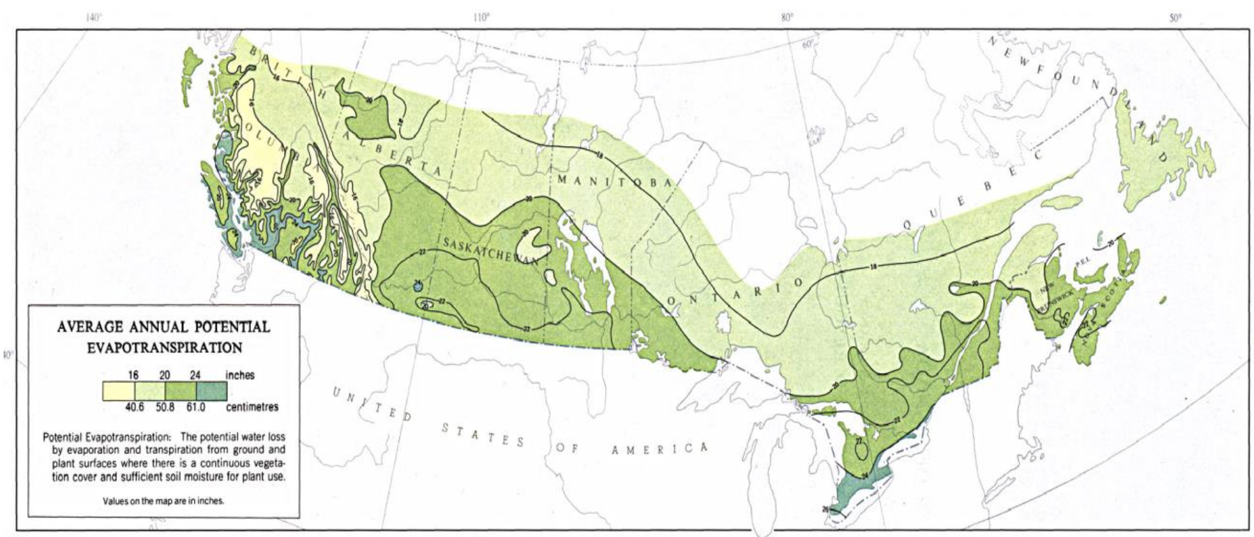

Figure 5.5. Average Annual Potential Evapotranspiration
Source: The National Atlas of Canada, 1974

Table 5.3. Average Monthly and Annual Potential Evapotranspiration (mm)

Eco Districts	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
413	0	0	11.6	63.0	97.6	115	129	103	64.7	30.5	8.2	0	612.8
552	0	0	9.4	65.0	103	117	132	103	64.2	29.7	7.3	0	630.6

5.6 Climate Change

Climate change is defined as a shift in long-term average weather patterns (with respect to a baseline or a reference period), that can include changes in temperature and precipitation amounts. Climate change may be due to both natural (i.e. internal or external processes of the climate system) and anthropogenic reasons (i.e. increase in concentrations of greenhouse gases). Climate variability is defined as a deviation from the overall trend or from a stationary state, and refers to variations in the mean state and other statistics (such as standard deviations, the occurrence of extremes, etc.) of the climate on all temporal and spatial scales (CCCSN, 2014). Climate variability can be thought of as a short term fluctuation superimposed on top of the long term climate change or trend.

Observations throughout the globe show that atmospheric temperature has exhibited an increasing trend during the last century. This somewhat rapid increase in temperatures is referred to as atmospheric global warming. Increasing concentrations of carbon dioxide and methane (greenhouse gases - GHG) in the atmosphere caused by human activities is believed to be important contributing factor to this phenomenon. It is expected that climatic warming in some portions of the globe will bring significant changes to weather and climate conditions, including its variability and magnitude in the near future.

There is a general consensus in the international scientific community that the impacts of climate change are already being felt. An increase of atmospheric greenhouse gas concentrations is expected to occur even if the global-wide commitments to reduce GHG emissions are fully met by all participating countries. While the absolute magnitude of predicted changes is uncertain, there is a high degree of confidence in the direction of changes, and in the recognition that climate change effects will persist for many centuries. As we head towards an increasing atmospheric concentration of both carbon dioxide and methane, we can expect that increasing impacts of climate change will create both negative and positive results for communities everywhere: in our watershed and our communities, in our province, in our country and around the world.

An important tool within this area of study is the construction of climate change scenarios (alternatives or future options), termed climate change modeling. Each scenario is one created or developed image of how the future might unfold under a different combination of factors such as population growth, energy use, land use change, technology change, etc. A set of scenarios assists in the understanding of possible future developments of complex systems.

Under all scenarios, it is expected that mean annual temperature will increase for the study area (Table 5.4, Figure 5.6). The highest increase in temperature will be observed during winter (5.1^{o}C increase according to High Emission Scenario) compared to current normals.

An increase of annual mean precipitation is expected under all scenarios, with winter and spring experiencing the highest rise with up to 30 mm per season under the Medium Emission Scenario (Table 5.5, Figure 5.7). It is important to note that with winter being milder, winter precipitation will fall as rain, affecting the hydrological cycle, monthly stream flows, lake levels, and water resources overall.

These expected weather and climate changes will trigger shifts in all aspects of the environment, including water resources, ecosystems and biodiversity. For example, more frequent and intense rainfall events may lead to increased occurrence of minor and major flooding; development of new, unsuspected flood-prone areas; and increased transportation of contaminants, pollutants and nutrients from the land surface to lakes, rivers and

Table 5.4. Mean Air Temperature Predictions Under Different Emission Scenarios

Time Period	Annual	Winter	Spring	Summer	Autumn
1971-2000	6.3	-7.1	5.6	18.8	7.9
Low Emission Scenario (LES)					
2020s	7.6 ± 0.4	-5.6 ± 0.5	6.7 ± 0.4	19.9 ± 0.4	9.2 ± 0.4
2050s	8.3 ± 0.6	-4.8 ± 0.7	7.5 ± 0.7	20.7 ± 0.7	9.9 ± 0.6
2080s	9.0 ± 0.7	-3.9 ± 0.8	8.1 ± 0.8	21.3 ± 0.8	10.5 ± 0.8
Medium Emission Scenario (MES)					
2020s	7.7 ± 0.4	-5.5 ± 0.6	6.8 ± 0.5	20.1 ± 0.5	9.2 ± 0.4
2050s	9.0 ± 0.8	-3.9 ± 0.8	8.1 ± 0.9	21.4 ± 0.8	10.5 ± 0.8
2080s	10.1 ± 1.0	-2.7 ± 1.2	9.2 ± 1.1	22.4 ± 1.2	11.6 ± 1.0
High Emission Scenario (HES)					
2020s	7.5 ± 0.4	-5.7 ± 0.5	6.7 ± 0.5	19.9 ± 0.4	9.2 ± 0.4
2050s	9.0 ± 0.6	-3.9 ± 0.8	8.0 ± 0.7	21.4 ± 0.7	10.4 ± 0.6
2080s	10.8 ± 1.0	-2.0 ± 1.1	9.7 ± 1.1	23.3 ± 1.3	12.3 ± 0.9

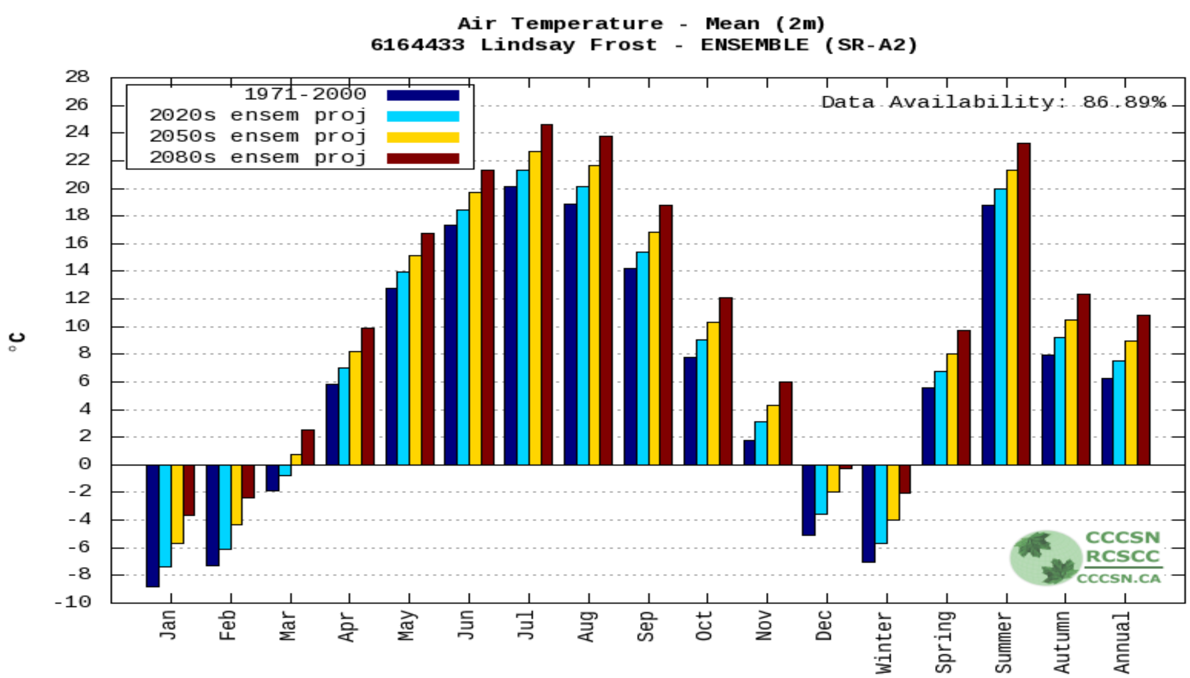

Figure 5.6. Mean Air Temperature - High Emissions Scenario (CCCSN, 2014)

Table 5.5. Total Precipitation Predictions Under Different Emission Scenarios

Time Period	Annual	Winter	Spring	Summer	Autumn
1971-2000	**878.3**	**182.9**	**200.7**	**247.0**	**247.7**
Low Emission Scenario					
2020s	903.3 ± 26.0	196.1 ± 6.8	207.6 ± 10.5	251.3 ± 10.8	247.9 ± 15.6
2050s	923.1 ± 31.5	199.1 ± 9.1	216.1 ± 8.9	253.3 ± 17.5	254.9 ± 20.4
2080s	939.9 ± 29.6	207.3 ± 9.9	223.0 ± 12.4	251.0 ± 16.2	256.9 ± 18.0
Medium Emission Scenario					
2020s	910.6 ± 25.2	196.9 ± 7.2	209.9 ± 8.2	251.0 ± 14.3	252.3 ± 14.4
2050s	930.1 ± 33.6	203.9 ± 10.4	219.3 ± 16.4	249.7 ± 17.3	257.1 ± 17.3
2080s	960.3 ± 43.3	213.8 ± 13.4	231.0 ± 19.6	250.4 ± 24.2	264.5 ± 22.6
High Emission Scenario					
2020s	903.3 ± 26.0	196.1 ± 6.8	207.6 ± 10.5	251.3 ± 10.8	247.9 ± 15.6
2050s	923.1 ± 31.5	199.1 ± 9.1	216.1 ± 8.9	253.3 ± 17.5	254.9 ± 20.4
2080s	939.9 ± 29.6	207.3 ± 9.9	223.0 ± 12.4	251.0 ± 16.2	256.9 ± 18.0

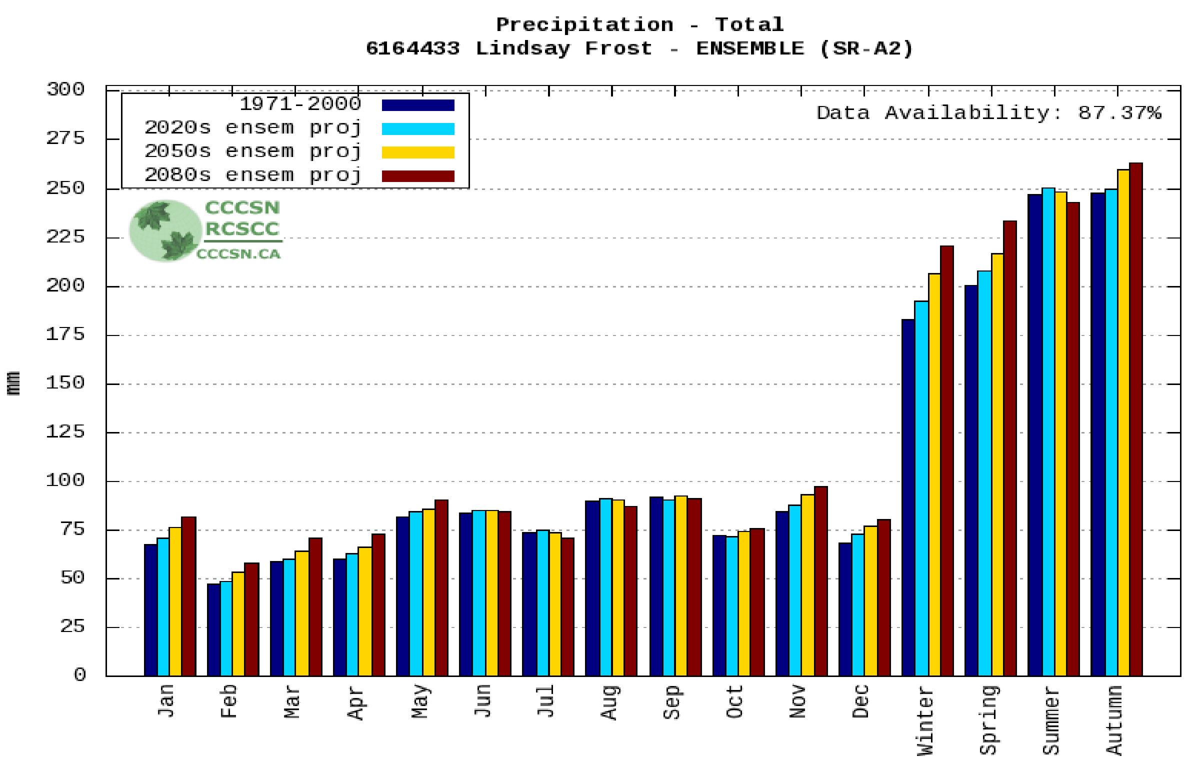

Figure 5.7. Total Precipitation - High Emissions Scenario (CCCSN, 2014)

streams. In addition, increased bank and channel erosion should be anticipated from the rapid rise of water which will contribute to surging of streams and rivers.

Decreased summer runoff will result in low flow conditions that, in turn, have the potential to impact aquatic habitat and lead to degraded water quality as less water will be available for dilution of sewage treatment plant effluents, agricultural runoff and nutrients entering waterways from urban lands. Low flow conditions may cause increased competition and conflict over reduced water supplies among water users during drought periods.

As winter precipitation increasingly falls as rain, and the accumulated snowpack decreases, groundwater recharge will most likely be negatively impacted, consequently decreasing the groundwater levels and rates of groundwater discharge to local streams and lakes. As a result, streams dependent on base flow (i.e. the portion of stream flow that comes from groundwater discharge, rather than direct runoff related to rain or snowmelt events) will experience lower levels and reduced flows, adding stress on aquatic ecosystems. Some portions of the study area, as shown further in Chapter 6, could be especially vulnerable to an increase in periods of dry or low flow.

Decreased groundwater levels and discharges may change forms and functions of wetlands. In addition, decreased groundwater levels will also put strain on the groundwater supply, including those that service private wells. Risk of water shortages and additional competition for a scarce supply will increase. More private wells may dry up, perhaps causing water shortages to develop in areas never having experienced them before.

The above-mentioned list is only a small portion of the possible local changes as a result of global climate change. Beyond the environmental effects, a changing climate can impact the social and economic well-being of the Pigeon Lake watershed residents.

6.0 Water Quantity

6.1 Summary of Observations, Key Issues, and Information Gaps

OBSERVATIONS

- ***The water level regime of Pigeon Lake is regulated and generally follows natural seasonal patterns.*** Water levels are defined and regulated by the Trent-Severn Waterway. Patterns in water levels typically follow a natural regime whereby levels are highest in spring and fall, and lowest in summer and winter.

- ***Tributaries of Pigeon Lake demonstrate the seasonal flow pattern*** when the highest flow is observed in spring associated with snowmelt, and throughout the year following high volume precipitation events. Low flows are typically observed in the summer and winter months.

- ***Two major tributaries of Pigeon Lake, Pigeon River and Nogies Creek, are regulated through three major dams on Nogies Creek and one on Pigeon River.*** Despite of being regulated, those watercourses still keep the seasonal flow pattern.

- ***Baseflow values throughout the Pigeon Lake watershed vary considerably.*** Headwaters of the Pigeon River, located within the northern slope of the Oak Ridge Moraine and the adjacent portion of the Peterborough Drumlin Fields physiographic region, produce the most substantial groundwater input in the watershed. The northern-most portion of the watershed (Nogies Creek and Eel's Creek subwatersheds), demonstrate moderate baseflow inputs. As this part of the watershed is composed of bedrock formations, granites and gneisses, the movement of the groundwater is less predictable and highly variable. Baseflow in the middle portion is extremely limited as the majority of watercourses measured in the area between Omemee and Bobcaygeon go dry or have stagnant water during the periods of low precipitation.

- ***Wetlands and forested areas that are abundant in the Pigeon Lake watershed provide significant benefits for the surface water***. These natural areas moderate stream flow, providing high and low flow mitigation and assist in groundwater recharge.

KEY ISSUES

- ***Some aspects of the land use change, such as increasing impervious surfaces, urban development and agricultural practices can affect the quantity of both surface and groundwater resources***. Under the pressure of further development within the watershed, it is important to regulate those practices in the manner that surface and ground water remain not adversely affected.

- ***Climate change as it is currently forecasted has the potential to impact the flow regime of the local watercourses.*** Climate change predictions indicate watercourses may experience a reduction in the duration and intensity of spring runoff and aquifer recharge, and an increase in the potential for dry conditions and/or extreme high flow events during the summer.

INFORMATION GAPS

- ***Annual monitoring data on lake evaporation are not available.*** In absence of the current and reliable evaporation values it is difficult to calculate accurate lake water budget. A lake water budget makes basis for calculation of the nutrient loading to a lake.
- ***The cumulative water taking both from surface and ground water sources that does not require permitting is not known.*** Although water takings from Pigeon Lake falling under the regulation of the "Permit To Take Water Program" (PTTW) is not significant, the cumulative water takings from other sources that do not require reporting is unknown. Quantification of these sources is necessary to better estimate water balance equations.
- ***Flow monitoring data from the northern portions of the Pigeon Lake watershed are limited***. Monitoring data are key source of information on any natural phenomena. Only three years of water level and flow data have been collected for the purposes of water quantity characterization of the Pigeon Lake watershed. That is not statistically sufficient for making sound conclusions about the water resources conditions and trends; long-term data is required. Water level and flow monitoring should be continued.

6.2 Drainage Network

Pigeon Lake is part of the Kawartha Lakes chain and, consequently, the Trent-Severn Waterway. The lake is connected to Sturgeon Lake by the Big Bob and Little Bob channels upstream and to Buckhorn Lake through the Gannon Narrows downstream. Pigeon Lake water levels are highly regulated by a series of dams and locks of the Trent-Severn Waterway. Two dams and a lock in Bobcaygeon restrict the water flow from Sturgeon Lake to Pigeon Lake. The next dam downstream from Pigeon Lake is located in the village of Buckhorn, separating Buckhorn Lake from Lower Buckhorn Lake. Therefore, Pigeon Lake, Buckhorn Lake and Chemong Lake make one body of water and are often considered as a one big lake known as Tri-Lakes.

In addition to the inflow from Sturgeon Lake, Pigeon Lake is also fed by two major tributaries: Pigeon River and Nogies Creek. Pigeon River and its main tributary, Fleetwood Creek, drain the south portion of the subwatershed and inflows into Pigeon Lake from the south. Both watercourses originate in the Oak Ridges Moraine and flow north through the rolling terrain of the Peterborough Drumlin Field (Figure 6.1). The Pigeon River begins on the Oak Ridges Moraine at the elevation of more than 340 metres above sea level (masl). It flows almost 54 km to Pigeon Lake and discharges into the lake at an elevation of 245 masl. The river's morphology considerably changes on this drainage route. The channel gradient is much higher in the headwaters portion that is located within the Oak Ridge Moraine where the river and its tributaries are fast-flowing, have well-defined channels and narrow valleys. After the confluence with Fleetwood Creek, within the Peterborough Drumlin Fields, the Pigeon River meanders slowly through the flat, wide floodplain abounding with large wetlands. On some reaches within this portion, the Pigeon River does not have a defined channel or valley. Fleetwood Creek begins at the higher elevation of the Oak Ridges Moraine (~310 masl.) and after flowing 17.6 km through the Oak Ridges Moraine and Peterborough Drumlin Field, joins the Pigeon River at an elevation of 247 masl.

Flow of the Pigeon River is controlled by the dam located in the village of Omemee. Built originally in the 1820s, the dam provided power and water for industrial operations (a gristmill, sawmill and carding mill). It has been a long time since those industries stopped operating. Currently the main use of the upstream reservoir (Omemee Pond) is recreation, as the dam has limited capacity for flood regulation. Omemee Dam was rebuilt in 1970 and is currently owned and operated by the Ministry of the Natural Resources and Forestry. The dam is a concrete structure designed as a circular segment to increase the crest length relative to the size of the site. The dam has eight bays, seven of which are equipped with steel panels in place of stop logs to facilitate operations during high flow conditions. One bay is a stop-log sluiceway. Additional details on the significant dams within the Pigeon Lake Watershed are listed in Table 6.1.

Nogies Creek drains the northern-most portion of the Pigeon Lake watershed. The river originates on the Precambrian Shield, and flows across the Dummer Moraine region for approximately a quarter of its length (8 km). Similar to other streams located on the Precambrian Shield, Nogies Creek is characterized by a high main channel gradient and watershed slope, poorly defined floodplain and valley with numerous small wetlands and lakes. There are three dams on the main channel of the creek. One (Crystal Lake Dam) is located at the outlet from Crystal Lake in the upper portion of the watershed and is owned and maintained by Trent-Severn Waterway. It was built at the end of the 19th century and currently serves as a reservoir for the TSW for system's water level regulation and low water augmentation. It is a concrete structure with one sluiceway that is controlled by nine stop logs.

The Bass Lake Dam controls the outlet of Bass Lake and is situated at the middle portion of the creek approximately 10 km upstream of creek's convergence with Pigeon Lake. This dam is privately owned and additional information is limited.

The Nogies Creek Dam is the last dam on the creek, located at its lower section (~4 km upstream from Pigeon Lake). This dam is owned and operated by the Ministry of the Natural Resources and Forestry. The concrete structure was constructed in 1991 at the outlet of Nogies Marsh, replacing the older dam that existed before. The current dam consists of a concrete structure with one stop-log controlled sluiceway and one overflow spillway. The main purpose of the dam is to maintain water levels in the impoundment area of the Nogies Creek Fish Sanctuary, located upstream of the dam, for the purpose research and spawning (muskellunge and frogs). In addition, the dam provides some (not significant) flood control by storing water in Nogies Marsh.

There are a number of small private dams on tributaries throughout the Pigeon Lake watershed. In addition, watercourses, especially within watershed's northern portion, are highly affected by beaver activity.

The water from Pigeon Lake moves in an easterly direction to Buckhorn Lake, which is the next lake in the Kawartha Lakes chain.

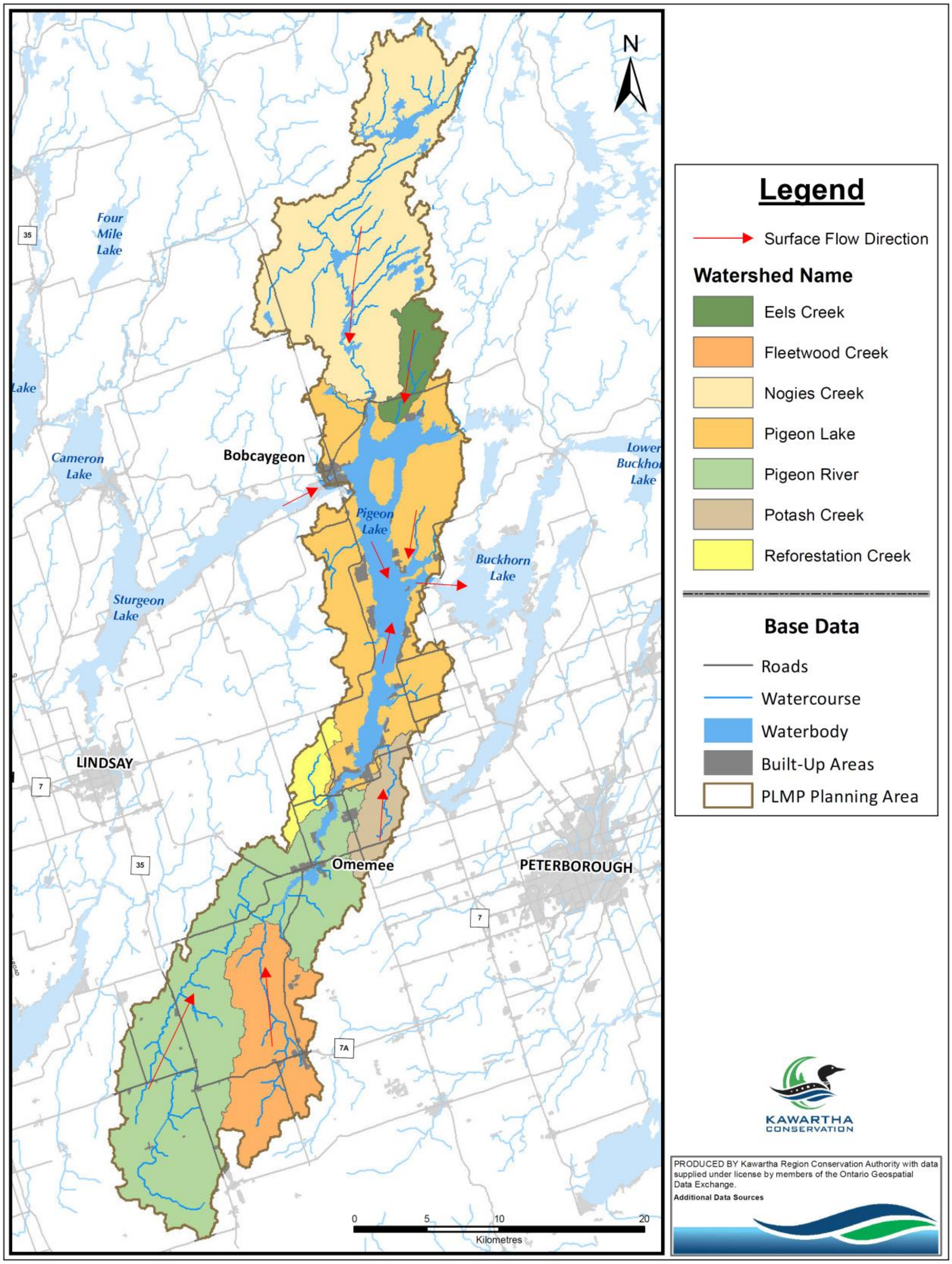

Figure 6.1. Drainage Network and Flow Directions in the Pigeon Lake Watershed

Table 6.1. Significant Dams Within the Pigeon Lake Watershed

Name	Water body	Length, m	Height, m	Surface Area of Reservoir, ha	Dam Purpose	Dam Specifics
Nogies Creek Dam	Nogies Creek	16.5	3.5	210	Low flow augmentation, Provincially Significant Class 1 Wetland, Fish sanctuary	Owned and operated by the MNRF. Concrete dam with one 15-foot stop log section and spillway.
Crystal Lake Dam	Nogies Creek	27.8	2.25	450	Water level regulation, Water storage	Owned and operated by the TSW. Concrete dam with one stop log sluice and spillway. No. of sluiceway: one, 2.25 m wide. No. of stoplogs: 9.
Omemee Dam	Pigeon River	47.5	5.8	104	Fish and wildlife, Recreation, Flood control, Originally built to facilitate a mill	Owned and operated by the MNRF. Curved concrete dam with eight gated sluiceways with electric hoists. Six gates have variable geometry flaps fix on top of gate. No. of sluiceways: eight, 7 metres each. No. of stoplogs per bay: steel panels with adjustable topsill

Land use within a watershed reflects on the hydrological regime of a watercourse. Naturally covered areas provide significant benefits in keeping water resources abundant and clean. Forest helps to moderate stream flow, providing high and low flow mitigation and assisting in groundwater recharge. Similar to forested areas, wetlands provide peak flow mitigation and flood storage capacity as well as assist in improving water quality by sediment trapping and nutrient retention and removal.

Conversely, development areas that have greater areas of impervious surfaces alter spatial and temporal distribution of flow, increasing the flood peaks and volumes and decreasing groundwater recharge, storage and discharge.

While agricultural activities impact water quality the most, they change some aspects of the stream flow regime as well, including higher velocity of run-off over tilled soils that can alter peak flows.

Approximately 32% of the Pigeon Lake subwatershed is agriculture, and almost 57% of the watershed area is occupied by forests (39%), wetlands (15%) and meadows (5%) that are collectively classified as natural cover. Agricultural lands are not evenly distributed throughout the watershed; the majority are located at the southern and central portion of the watershed where soils and drainage are more suitable. For example, almost 55% of Potash Creek and 48% of the Pigeon River are involves into agriculture, while area effected by agricultural activities is only 0.75% for Nogies Creek subwatershed and 6% for Eels Creek (Table 6.2). Conversely, 85% of the Nogies Creek drainage area and 82% of Eels Creek drainage area is covered by forest, wetland and meadows that ensure the flow in the creek closest to natural.

6.3 Water Levels and Flow Regime

Surface water quantity (volume of water in watercourses and water bodies) assessments are usually achieved through water level and flow monitoring. Collected long-term data assist in identifying changes that may affect water quality, geomorphic stability and aquatic health of a watercourse as well as providing invaluable data for modeling of water resources, water budget calculation, and water allocation. Changes in flow conditions may reflect changes in climate (precipitation, evapotranspiration), water demand, land use or watershed's natural cover. Water level monitoring data also provide information for flood forecasting, warning and emergency management.

Continuous water level monitoring within the Pigeon Lake management planning study area is available at three locations (Figure 6.2). Two gauges monitor water levels of the Pigeon River; and one more is situated on Nogies Creek. All monitoring gauges consist of a sensor that measures water level on pre-set intervals (15 min, 30 min or 1 hour) and a data logger that records measured values. Details on the water level monitoring locations are shown in Table 6.3.

Water levels represent heights of water above the sensor. Information on water levels is very important for flood forecasting and emergency management, floodplain development and other applications. In order to develop a water budget or calculate amount of pollutants carried with water into the lake, data on volume of water that flows through the watercourse is required. It is achieved through developing an equation that describes relationship between water level and discharge. The graphical expression of the equation is called rating curve. In order to develop a rating curve and corresponding equation, discharge (volume of water that flows through a cross section of a watercourse in one second) and corresponding water levels are measured numerous times at the monitoring location and graphed. A wide range of water levels and flow (from the highest to the lowest) are targeted in order to establish reliable relationship. Once a rating curve and an equation are developed, water level values are converted to discharges that characterize water quantity at the gauging location.

The monitoring station on the Pigeon River at Omemee Dam is located upstream of the dam, in the lake-like settings that are not suitable for the flow measurements. Flow via the Omemee Dam was determined by using an empirical equation that calculates flow through the dam’s gates relating to gate’s geometry and the actual water levels.

Water levels and flow vary over time and space. Floods and low-flow periods occur, sometimes in a predictable seasonal pattern, and sometimes less predictably. Rivers and lakes in variable climates tend to have variable flows, and rivers and lakes that are groundwater fed tend to have more constant and predictable water levels and flows. Flow regime describes the average seasonal water level and flow variability for a particular river or lake and reflect climatic and physiographic conditions in a watershed. The best way to explore the regime of a watercourse or a waterbody is to study its long-term average water levels and flow.

Table 6.2. Stream and Subwatershed Characteristics, the Pigeon Lake Watershed

Sub watershed	Drainage area (km^2)	Stream Network Length (km)	Main Channel Length (km)	Main Channel Gradient (m/km)	Natural Cover (%)	Agriculture (%)	Rural/Urban Development (%)	Stream Density (km/km^2)	Average Watershed Slope (%)
Pigeon Lake Subwatershed	195.5	130.0	n/a	n/a	52.8	32.0	10.5	0.66	2.46
Pigeon River	201.0	258.4	53.9	1.08	42.0	48.0	5.33	1.28	5.30
Fleetwood Creek	72.9	109.3	17.6	1.40	56.1	35.2	4.87	1.50	6.86
Nogies Creek	185.5	326.4	33.9	1.65	88.2	0.75	1.23	1.76	5.35
Eels Creek	119.3	31.6	9.75	4.04	87.2	6.22	1.60	1.64	5.28
Potash Creek	21.8	29.1	9.53	1.11	37.6	54.9	5.12	1.33	4.76
Reforestation Creek	15.3	1.92	8.33	3.04	41.9	52.0	3.64	1.17	3.49

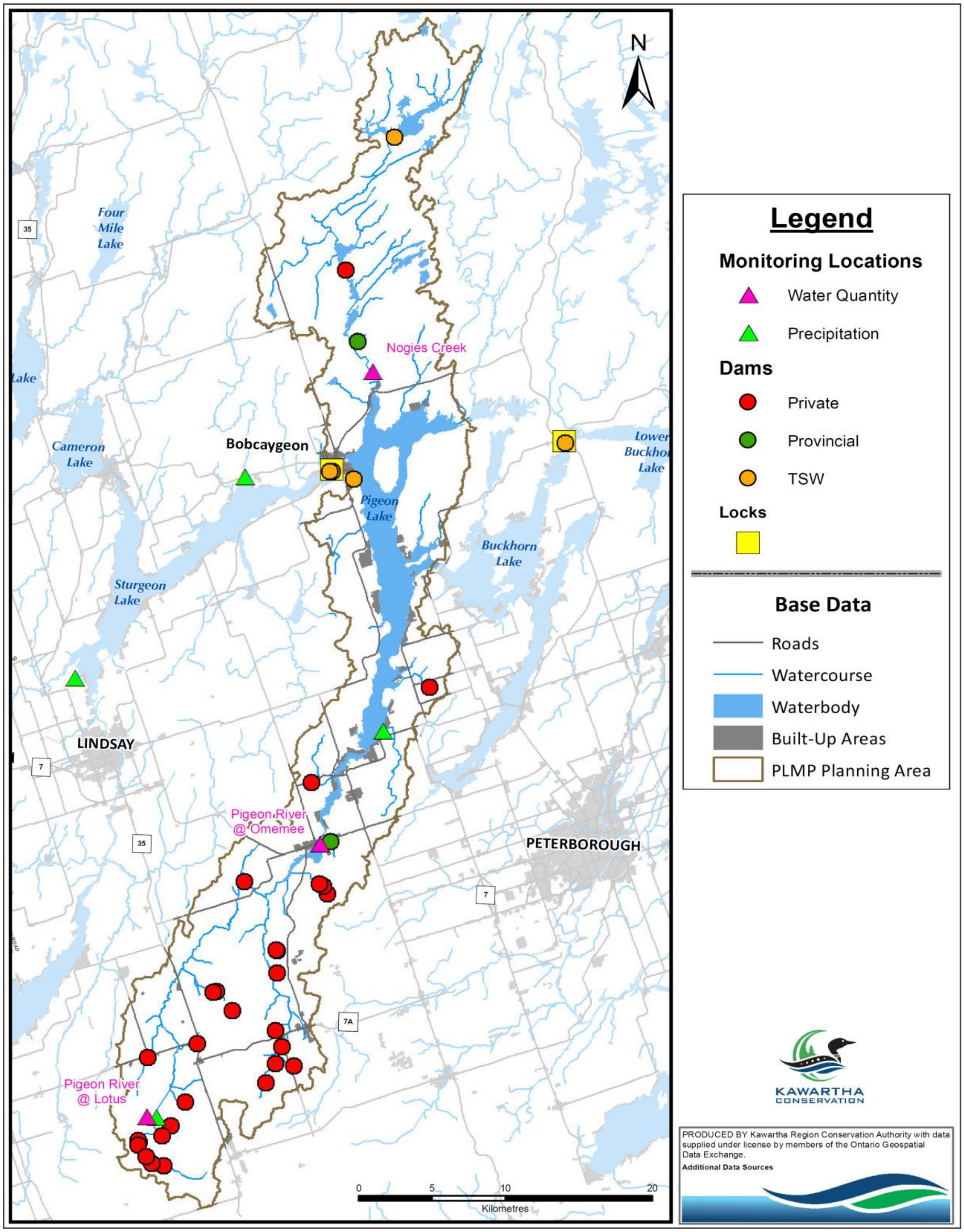

Figure 6.2. Water Structures and Flow Monitoring Locations in the Pigeon Lake Watershed

Table 6.3. Continuous Water Level and Stream Flow Monitoring Locations

Waterbody / Watercourse	Location	Drainage Area, km^2	% of total subwatershed area	Data Interval	Data Record	Type	Parameters Measured	Ownership
Pigeon River	at Lotus	31.6	15.7	15 min	2004 - current	Permanent, stilling well	• Water levels • Water temperature • Precipitation	Environment Canada - Water Survey Division, 02HH003
Pigeon River	at Omemee Dam	257.5	94.0	30 min	2007 - current	Permanent, pressure transducer	• Water levels	Environment Canada - Water Survey Division, 02HH005
Nogies Creek	at Fire Route 116	175.03	94.3	1 hour	2012 - current	Temporary, pressure transducer	• Water levels	Kawartha Conservation

As it has been previously mentioned, water levels in Pigeon Lake are highly regulated by the Trent-Severn Waterway dam in Buckhorn. The lake level is monitored by the gauge located on the Buckhorn Lake, assuming Pigeon Lake being part of the Tri-Lake system.

Management of water levels is one of the great challenges for the TSW. It is based on an annual cycle of operations augmented by over 100 years of recorded water levels, flows, weather data, and new technologies. Water levels, water current velocities and precipitation data from monitoring network are accessed and analyzed on a daily basis by the TSW officials. Figure 6.3 demonstrates long-term average, maximum and minimum water levels recorded by monitoring location in Buckhorn.

A variety of groups, such as cottagers, year-round residents, commercial operators, power generators, and others are all concerned about water level fluctuations. The TSW water management goal is to provide for safe navigation while trying to accommodate the other water users (Ecoplans Limited, 2007). There are a variety of constraints to reconciling the conflicting demands to regulate water levels and flows within the watersheds, not the least of which is climate and weather, which can be neither controlled nor guaranteed.

Overall water level management on lakes and rivers within the Waterway including Pigeon Lake is based on a yearly cycle. Pigeon Lake, as one of the larger Kawartha Lakes, is allowed to decline to the middle or bottom of their navigation range and then is drawn down from January 1 to March 15. Normally, this ensures that the lakes are at their natural low levels prior to the spring freshet. The date by which the final level is attained varies with the natural inflow during the winter. Winters with high inflows mean that lakes would not drop as far as is desirable, thus reducing flood storage. Dry cold winters with low inflow can cause some lakes to drop lower than normal (Ecoplans Limited, 2007).

Throughout the spring freshet, the TSW has two difficult and sometimes competing objectives:

1. Create reservoir space for the spring freshet to reduce or eliminate possible flooding, and
2. Store as much water as possible for summer use.

Once the freshet starts, some reservoir lakes (lakes located at headwaters of the TSW including Crystal Lake) and many Kawartha Lakes fill or overfill even with fully open dams. Downstream conditions are also critical to take into consideration. For example, during extreme flood conditions, a decision may be required to fill the lakes above normal levels in order to prevent much more serious flooding downstream.

During the summer, attention shifts to maintaining water levels and flows. The three main objectives for the summer water control are:

1. Maintain the lakes within navigable depth ranges;
2. Use as little water as possible from the reservoir lakes and maintain them at the same percentage of storage depth; and
3. Maintain sufficient flows through the system to ensure water quality.

During the summer season evaporation from the Kawartha Lakes is usually greater than water inflow from unregulated tributaries, precipitation and ground water. Therefore, additional water must be supplied to the lakes from the reservoir lakes.

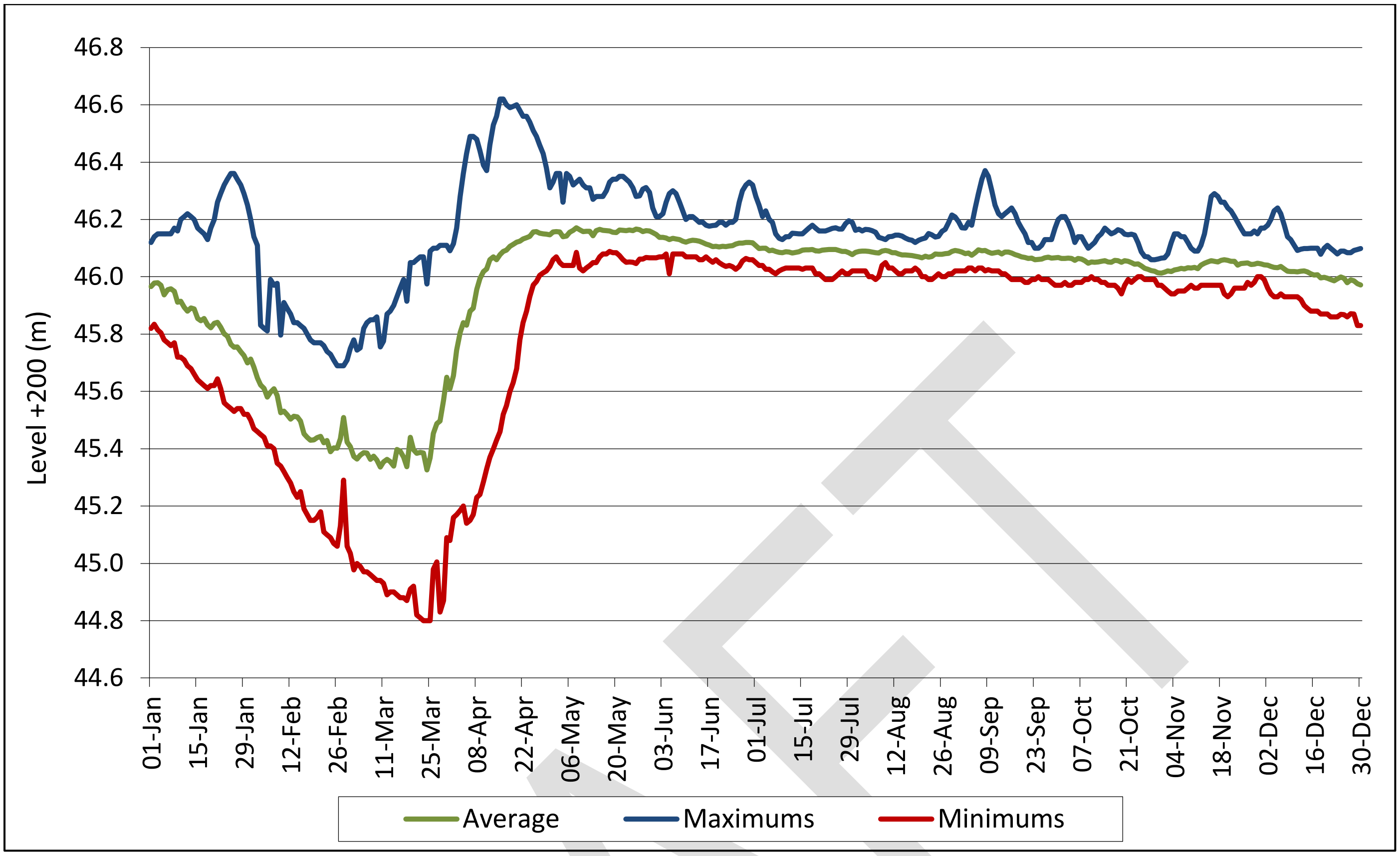

Figure 6.3. Long-term Average, Maximum and Minimum Water Levels of Tri-Lakes (Pigeon, Buckhorn and Chemong lakes)

Lake Tributaries

Data from flow monitoring locations at the Pigeon River watershed were used to characterize streams hydrological regime and calculate volume of water that enters the lakes (Table 6.2). The hydrometric gauge on Pigeon River at Lotus (**02HH003 Pigeon River at Lotus**) is a component of the Canada-wide hydrometric monitoring network that is maintained by the Water Survey Division, a division of Environment Canada. This station was established in 2003 in partnership with Kawartha Conservation. It is a permanent monitoring location with a real-time connection capacity. Additional environmental variables, such as precipitation and water temperature, are measured in this location.

The hydrometric station is situated at the headwaters portion of the river system, just east of the Hamlet of Lotus. The gauge captures natural, uncontrolled flow that is generated by about 16% of the watershed's drainage area, all located within the Oak Ridge Moraine.

The water level monitoring gauge on Pigeon River at Omemee (**02HH005 Pigeon River at Omemee**) is also a part of the hydrometric monitoring network (Water Survey Division, Environment Canada). The station was established in 2007, in partnership with Ministry of the Natural Resources and Forestry. It provides information on flow that is generated by 94% of the Pigeon River watershed. This station is situated upstream of the dam, in the reservoir, and provides data on water regime of water course in dam-controlled, lake-like conditions.

The water level monitoring gauge on **Nogies Creek at Fire Route 116** provides information on flow and its regime at the norther portion of the Pigeon Lake watershed. The station is located in the lower portion of the watershed and monitors flow that is produced by almost 96 % of the subwatershed. Flow regime at this location is affected by water control structures, situated upstream. Currently, this monitoring location set as temporary, established specifically for the purposes of the Pigeon Lake Management Planning project, operated and maintained by Kawartha Conservation. However, conditions at the site are very suitable for long-term monitoring, therefore establishment of the permanent flow monitoring location should be considered.

The water level and flow data, including the long-term average values, confirm that all monitored watercourses have defined seasonal pattern, reflecting seasonal variations of water inflow. The Pigeon River in Lotus demonstrates the most defined pattern. It can be explained by two reasons: 1) the river flow at this location is in natural conditions and 2) data describes the headwater portion of the watershed, where pattern is always best defined because of watershed and stream morphology.

The seasonal pattern at the Pigeon River at Omemee monitoring location is not as defined, because the gauge reflects hydrological regime of highly regulated portion the river.

Overall, the highest monthly flows and water levels on tributaries within the Pigeon River subwatershed are typically observed in April in response to a spring freshet. However, the instantaneous peaks at the Pigeon River monitoring locations have also been recorded in January, March, August, September and December, in conjunctions with significant precipitation or thaw events.

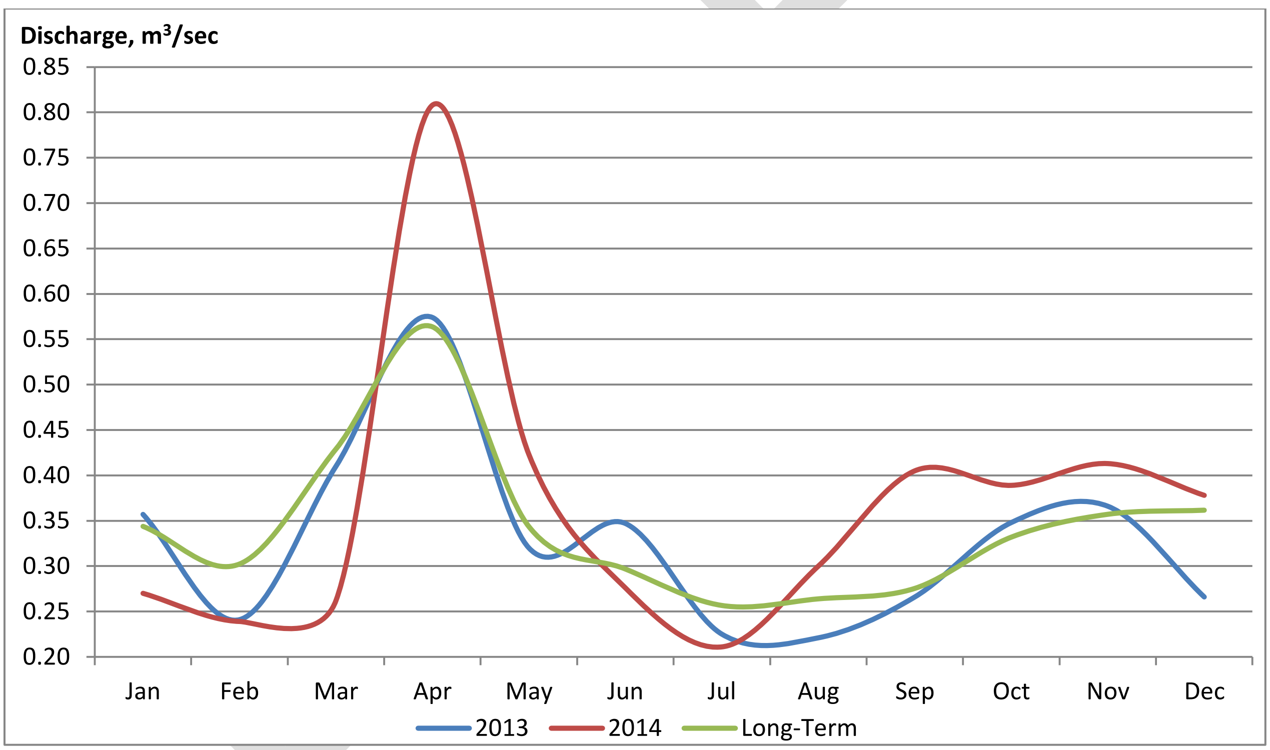

Figure 6.4. Average Monthly Flow of the Pigeon River at Lotus: Long Term Average, 2013 and 2014

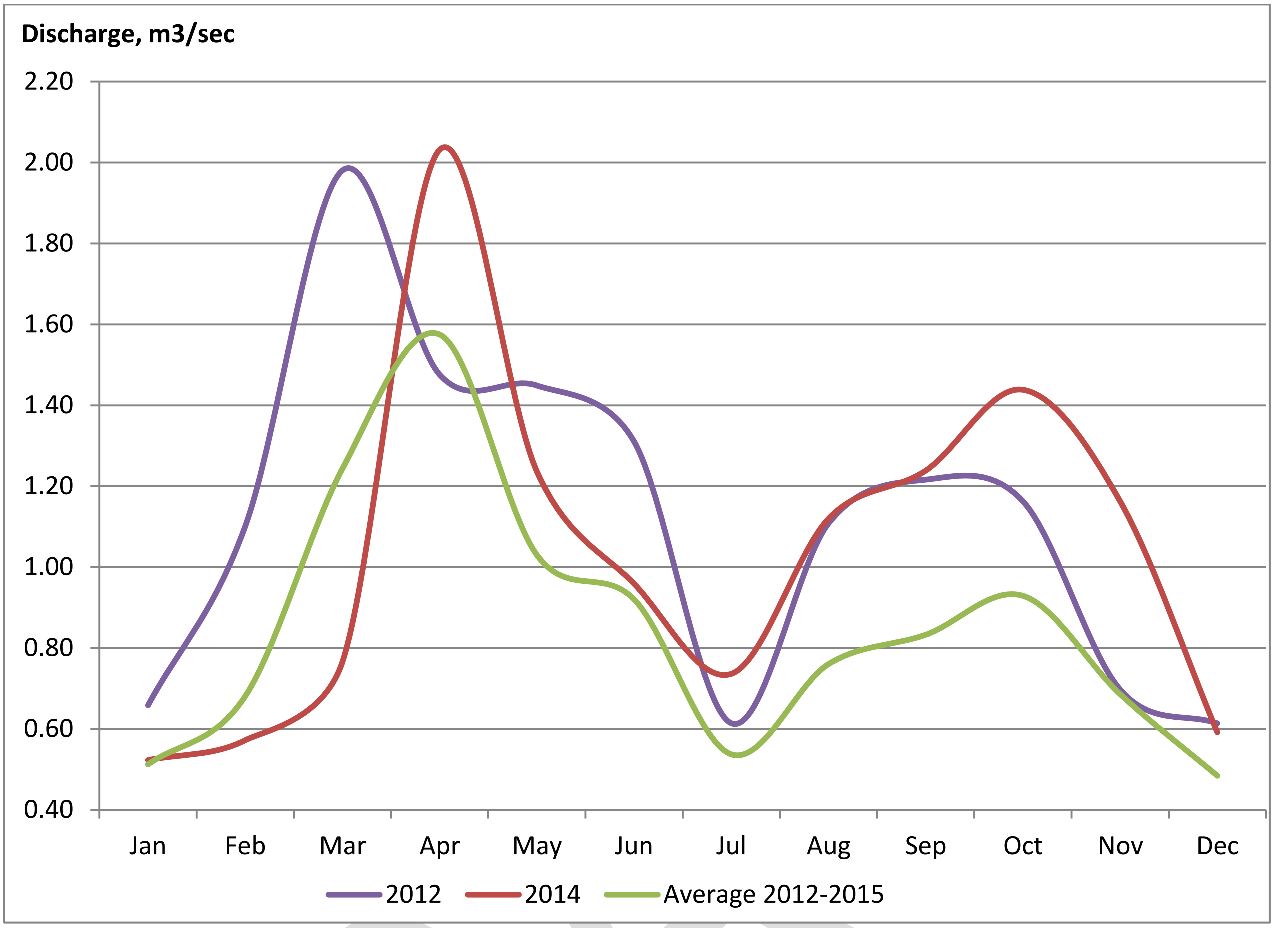

Figure 6.5. Average Monthly Water Levels of Pigeon River in Omemee: Average, 2012 and 2014

July-October is a period of low flow in local watercourses. By that time, the groundwater reserve is already depleted and sporadic precipitation and high evapotranspiration rates keep the surface run-off component of stream flow low.

The lowest water levels and flows at Pigeon River headwaters section are usually occur in late June-August. However, occasionally the lowest water levels have been observed in winter months, specifically in February, when precipitation falls in form of snow, no surface inflow is available and stream flow depends on groundwater component only.

Typically, water levels start gradually increase in October and keep rising in November-December, responding to the higher precipitation volumes and lower rates of evapotranspiration. During the winter months (December-February), ice cover establishes on the tributaries of Pigeon Lake, and water levels remain low.

Sometimes cold winter weather is interrupted by milder temperatures and even occasional rains. Especially typical is a January thaw. When a thaw is significant enough to melt the existing snowpack and create a runoff, water levels and flows in the local watercourses increase, significantly at times.

6.4 Baseflow

Baseflow is the portion of flow in a watercourse that comes from groundwater discharge, rather than direct runoff related to rain or snowmelt events. During most of the year, stream flow is composed of both groundwater contribution and surface runoff. Baseflow conditions are deemed to exist when groundwater provides the entire flow of a stream. Ultimately, sustained groundwater inflow into the tributaries means sustained water levels and healthy conditions for the lakes.

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. It also provides valuable information for fish and water resources management.

Methodology

Baseflow monitoring involves measuring the discharge at designated locations during prolonged periods of dry weather. In general, the sample sites were located at every stream-road crossing throughout the watershed.

Criteria for the 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, 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 described in Hinton, 2005. In order to collect comparable and reliable data, the stream flow measurements are to be performed under consistent groundwater inflow conditions; meaning the volume of groundwater storage should not experience significant change. Therefore, the survey is to be conducted under dry conditions when no significant precipitation has occurred during the previous two weeks, in the shortest possible period of time. Data analysis involves calculation and mapping of discharge and net discharge at every measured point and net discharges per a square kilometer (Figure 6.6).

The baseflow data for the Pigeon Lake watershed were collected during the summer of 2012 and 2015. In total, 118 sites throughout the study area were visited (Table 6.4). Fifty eight sites were found flowing and were measured. Fourteen sites were visibly flowing, but not suitable for measurements (too deep to measure by wading).

Thirty nine sites were found dry or with standing water in the channel, indicating that no groundwater contribution was occurring upstream of the sampling location.

Table 6.4. Baseflow Monitoring in the Pigeon Lake Watershed

Watershed	Number of Stations				
	Total	Measured	Not suitable for measurement	Dry / No Flow	Not found / Not accessible
Pigeon River	39	25	6	7	1
Fleetwood Creek	21	14	0	7	0
Pigeon Lake	31	8	4	17	2
Nogies Creek	27	11	4	8	4
Total	**118**	**58**	**14**	**39**	**7**

Further data analysis involves calculation of net discharges at every measuring point and net discharges per square kilometer. Based on the observed data, map of the groundwater net discharge has been generated (Figure 6.8). This map shows distribution of the groundwater discharge throughout the watershed.

Overall, analysis has revealed that:

- Baseflow values throughout the Pigeon Lake watershed vary considerably. The highest baseflow was observed at the headwaters of the Pigeon River, recorded at more than 100 l/sec/km^2.
- However, at the number of locations, a loss of flow in a channel was recorded. There are number of possible reasons and for a watercourse to lose flow on a particular stretch, including geology of the area, large wetlands that may cause extensive evaporation and retain water, extensive water taking, both directly from the stream as well as well by pumping.
- Headwaters of the Pigeon River, located within the northern slope of the Oak Ridge Moraine and the adjacent portion of the Peterborough Drumlin Fields physiographic region, produce the most substantial baseflow in the watershed, more than 10 l/sec/m^2.
- However, the most southern portion of the Pigeon River watershed at the top of the Oak Ridge Moraine produces no baseflow because of hummocky topography of the region and its highly permeable sand-gravel composition.
- Baseflow in the middle portion of the watershed, between Omemee and Bobcaygeon, is extremely limited. This part of the Pigeon Lake watershed is composed by clay tills that do not have good water holding capacity. Majority of watercourses, measured in this area, were found dry or had standing water, what indicates absence of the groundwater input (baseflow).
- The northern-most portion of the watershed that includes Nogies Creek and Eel's Creek, demonstrates baseflow about 5 l/sec/km^2. As this part of the watershed is composed of bedrock formations, granites and gneisses, the movement of the groundwater is lee predictable and highly variable.

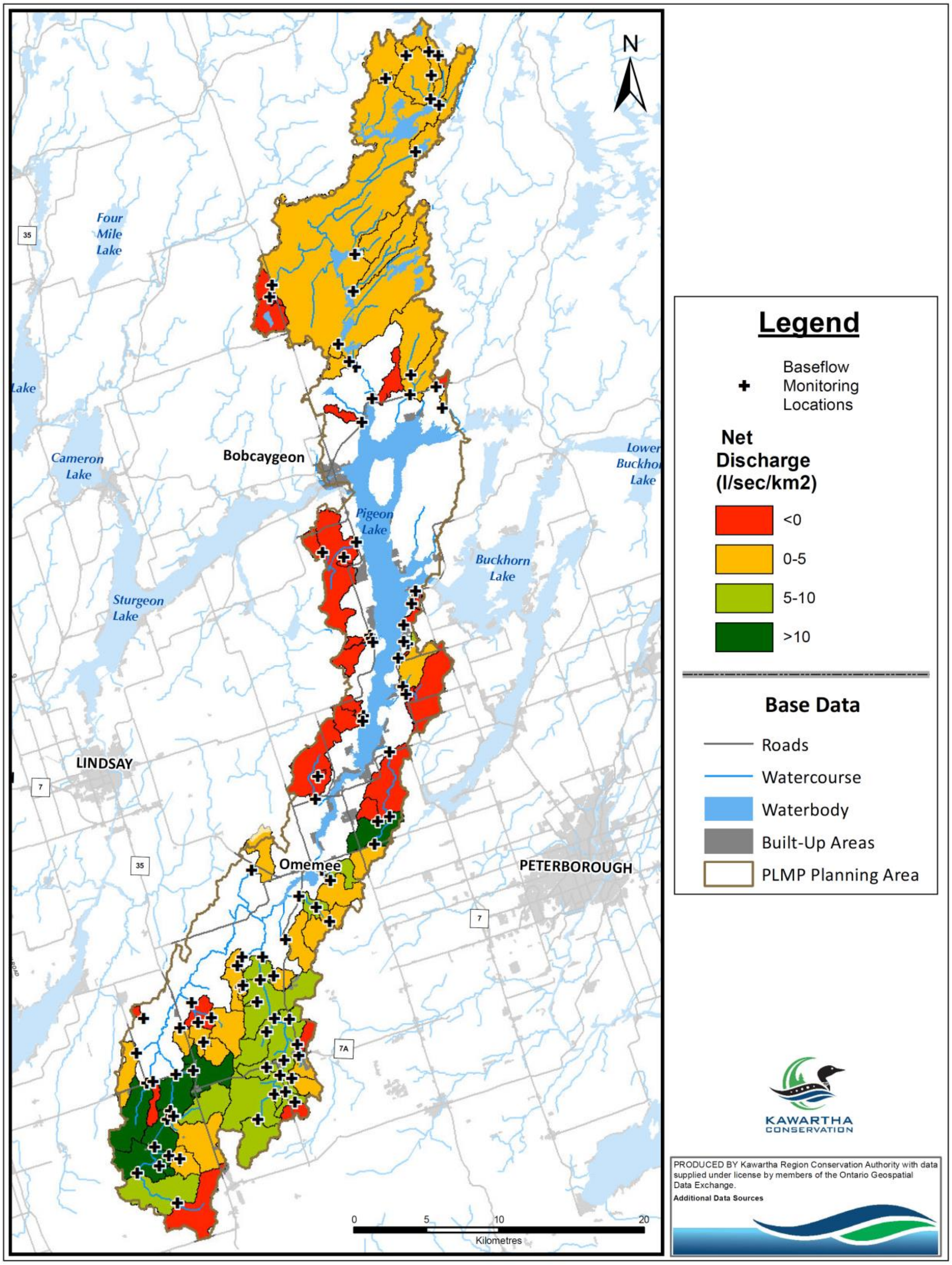

Figure 6.6. Baseflow Distribution in the Pigeon Lake Watershed

In addition to the field monitoring of baseflow, baseflow separation analysis was performed for monitoring locations where data permitted. The WHAT-Web Based Hydrological Assessment Tool application, developed by a group of researchers from Purdue University, West Lafayette, Indiana, was used (Lim et al., 2005). This analysis allows to separate groundwater component of the flow for the different hydrological conditions. Figures 6.9 and 6.10 demonstrate the example of the baseflow separation analysis for the Pigeon River at Lotus and Nogies Creek. As a part of the analysis, the baseflow indexes (BFI) were calculated (Table 6.5). A BFI indicates proportion of baseflow component in the total runoff of a catchment and describes the influence of watershed's geology and soils on river flow. It varies between 0 and 1, indicating the range of conditions from an absence of the groundwater inflow to fully groundwater fed watercourses, respectively.

Table 6.5. Calculated Baseflow Indexes for the Pigeon River and Nogies Creek

Year	Pigeon River at Lotus	Nogies Creek at FR 116
2012	0.755	
2013	0.74	0.262
2014	0.73	0.256

Figures 6.7 and 6.8 demonstrate how geological and morphological settings define the hydrological regime of a watercourse. As it was mentioned before, the Pigeon River monitoring location is situated at the headwaters of the stream within the Oak Ridge Moraine. Channel gradient is high, watershed slopes are steep, sand and gravel aquafers are layered with clayish aquitards. As a result, a hydrograph in Figure 6.7 demonstrates a flashy nature of the Pigeon River flow at this monitoring location, supported by significant groundwater component that makes about 75% of the total flow.

To the contrary, the Nogies Creek base flow separation analysis shows that the groundwater inflow to the watercourse makes about 25% of the total flow only. It is determined by the fact that majority of the Nogies Creek watershed is composed by the rocky formation of the Canadian Shield, where aquafers are erratic and inconsistent.

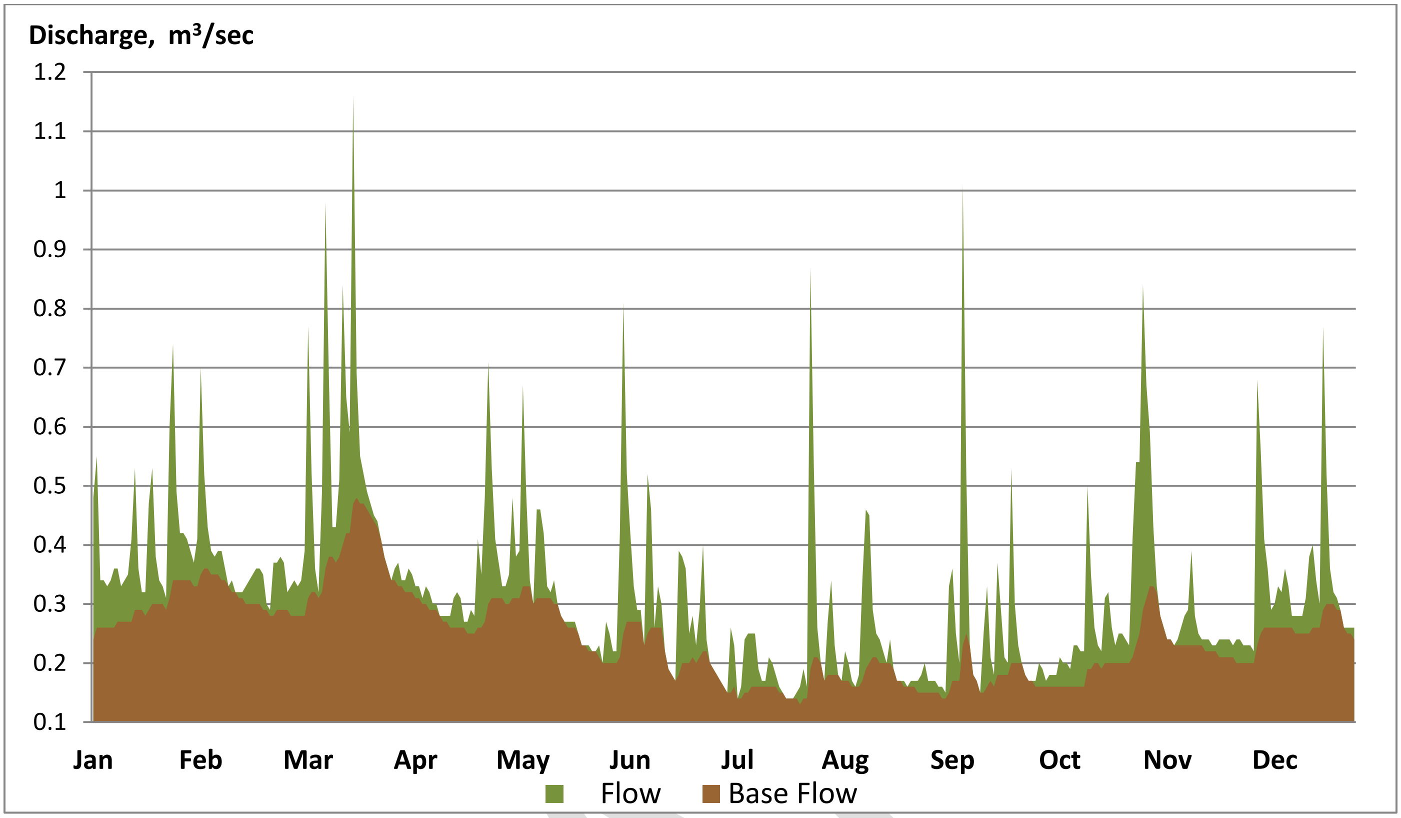

Figure 6.7. The Pigeon River at Lotus Hydrograph and its Baseflow Component, 2012

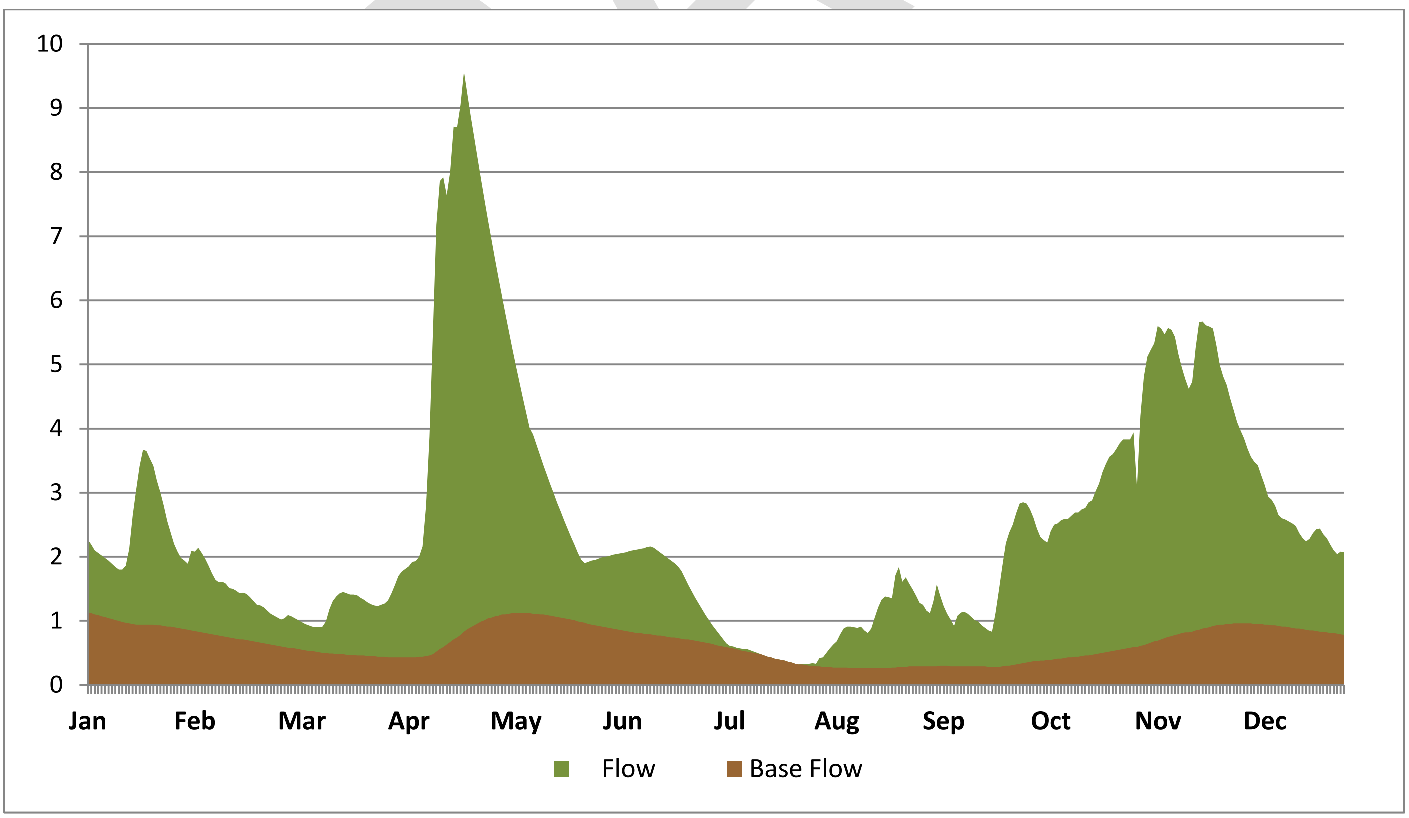

Figure 6.8. The Nogies Creek Hydrograph and its Baseflow Component, 2013

6.5 Water Use

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 permitted water use within the Pigeon Lake watershed.

Water users that withdraw or holdback (e.g., through impoundments) more than 50,000 litres of water per day are considered major water takings and are regulated under the Ontario Water Resources Act. These activities require a Permit to Take Water (PTTW) from the Ontario Ministry of Environment and Climate Change and the amount of water used is documented and reported to the MOE. Water takings for domestic use, agriculture (livestock and poultry watering) and emergency purposes (e.g., firefighting) do not require a permit. Major water taking information is managed in a provincial dataset, maintained by the MOECC, 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 current water taking information for study area was obtained from that dataset. The best available data were used to determine active permits and volume of permitted water withdrawals within the watershed (as of April 2015).

Overall, the permitted water taking within the study area is not significant. There are 30 active Permits to Take Water within the study area (Table 6.6, Figure 6.9). Nineteen of them are issued the purposes that are considered as non-consumptive water taking: agricultural and commercial (golf courses) irrigation, pit and quarry dewatering and aggregate washing, snowmaking, wildlife conservation and groundwater remediation. In total, more than 93% (62729.6 m^3) of allocated daily maximum water taking within the study area is for non-consumptive water use. Fourteen permits are used for water supply that accounts for approximately 6.3% (4303.3 m^3) of allocated daily maximum water taking. Seven of those PTTWs serve municipal drinking water systems, all of them withdraw groundwater.

There are six municipal drinking water systems within the study area. They serve local communities that range in size from 100 to 500 residents. As reported, average pumping rate for municipal drinking water systems does not exceed 0.2 m^3/day per person. The largest system, Victoria Place, situated at the western shore of the lake, withdraws about 87 m^3/day. Other PTTWs, allocated for drinking water, serve campgrounds including Emily Provincial Park, and a golf and country club.

Table 6.6. Summary of Permits to Take Water in the Pigeon Lake Watershed

Source / Category	Groundwater		Surface Water		Ground and Surface Water		Total	
	Number of permits	Maximum per day, L	Number of permits	Maximum per day, L	Number of permits	Maximum per day, L	Number of permits	Maximum per day, L
Commercial	1	6541191	4	1245604	2	790500	7	8577295
Industrial	1	16372800	--	--	2	5718240	3	22091040
Water Supply	10	4171660	--	--	1	31625	11	4203285
Remediation	1	80640	--	--	--	--	1	80640
Miscellaneous*	1	10415000	4	9841540	1	5388020	6	25644560
Agricultural	--	--	1	3065850	--	--	1	3065850
Dewatering	--	--	--	--	1	3270240	1	3270240
Total	**14**	**37581291**	**9**	**14152994**	**7**	**15198625**	**30**	**66932910**
Total, m^3/day		**37581.3**		**14153**		**15198.6**		**66932.9**

* Includes permits for wildlife conservation

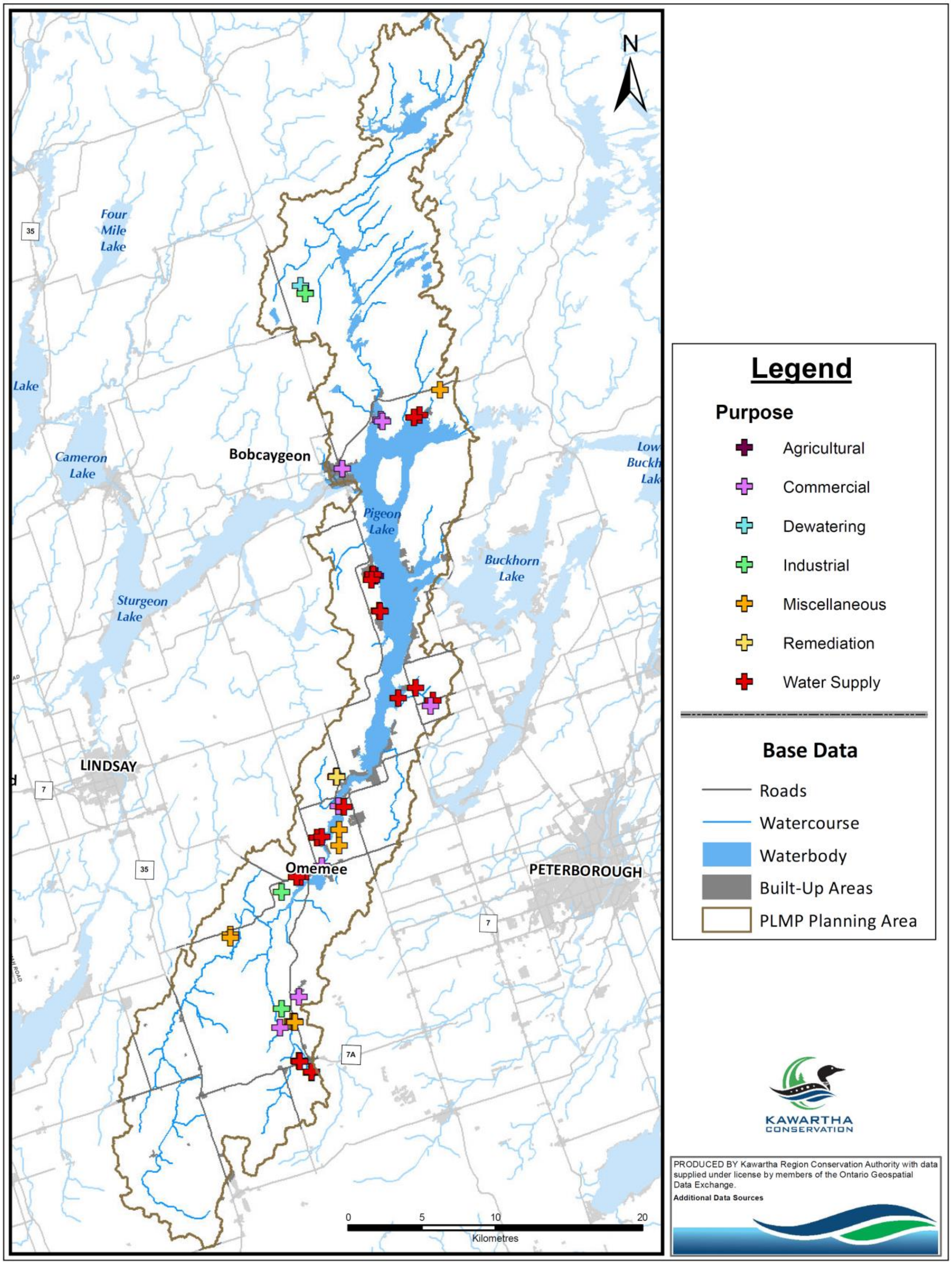

Figure 6.9. Permit to Take Water Sites in the Pigeon Lake Watershed

6.6 Water Inflows and Outflows

A water budget is an essential component of any hydrological and water quality study. In the framework of a Lake Management Plan, the water budget can be used for multiple purposes. For example, the lake water budget and its components are necessary to evaluate cumulative effects of various land uses on water quality in the lake and its tributaries as well as to determine priority areas for environmental monitoring. Moreover, the accurate water inflow values are crucial for further calculations of phosphorus and nitrogen loadings for the lake.

A water budget for any given water body or watershed is a sum of all water inputs, outputs and changes in storage. All water inputs into the lake such as precipitation, surface and groundwater inflows, discharges from sewage treatment plants and septic systems should equal the sum of all water outputs from the lake such as evaporation and evapotranspiration, surface and groundwater outflows, water extraction for the water supply purposes. Consequently, the water budget equation for Pigeon Lake can be expressed as:

$$P - E + Q_{in} - Q_{out} + G_{in} - G_{out} + A_{in} - A_{out} \pm \Delta S \pm \Delta = 0$$

Where:
P – precipitation on the water surface of the lake,
E – evaporation from the water surface of the lake,
Q_{in} – sum of all surface inflows into the lake,
Q_{out} – sum of all surface outflows,
G_{in} – groundwater inflow into the lake,
G_{out} – groundwater outflow from the lake (in this case no measurements have been done for the groundwater flows),
A_{in} – anthropogenic inputs from the Bobcaygeon WWTP and septic systems along the shorelines,
ΔS – change in lake storage.

As it was mentioned before, Pigeon Lake is a one of three lakes that form a tri-lake system. The schematic diagram of the tri-lake system is outlined at Figure 6.10. The system is defined by the water control structures: two dams and a lock in Bobcaygeon and a dam and a lock in Buckhorn. Water enters Pigeon Lake from Sturgeon Lake in Bobcaygeon and moves through Pigeon and Buckhorn lakes first in the southern and then in the north-eastern direction, where it exits the system into Lower Buckhorn Lake through the Buckhorn dam. Chemong Lake is connected to Buckhorn Lake from the south-east. The dams in Bobcaygeon are operated by the TSW and inflow data to the Pigeon Lake were calculated based on the dam operation. However, there is no means of measuring how much water leaves Pigeon Lake and enters Buckhorn Lake. The Buckhorn dam that is operated by the TSW is the first point where outflow estimation is possible. As a result, an accurate water budget can be theoretically calculated for the entire tri-lake system, but not for Pigeon Lake alone. However, the tri-lake water budget calculation has limited value for the Pigeon Lake Management Plan and is outside of the scope of the Plan.

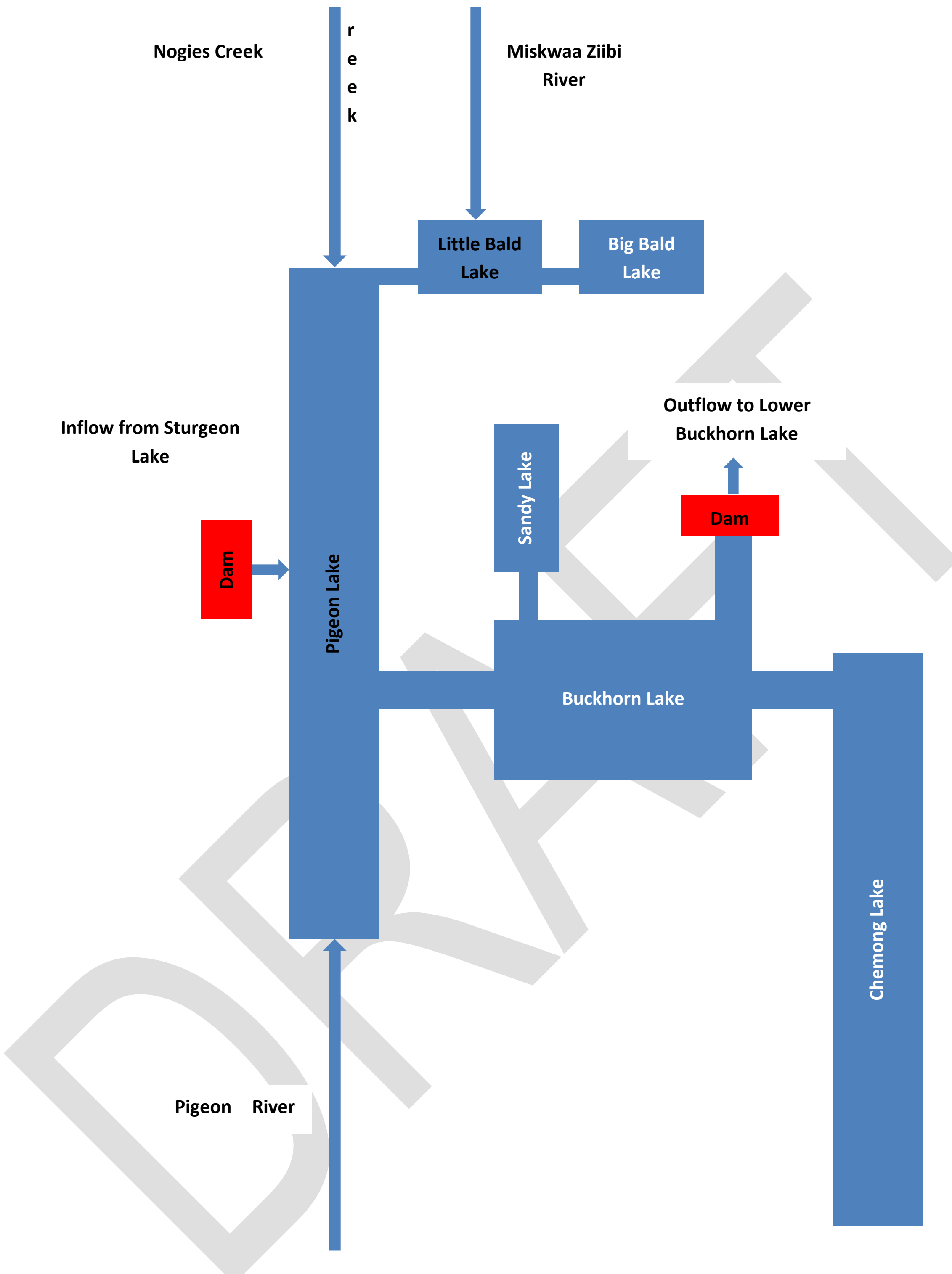

Figure 6.10. Schematic Diagram of the Tri-Lake System (Pigeon, Buckhorn and Chemong Lakes)

All water input components of the Pigeon Lake water budget, such as inflow volumes, precipitation and anthropogenic inputs were calculated in this study. As data on outflow was not available, it was assumed that all water that enters the lake either moved downstream or evaporated. Changes in the lake storage were taken into consideration as well.

The Pigeon Lake water budget components for the 2012–2013, 2013–2014 and 2014–2015 hydrologic years are demonstrated in Table 6.7.

A hydrologic year is the year-long cycle of the development of hydrologic processes. In Ontario the hydrologic year starts on June 1st and ends on May 31st of the next year, and reflects the natural hydrological cycle from the beginning of the summer low water period to the end of the spring freshet.

Table 6.7. Calculated and Estimated Components of the Pigeon Lake Annual Water Budget in the 2012-2013, 2013-2014 and 2014-2015 Hydrologic Years

	2012 – 2013		***2013 – 2014***		***2014 – 2015***		***Average***	
	Volume, mln. m^3	**% of total supply or loss**	**Volume, mln. m^3**	**% of total supply or loss**	**Volume, mln. m^3**	**% of total supply or loss**	**Volume, mln. m^3**	**% of total supply or loss**
Total water inflow:	**2,186.6**	**100**	**2,660.4**	**100**	**1,910.4**	**100**	**2,252.5**	**100**
Precipitation (P)	45.42	2.1	45.93	1.7	38.06	2.0	43.14	1.9
Sturgeon Lake Outlet	1,929.0	88.2	2,367.8	89.0	1,689.9	88.5	1,995.6	88.6
Pigeon River	81.85	3.7	84.48	3.2	75.45	3.9	80.59	3.6
Nogies Creek	64.86	3.0	87.16	3.3	50.55	2.6	67.52	3.0
Potash Creek	6.56	0.3	9.66	0.4	5.92	0.3	7.38	0.3
Reforestation Creek	5.75	0.3	5.25	0.2	4.24	0.2	5.08	0.2
Local surface inflow	52.16	2.4	59.03	2.2	45.22	2.4	52.14	2.3
Anthropogenic inputs	0.95	0.04	1.07	0.04	0.98	0.05	1.00	0.04
Total water outflow:	**2,186.6**	**100**	**2,660.4**	**100**	**1,910.4**	**100**	**2,252.5**	**100**
Evaporation (E)	32.48	1.5	32.48	1.2	32.48	1.7	32.48	1.4
Pigeon Lake Outlet	2,143.6	98.0	2,630.4	98.9	1,883.1	98.6	2,219.0	98.5
Change in lake storage (ΔS)	10.52	0.5	-2.47	-0.09	-5.26	-0.3	0.93	0.04

The total amount of precipitation for the lake has been calculated as an average from two precipitation gauges around the lake: the Potash Creek gauge near the southern end of the lake and Hawkers Creek gauge, which is located in close proximity to the Pigeon Lake northern end. The average amount of precipitation between the two stations was 881 mm in 2012-2013, 891 mm in 2013-2014 and 738 mm in 2014-2015. Although the precipitation amount is usually expressed in millimetres, it was converted into cubic meters for the purposes of convenient comparison with flow components.

Evaporation from the water surface of the lake is the least studied component of the water budget. Evaporation depends on many weather factors as, for example, daily air temperature, relative humidity, solar radiation, wind speed and direction as well as on such physiographic factors as local elevation, topography, vegetation and distance to the large water bodies (Great Lakes, oceans). There are no meteorological stations that monitor evaporation and evapotranspiration within the Kawartha Watershed as well as nowhere nearby. That's why evaporation and/or evapotranspiration value can be determined only theoretically taking into consideration available information found in scientific literature. After an extensive research in a variety of scientific sources, the long-term average amount of 625 mm per year was taken from the National Soil Database as the most accurate and appropriate potential evaporation/evapotranspiration value for Pigeon Lake (Soil Classification Working Group, 1998). This number was also converted into cubic meters for the convenient comparison.

Data from two flow monitoring stations, namely Nogies Creek at Fire Route 116 and Pigeon River in Omemee, have been used for calculations of an annual average flow rate and a yearly flow volume. Both stations are located somewhat upstream of their mouths and therefore calculated flow rates and volumes have been prorated accordingly to the size of the remained ungauged portion of the corresponding watersheds. The flow of Potash Creek, Reforestation Creek and other ungauged subwatersheds have been calculated with the use of the unit area discharge (L/sec/km^2) from similar gauged watersheds. For example, the Nogies Creek data were used for the flow volume calculations for Eels Creek.

Changes in lake storage (ΔS) have been calculated as a difference in the lake levels on June 1, 2012 and May 31, 2013; on June 1, 2013 and May 31, 2014; and on June 1, 2014 and May 31, 2015 multiplied by the lake water surface area. Those data have been obtained from the Trent-Severn Waterway water level monitoring station on Buckhorn Lake near Buckhorn. The change in lake storage can be positive or negative depending on difference in the lake water levels from year to year.

The highest inflow into Pigeon Lake was observed during the 2013-2014 hydrologic year when more than 2660 million cubic meters of water entered the lake. The lowest inflow was observed in the 2014-2015 hydrologic year (see Table 6.7).

7.0 Water Quality

7.1 Summary of Observations, Key Issues, and Information Gaps

Results and observations presented in this summary and the following chapter were obtained during a three-year monitoring period, which was initiated in 2012 and ended in 2015. The water quality monitoring network in the Pigeon Lake watershed included six stations on the lake's tributaries across the study area, one station at the Sturgeon Lake outlet, five monitoring stations on Pigeon Lake and one precipitation sampler situated west of the study area.

OBSERVATIONS

- ***Pigeon Lake can be characterized as mesotrophic water body with fair water quality.*** While the water quality is fair, there are times when nutrient levels exceed the Provincial Water Quality Objectives in both the Lake and the surrounding tributaries. High nutrient levels can create problematic aquatic macrophyte and algae growth, reducing recreational enjoyment of the lake and impacting the natural communities that live in and around the lake.

- ***Water quality is improving as is demonstrated by the long term results obtained from the Provincial Water Quality Monitoring data.*** Average phosphorous concentrations at the Sturgeon Lake outlet were 0.029 mg/L from 1971-75 and 0.016 mg/L from 2011-2015, while the average in Pigeon River was 0.022 mg/L and 0.017 mg/L in the same respective periods. Phosphorous loading has decreased significantly since the early 70's and has now been fairly stable for the last several years at a level that is roughly half that of the high period, likely due to improved effectiveness in wastewater water treatment.

- ***Average phosphorus concentrations in Pigeon Lake are usually around 0.014-0.019 mg/L while the highest observed readings in summer time were 0.025-0.033 mg/L.*** The Provincial Water Quality Objectives for lakes is 0.020 mg/L, therefore the average phosphorous concentrations are below these objectives while individual readings often exceed the objectives in the summer months.

- ***Nitrogen concentrations in the lake fluctuate within 0.30-0.76 mg/L in the Northern Pigeon and 0.54-0.95 mg/L in Southern Pigeon.*** Organic nitrogen constitutes most of the total nitrogen amount in the lake water, ranging from 57 to 99% of TN amount. Organic nitrogen originates in living material and often enters lake water as bodily waste from mammals, discarded food material, a component of cleaning agents and from organic forms of fertilizer (manure). Nitrogen, like Phosphorous, is a macronutrient in aquatic ecosystems and can lead to increased aquatic macrophyte and algae growth

- ***E.coli monitoring results have revealed that most of monitored streams in the watershed usually have E.coli levels below the Provincial Water Quality Objective (100 cfu/100 mL).*** Two streams, namely Potash Creek and Reforestation Creek, have quite elevated E.coli concentrations.

KEY ISSUES

- ***Water quality monitoring revealed that Pigeon Lake often has elevated phosphorus levels that exceed the Provincial Water Quality Objective (0.02 mg/L)***. Phosphorous can reach as high as 0.027-0.033 mg/L, at a level that can stimulate blue-green algae blooms and excessive aquatic plant growth.

- ***Small southern tributaries, namely Potash Creek and Reforestation Creek, quite often have elevated phosphorus levels***. Phosphorous levels can be elevated as a result of human activities in the corresponding subwatersheds. Reforestation Creek exhibited extremely high levels of phosphorus throughout the monitoring period.

- ***The most significant anthropogenic sources of phosphorus to Pigeon Lake include urban runoff (Bobcaygeon and small urban hamlets along the shoreline) and septic systems around the lakes.*** Better management of urban stormwater and the use of fertilizers and pesticides on urban properties would improve water quality that is responsible for a disproportionate amount of nutrient pollution into Pigeon Lake.

- ***Nitrogen concentrations were constantly elevated in Reforestation Creek.*** Both nitrate and total Kjeldahl nitrogen concentrations in the stream are very high and resulting in very high total nitrogen levels, up to 8.4 mg/L.

- ***Potential eutrophication of the lake through excessive nutrient and sediment input.*** Eutrophication is the accelerated aging process of lakes from high nutrient inputs, particularly nitrogen and phosphorous. Frequent blue-green algae blooms, high algae and aquatic macrophyte growth and the resulting oxygen depletion are symptoms of eutrophication. Pigeon Lake and its watersheds have demonstrated these symptoms, and despite meeting Provincial Water Quality Objectives, has had reports of blue green algae in the north end of the lake in recent years.

- ***Elevated E.coli levels in excess of the provincial objective have been often observed at local beaches***. Within the last five years, all beaches have been posted as unsafe for swimming at least once. Peace Park at Omemee Beach was frequently posted due to *E.coli* contamination in 2012, 2013 and 2014. High *E.coli* concentrations can likely be attributed to excessive bird feces (Canada Geese), urban runoff contaminated with pet feces, and/or shallow warm water with limited circulation.

- ***E.coli concentrations are extremely high in Reforestation Creek and exceeded the PWQO in 100% of samples and the seasonal E.coli geometrical mean reached 625 cfu/100 mL.*** Reforestation creek shows high levels of Phosphorous and Nitrogen concentrations, and *E.coli* is similarly very high, likely due to the significant proportion of the watershed that is in agricultural use. The watercourse has been altered at Peace Road in recent years, likely contributing to the deterioration of water quality.

- ***Potential contamination from other sources.*** Contaminant spills from power boats, grey water discharge from houseboats, oil spills from shoreline properties, raw wastes from partial bypasses at Bobcaygeon Sewage Treatment Facility, and other disturbances are all potential areas of concern when trying to maintain good water quality conditions.

INFORMATION GAPS

- ***No information on nearshore water quality data***. Water sampling on Pigeon Lake has taken place in the mid lake area, while no data exists on nearshore water quality, therefore little is known about the relationship between shoreline conditions and activities and the impacts to water quality directly adjacent to those areas.

- ***No data collected during the ice cover period on the lake.*** Winter ice cover changes the availability of Oxygen below the ice and therefore all biotic systems are impacted. The decomposition of plants and algae can reduce available oxygen for fish and other aquatic organisms. A comprehensive set of data for the entire year would create a complete water quality picture.

- ***Limited data on upstream Water Quality in order to pinpoint sources of pollution in the watersheds around Pigeon Lake.*** The water quality data that has been collected for this report focuses on the outlets of watersheds, helping to determine which watersheds contribute clean water to Pigeon Lake and which watersheds are polluting the lake. By moving upstream in the watersheds with the poorest water quality, water sampling and analysis can help determine what areas in these watersheds are problem areas.

- ***No data collected to determine if Pigeon Lake contains any emerging contaminants.*** Emerging contaminants such as Endocrine disrupting chemicals, Pharmaceuticals and personal care products, Polybrominated diphenyl ethers and road salt. Endocrine disruptors originating from pharmaceuticals and pesticides can alter the overall physiology and reproductive health of aquatic animal species. Personal care products including microbeads can impact aquatic systems greatly and have a great effect on habitat for juvenile fish and benthic feeders. Polybrominated diphenyl ethers are a group of chemicals used as flame retardants in a number of manufactured products which bioaccumulate and are persistent in the environment and are considered toxic to the environment as defined under the Canadian Environmental Protection Act. Elevated concentrations of chloride and sodium originating from road salt can have an effect on aquatic plant and animal communities in addition to an impact on human health.

7.2 Introduction

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

Human activities often have direct and indirect impacts on water quality that can result in changes to the natural environment. 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 landfills. Point sources of pollution are typically more easily identified and managed. In contrast, a non-point source of pollution reflects land use and refers to diffuse sources such as an agricultural drainage, 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 are often difficult to pinpoint to a specific site.

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. Current results can be compared against historical results to establish trends in water quality over time. Obtained results can also be compared to the Provincial Water Quality Objectives (PWQOs) (MOECC, 1994) and Canadian Water Quality Guidelines for the Protection of Aquatic Life (CWQGs) (CCME, 2007).

The Provincial Water Quality Objectives represent a desirable level of water quality that the MOECC strives to maintain in surface waters. The PWQOs are set at a level of water quality, which is protective of all aquatic species at all stages of their life cycle, including the most sensitive life stages of the most sensitive species over the long term and are helpful in assessing the degree of impairment to a surface water body. In some cases they are established to protect recreational water uses, which are based on public health and/or aesthetic values (MOECC, 1994).

Canadian Water Quality Guidelines are intended to provide protection for freshwater and marine life from anthropogenic stressors such as chemical inputs or changes to physical components (e.g., pH, temperature, and sedimentation). Guidelines are numerical limits or narrative statements based on the science-based benchmark for a nationally consistent level of protection for aquatic life in Canada (CCME, 1999).

Finally, it can be said that the main goal of the water quality data analysis is to convert water quality observations into information for educational purposes and decision-making at various levels of government.

7.3 Methodology

Water quality monitoring plays an important role in meeting the objectives of the Pigeon Lake Management Plan. Water quality data are obtained by collecting water samples at monitoring sites across the entire study area. As of 2015, the Pigeon Lake watershed has two long-term monitoring sites (ST5 and P2) sampled in the framework of the Provincial Water Quality Monitoring Network (PWQMN). Water quality sampling started at the Sturgeon Lake outlet (ST5) in 1966 and at the Pigeon River mouth (P2) in 1971. As well, widespread intensive additional sampling for the purposes of the Pigeon Lake Management Plan development was undertaken in 2012-2015 at seven tributary/inlet sites including those two PWQMN sites. There are also five open water sampling sites on the lake (Figure 7.1).

The monitoring stations are dispersed across the entire watershed at key locations covering all major tributaries. The monitoring stations on the lake are located in such way as to cover all main parts of the water body. 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 total suspended solids and nutrients including ammonia, nitrites, nitrates, total Kjeldahl nitrogen and total phosphorus. Samples for the lake management planning monitoring program are collected bi-weekly year round from tributaries and monthly from May to September from the lake monitoring sites.

Samples for the PWQMN program are collected during the ice-free period eight times per year and sent to the MOECC Laboratory Services Branch to be analyzed for alkalinity, metals, hardness, total suspended solids, anions such as chlorides, and all nutrients including ammonia, nitrites, nitrates, total Kjeldahl nitrogen, total phosphorus and orthophosphates. Furthermore, pH, dissolved oxygen, conductivity and temperature readings are taken at the time of sampling using an YSI hand held multi-meter.

In order to characterize bacteriological quality of surface water, a number of tributaries have been sampled during summer periods for *Escherichia Coli* (*E.coli*). A complete list of parameters sampled and corresponding guidelines or objectives are available in Appendix 2.

Statistical analysis of data was completed for total phosphorus (TP), total nitrogen (TN), *E.coli* and total suspended solids (TSS). Water temperature and dissolved oxygen data were also analyzed and graphically presented for the open lake monitoring sites. Table 7.1 shows the site ID, location, number of samples and date of the most recent sample. Historical water quality information from the 1970s, 1980s and 1990s has been also used for a comparison of current water quality data against long-term data sets in order to determine whether the lake's and tributaries' water quality is improving or deteriorating.

7.4 Pigeon Lake Tributaries

From a hydrological point of view the Pigeon Lake watershed includes all areas that supply water to the lake. This means that the Pigeon Lake watershed is comprised of not only small local subwatersheds (Potash Creek, Nogies Creek, Reforestation Creek, Eels Creek and Pigeon River), but also includes watersheds draining into Sturgeon, Cameron and Balsam lakes. It is a vast area that extends far north beyond the Kawartha Conservation jurisdiction to the edge of Algonquin Park. Another similar area includes Big Bald and Little Bald lakes and their corresponding watersheds situated to the north-east of Pigeon Lake. Therefore, for practical purposes we will consider only the portion of the Pigeon Lake watershed, which is adjacent to the lake and includes small and large tributaries that empty directly into the lake.

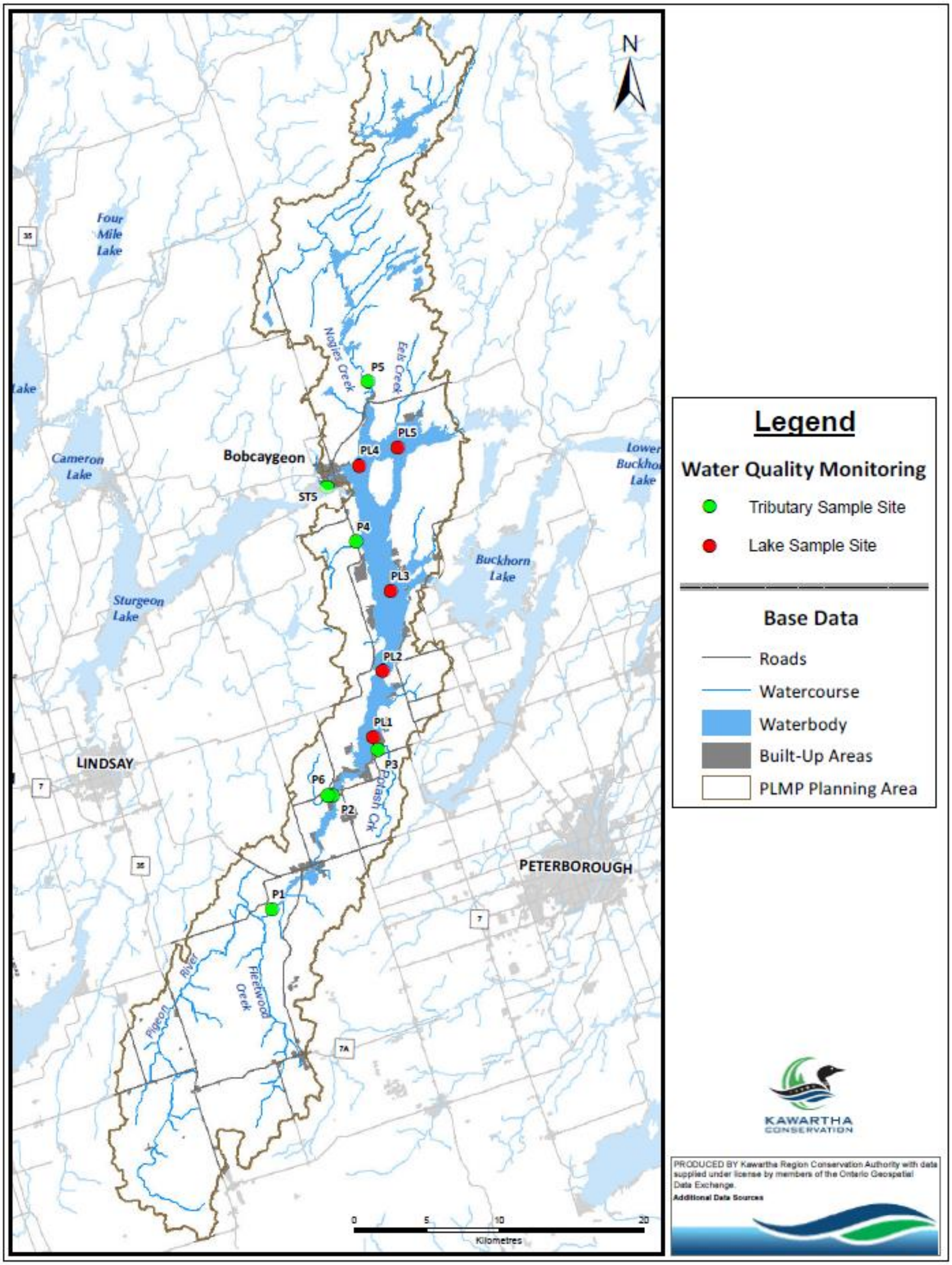

Figure 7.1. Water Quality Monitoring Stations in the Pigeon Lake Watershed

The study area includes the Pigeon River, Nogies Creek, Potash Creek and Reforestation Creek subwatersheds as well as drainage areas adjacent to the lake, with the largest input of water coming from Sturgeon Lake through Bobcaygeon (Table 6.7).

The Pigeon Lake watershed occupies the north-eastern portion of the Kawartha Conservation watershed. The total area of the Pigeon Lake watershed within the Kawartha Conservation jurisdiction is approximately 580 km^2 including the surface water area of the lake, which is 51.6 km^2. The study area for the Pigeon Lake Management Plan is 711.4 km^2 and includes areas adjacent to the lake from the east as well as the Eels Creek subwatershed. The major human land use in the watershed is agriculture, which occupies more than 28% of the land portion of the watershed. Rural development and roads occupy 4% and 1% of the watershed correspondingly. Natural areas such as forests (39%) and wetlands (15%) cover the largest portion of the study area.

Water quality concerns in the Pigeon Lake watershed include elevated concentrations of phosphorus in the lake and its southern tributaries as well as high *Escherichia Coli* concentrations in some streams and at public beaches, in addition to high nitrogen concentrations in Reforestation Creek. All forms of nitrogen in this creek have shown highly elevated concentrations over monitoring period. Reforestation Creek also has the highest phosphorus levels in the entire study area. All other parameters have concentrations far below the corresponding PWQOs or CWQGs and do not currently present any threat to aquatic life or human health.

Table 7.1. Water Quality Monitoring Stations in the Pigeon Lake Watershed

Station ID	Location	Number of Samples	Most Recent Sample
P1	Pigeon River at Hogsback Road	68	June-2015
P2	Pigeon River at Peace Road	96	June-2015
P3	Potash Creek at Westview Road	66	June-2015
P4	Unnamed Tributary at R.R.17	59	June-2015
P5	Nogies Creek at Tully's Road	68	June-2015
P6	Reforestation Creek at Peace Road	48	June-2015
ST5	Sturgeon Lake outlet in Bobcaygeon at Hwy 36	99	June-2015
PR1	Precipitation sampler	75	May-2015
PL1	Pigeon Lake, Southern End	19	Sept-2015
PL2	Pigeon Lake, Floods Landing	19	Sept-2015
PL3	Pigeon Lake, Jacob Island	19	Sept-2015
PL4	Pigeon Lake, East of Bobcaygeon	19	Sept-2015
PL5	Pigeon Lake, North-East of Big Island	19	Sept-2015

** Stations P2 and ST5 are monitored through the CKL LMP and PWQMN monitoring programs*

Phosphorus

Phosphorus is one of the two primary nutrients required for the growth of aquatic plants and algae in streams and lakes. Even in elevated levels phosphorus is not considered toxic to plants and animals, but its high concentrations in water can cause the process of eutrophication, which results into excessive algae and aquatic plant development, and a corresponding depletion of dissolved oxygen in the water column. The PWQO for total phosphorus (TP) concentrations in watercourses is set at 0.030 mg/L, in order to prevent nuisance algae and aquatic plant growth (MOECC, 1994). The PWQO for TP concentrations in lakes is 0.020 mg/L and/or 0.010 mg/L for those lakes with a natural TP level below this value (MOECC, 1994). As the Pigeon River and Pigeon Lake historically had TP concentrations well above 0.010 mg/L, the PWQO of 0.020 mg/L applies to the lake.

Total phosphorus is a measure of both soluble and insoluble phosphorus forms within a water sample. The insoluble component is primarily decaying plant and animal matter or soil particles, which either settles to the bottom or remain suspended in the water column as part of the total suspended sediments (solids). This form of phosphorus is not readily available to plants, and does not instantly change the biological productivity of a water body. In contrast, soluble phosphorus (e.g., orthophosphates) can be readily taken up by aquatic plants and algae, causing increased biological productivity and plant growth. Soluble phosphorus has primarily anthropogenic origins and poses a greater threat to the ecosystem than its insoluble forms.

In the Pigeon Lake watershed, phosphorus concentrations often exceed the PWQO in the Pigeon River and in two small southern tributaries (Potash Creek and Reforestation Creek); which resulted in TP averages being above the provincial objective in the 2012-2013 hydrologic year in the Pigeon River upstream of Omemee and in Reforestation Creek in 2013-2015 years. In the northern streams of the watershed, TP levels are considerably lower and very seldom exceed the PWQO. As a result, phosphorus averages in Nogies Creek, as well as in the unnamed creek at R.R.17 have always been below 0.020 mg/L *(*Figure 7.2). Average phosphorus concentrations in water flowing from Sturgeon Lake were also significantly lower than 0.020 mg/L.

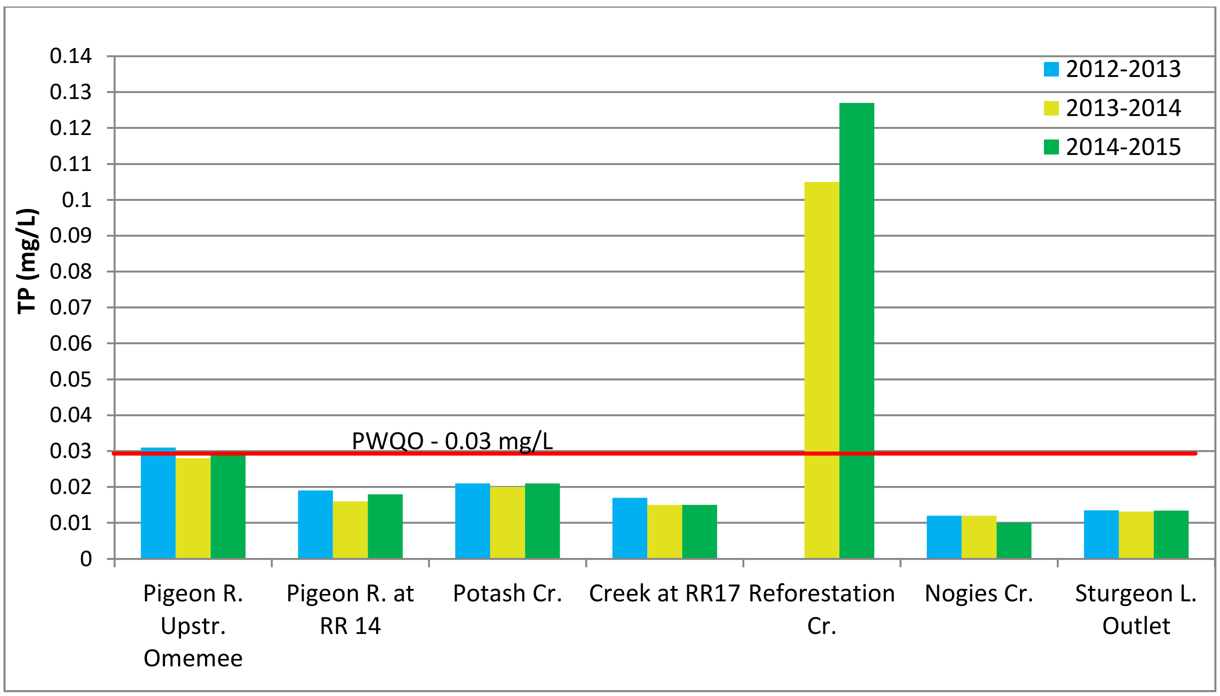

Figure 7.2. Average Phosphorus Concentrations (mg/L) in the Pigeon Lake Tributaries in 2012-2015

Nogies Creek begins in a vast forested area with many lakes and wetlands east of the Village of Kinmount. After leaving Crystal Lake, which is located in the utmost northern corner of its watershed, Nogies Creek flows among wetlands and forests into the northern portion of Pigeon Lake. Phosphorus levels in the creek over the period of monitoring (2012-2015) varied from 0.003 mg/L to 0.027 mg/L (Table 7.2). The average TP concentration in the creek over the three-year period is 0.011 mg/L, which is well below the PWQO. The annual averages ranged from 0.010 mg/L in 2014-2015 to 0.012 mg/L in 2012-2014 (Figure 7.2). Median concentrations were almost identical during the three years of monitoring, being 0.011 mg/L over that period (Table 7.2). No exceedances above the PWQO of 0.03 mg/L were detected in the stream. Phosphorus concentrations in the creek are slightly higher during the summer months (0.012-0.027 mg/L). The highest phosphorus readings were observed under both high and low flow conditions that can indicate that phosphorus is entering the watercourse with stormwater runoff and as a result of release from wetlands during prolonged dry periods. Phosphorus levels are lower during the other three seasons (0.003-0.018 mg/L). The lowest TP concentrations are usually observed throughout late autumn, winter and into early spring.

Table 7.2. Results of Statistical Analysis of Total Phosphorus Concentrations in Nogies Creek for the Periods of 1971-1973 and 2012-2015

Statistical Parameters	1971-1973	2012-2013	2013-2014	2014-2015	Total 2012-2015
Maximum	0.044	0.027	0.021	0.018	0.027
75th percentile	0.018	0.014	0.015	0.012	0.014
25th percentile	0.012	0.006	0.008	0.006	0.007
Minimum	0.003	0.003	0.003	0.003	0.003
Average	0.017	0.012	0.012	0.010	0.011
Median (50th percentile)	0.014	0.010	0.011	0.011	0.011
Exceedences, %	8	0	0	0	0
Number of samples	39	23	22	23	68

Comparisons of the current data with historical monitoring data from 1971-1973 demonstrates a noticeable decrease in phosphorus concentrations in Nogies Creek since the early 1970s (Table 7.2). While an average and median phosphorus concentrations were 0.017 and 0.014 mg/L respectively in 1971-1973, they remained consistently low at 0.011 mg/L 40 years later during the 2012-2015 monitoring period.

Potash Creek is a small southern tributary flowing into Pigeon Lake, with its subwatershed located in the central-eastern part of the study area (Figure 7.1). Most of its subwatershed is occupied by agricultural lands. As a result, water quality in the creek varies considerably throughout the year. Phosphorus concentrations are much higher during summer (0.024-0.052 mg/L) and spring freshet (0.031-0.072 mg/L), while during late autumn, winter and spring they vary from 0.005 to 0.024 mg/L which is far below the PWQO. The average phosphorus concentration is 0.021 mg/L, with results ranging between 0.005 and 0.072 mg/L. The median concentration is 0.019 mg/L which is very close to the average value. Over the three-year period, TP concentrations exceeded the PWQO in 15% of all collected samples. More samples exceeded the PWQO in 2012-2013 and 2013-2014 than in 2014-2015 and there is no obvious trend between years. During the first and second year, approximately 18 and 16% of samples exceeded the objective respectively and only 10% during the last year of monitoring (Table 7.3). The most frequent exceedances were observed during the month of July when flows in the creek was very low and the water was almost stagnant. In 2012 and 2013 there was often no flow occurring during the month of August.

Reforestation Creek occupies a small part of the watershed west of the Pigeon River and north of Omemee. Agricultural lands take up a considerable portion (52%) of the creek's subwatershed. Results of the water quality monitoring from the 2013-2015 period show an increasing trend in total phosphorus levels in this stream. Determination of a statistically significant trend or variations between years needs to be resolved by means of long-term monitoring.

Table 7.3. Results of Statistical Analysis of Total Phosphorus Concentrations in Potash Creek for the Period of 2012-2015

Statistical Parameters	2012-2013	2013-2014	2014-2015	Total 2012-2015
Maximum	0.052	0.038	0.072	0.072
75th percentile	0.026	0.024	0.024	0.025
25th percentile	0.011	0.015	0.013	0.013
Minimum	0.005	0.006	0.007	0.005
Average	0.021	0.020	0.021	0.021
Median (50th percentile)	0.018	0.020	0.019	0.019
Exceedences, %	18	16	10	15
Number of samples	22	19	21	62

The average phosphorus concentration in the creek is 0.116 mg/L which is a very high value for this area (Table 7.4). The annual average concentrations during two years changed from 0.105 mg/L in 2013-2014 to 0.127 in 2014-2015 which is considerably over the PWQO. The highest phosphorus concentrations (0.820 and 2.190 mg/L) were detected during spring freshets. Another extremely high TP concentration was found in the water of the creek under high water conditions in October 2013. The lowest TP concentrations in the range of 0.011-0.027 mg/L were observed during winter as well as in August-September (0.014-0.023 mg/L).

Phosphorus levels exceeded the PWQO in 57% of all samples (Table 7.4). Exceedances were usually observed in June-July, October-November and in March-April.

Table 7.4. Results of Statistical Analysis of Total Phosphorus Concentrations in Reforestation Creek for the Period of 2013-2015

Statistical Parameters	2013-2014	2014-2015	Total 2013-2015
Maximum	0.820	2.190	2.190
75th percentile	0.044	0.039	0.041
25th percentile	0.023	0.022	0.022
Minimum	0.019	0.011	0.011
Average	0.105	0.127	0.116
Median (50th percentile)	0.032	0.033	0.033
Exceedences, %	57	58	57
Number of samples	23	24	47

A small unnamed creek that crosses Regional Road 17 and empties into Pigeon Lake in the central portion of the study area which drains 17 km^2 of mainly swampy and forested area along western shore of the lake. The creek has good water quality with low phosphorus and nitrogen concentrations.

Since the onset of monitoring activities, phosphorus concentrations in the creek have usually been below the PWQO. Phosphorus levels varied from 0.004 to 0.064 mg/L, with an average of 0.016 mg/L (Table 7.5). The average annual phosphorus concentrations varied from 0.015 mg/L in 2013-2015 to 0.017 mg/L in 2012-2013.

Maximum values of 0.050 and 0.064 mg/L were observed in July and October of 2012 respectively, under dry weather conditions. It is possible to suggest that high phosphorus concentrations in the creek during dry hot weather are the result of phosphorus input (desorption) from sediments and organic material in a large wetland in the lower reach of the creek. Consequently, seasonal distribution of total phosphorus in the creek is characterized by the highest readings in summer time during both low flow conditions. The lowest TP concentrations are usually observed throughout late autumn, winter and early spring before snowmelt.

Table 7.5. Results of Statistical Analysis of Total Phosphorus Concentrations in Unnamed Creek at RR 17 for the Period of 2012-2015

Statistical Parameters	2012-2013	2013-2014	2014-2015	Total 2012-2015
Maximum	0.064	0.029	0.039	0.064
75th percentile	0.018	0.017	0.018	0.017
25th percentile	0.008	0.012	0.009	0.009
Minimum	0.005	0.004	0.006	0.004
Average	0.017	0.015	0.015	0.016
Median (50th percentile)	0.012	0.015	0.010	0.013
Exceedences, %	15	0	15	10
Number of samples	20	18	21	59

The Pigeon River is the largest Pigeon Lake tributary with a drainage area of 274 km^2, which begins on the Oak Ridges Moraine south from the lake. The river water quality is an important factor for quality of the water in the southern part of Pigeon Lake. Since the onset of monitoring activities in 2012, water quality in the river has been quite good, with phosphorus concentrations usually below the PWQO (Figure 7.2). As the river headwaters are located on the Oak Ridges Moraine in a scarcely populated area, the Pigeon River has relatively low concentrations of all potential contaminants including phosphorus. There are two monitoring stations on the river. One is located at Hogsback Road upstream of the Omemee pond and the other is located downstream of Omemee at Regional Road 14 (Peace Road). The average phosphorus concentration at the upstream monitoring location is 0.029 mg/L, with results ranging from 0.009 to 0.165 mg/L (Table 7.6). In 2012-2013 the average TP concentration exceeded the PWQO and the number of exceedances reached 40% of all collected samples.

Table 7.6. Results of Statistical Analysis of Total Phosphorus Concentrations in the Pigeon River Upstream of Omemee for the Period of 2012-2015

Statistical Parameters	2012-2013	2013-2014	2014-2015	Total 2012-2015
Maximum	0.153	0.117	0.165	0.165
75th percentile	0.035	0.026	0.027	0.031
25th percentile	0.014	0.022	0.014	0.016
Minimum	0.009	0.009	0.009	0.009
Average	0.031	0.028	0.029	0.029
Median (50th percentile)	0.024	0.024	0.023	0.023
Exceedences, %	40	15	18	25
Number of samples	25	20	22	67

Seasonal distribution of total phosphorus in the Pigeon River is characterized by the highest readings during spring freshet (0.117-0.165 mg/L). During late spring, TP concentrations can be also quite high, up to 0.053 mg/L, possibly as a result of runoff from upstream wetlands. The lowest TP concentrations are usually observed throughout late autumn – early spring.

Table 7.7. Results of Statistical Analysis of Total Phosphorus Concentrations in the Pigeon River at RR 14 for the Period of 2012-2015

Statistical Parameters	2012-2013	2013-2014	2014-2015	Total 2012-2015
Maximum	0.097	0.032	0.065	0.097
75th percentile	0.022	0.019	0.023	0.022
25th percentile	0.011	0.012	0.012	0.012
Minimum	0.004	0.003	0.003	0.003
Average	0.019	0.016	0.019	0.018
Median (50th percentile)	0.016	0.016	0.017	0.016
Exceedences, %	30	20	39	30
Number of samples	30	30	31	91

The average phosphorus concentration in the downstream monitoring location is 0.018 mg/L, with results ranging between 0.003 and 0.097 mg/L. Median concentration is 0.016 mg/L, very close to the average value (Table 7.7).

Over the three-year monitoring period phosphorus concentrations exceeded the PWQO in 30% of all collected samples. There were more exceedances in 2014-2015 and 2012-2013 than in 2013-2014. The first and last year showed that 30% and 39% of samples exceeded the objective respectively while only 20% of the samples during the second year of monitoring exceeded the PWQO (Table 7.7). Most exceedances were observed during the May – July periods with higher flows in the stream.

Water quality in the Pigeon River at Regional Road 14 has been monitored since 1972 in the framework of the PWQMN. During the 43 years of monitoring the highest phosphorus levels in the river were observed during 1970s into the early 1980s when waste water treatment plants were in a rudimentary state and the amount of phosphorus in laundry detergents, soaps and shampoos was much higher in addition to phosphate- fertilizer application rates higher as well (Table 7.8). Since the beginning of 1990s phosphorus concentrations stayed approximately in the same range with the five-year averages varying from 0.015 to 0.017 mg/L and the five-year medians varying from 0.015 to 0.017 mg/L as well. The number of exceedances varied from 14% to 26%. During the 2006-2010 period phosphorus levels were the lowest since 1972 (Table 7.8).

Table 7.8. Results of Statistical Analysis of Total Phosphorus Concentrations in the Pigeon River at RR 14 for the Period of 1972-2015

Statistical Parameters	1972-1975	1976-1980	1981-1985	1986-1990	1996-2000	2001-2005	2006-2010	2011-2015
Maximum	0.063	0.084	0.088	0.043	0.032	0.052	0.041	0.036
75th percentile	0.027	0.026	0.022	0.023	0.020	0.020	0.018	0.020
25th percentile	0.016	0.013	0.012	0.010	0.012	0.015	0.012	0.013
Minimum	0.003	0.005	0.001	0.003	0.004	0.006	0.005	0.004
Average	0.022	0.021	0.020	0.017	0.016	0.018	0.015	0.017
Median (50th percentile)	0.020	0.017	0.018	0.016	0.016	0.017	0.015	0.015
Exceedences, %	47	39	35	35	24	23	14	26
Number of samples	36	44	52	49	46	39	35	34

The largest amount of water (approximately 90% of the total incoming volume) enters Pigeon Lake from Sturgeon Lake. Indicating an importance of why the quality of Sturgeon Lake's water and phosphorus levels in impact Pigeon Lake's water quality.

The long-term water quality data collected through the PWQMN program at the Sturgeon Lake outlet in Bobcaygeon demonstrate that phosphorus concentrations were steadily decreasing since the 1970s until the 2000s (Table 7.9). Over the 30-year period average concentrations in the lake's water decreased by almost 50% from 0.029 mg/L to 0.016 mg/L. The number of exceedances has dropped from 84% in 1971-1975 to 17% in 2001-2005. Since 2001 and until present the average and median phosphorus levels have remained within the same narrow range, 0.015-0.016 mg/L (Table 7.9). The number of exceedances continued to decrease during the 2006-2010 period (8%), but increased recently to 26%.

The highest phosphorus concentrations at the Sturgeon Lake outlet were observed during late summer – July-August. Sturgeon Lake remains in the mesotrophic category of water bodies and supplies Pigeon Lake with water containing rather low levels of phosphorus.

Table 7.9. Results of Statistical Analysis of Total Phosphorus Concentrations at the Sturgeon Lake Outlet During May-October for the 1971-2015 Monitoring Period

Statistical Parameters	1971-1975	1981-1985	1990-1994	1996-2000	2001-2005	2006-2010	2011-2015
Maximum	0.054	0.093	0.067	0.046	0.024	0.022	0.032
75^{th} percentile	0.034	0.035	0.025	0.024	0.020	0.018	0.021
25^{th} percentile	0.021	0.017	0.014	0.014	0.012	0.012	0.011
Minimum	0.012	0.008	0.010	0.006	0.008	0.006	0.004
Average	0.029	0.029	0.022	0.020	0.016	0.015	0.016
Median (50^{th} percentile)	0.027	0.022	0.020	0.020	0.015	0.016	0.016
Exceedances, %	84	54	39	39	17	8	26
Number of samples	32	41	28	28	30	38	78

Nitrogen

Nitrogen is another key nutrient vital for the development of algae and aquatic plants. Nitrogen is present in surface water in several chemical forms such as free ammonia and ammonium, nitrite, nitrate and organic nitrogen. For the purpose of analytical and/or statistical analysis, the nitrite values are often combined with the nitrate concentrations, as nitrite-ions are the transitional form of nitrogen from ammonia to nitrate-ions and are usually present in surface water in very low concentrations. Eventually, all nitrites in lake or river water are transformed into nitrates in a very short time. The combined concentrations of nitrate and nitrite are usually called total nitrates and consist typically of 98.0-99.9% of nitrates and 0.1-2.0% of nitrites. In streams, nitrates often 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. Concentrations of total nitrates in surface water reflect general land use and anthropogenic pressure within the various parts of the watershed.

Total Kjeldahl nitrogen (TKN) is a measure of total organic nitrogen plus total ammonia and in some cases can show the presence of fresh organic pollution in a water body or the level of phytoplankton development in lake water.

Total nitrogen (TN) includes both inorganic and organic forms of nitrogen. There is no provincial or federal guideline for total nitrogen concentrations in surface water. Alberta Environment has established a surface water quality guideline for total nitrogen at 1.0 mg/L (Alberta Environment, 1999). This guideline was used by Environment Canada for reporting on water quality in Lake Winnipeg (Environment Canada, 2013a, 2013b). It provides us with an opportunity to use the above-mentioned guideline as a nitrogen interim guideline for streams and lakes in the Kawartha Conservation watershed. As well, the Canadian Water Quality Guidelines for the Protection of Aquatic Life (CWQGs) set the guideline for one of the chemical forms of nitrogen in natural water, namely nitrates, at 2.93 mg/L (CCME, 2007). This guideline was developed in order to protect freshwater life from direct toxic effects of elevated nitrate levels, which often are the result of anthropogenic contamination. Indirect toxic effects resulting from eutrophication may still occur at nitrate concentrations below the guideline value, depending on the total amount of nitrogen in water (CCME, 2007).

Within the Pigeon Lake watershed, total nitrogen occasionally exceeded 1.0 mg/L in the water of the Pigeon River upstream of Omemee (P1) and downstream of Omemee (P2) as well as in Potash Creek (P3) and the tributary at RR 17 (P4) (Table 7.10). In Potash Creek total nitrogen concentrations were above the 1.0 mg/L in 15% of all collected samples.

Table 7.10. Results of Statistical Analysis of Total Nitrogen Concentrations in the Pigeon Lake Tributaries for the Period of 2012-2015

Statistical Parameters	P1	P2	P3	P4	P5	P6	ST5
Maximum	2.09	1.78	1.69	1.05	0.64	8.40	1.68
75th percentile	0.64	0.69	0.81	0.62	0.47	3.98	0.54
25th percentile	0.44	0.50	0.61	0.39	0.35	2.67	0.39
Minimum	0.34	0.27	0.41	0.28	0.19	1.09	0.29
Average	0.61	0.63	0.76	0.54	0.41	3.48	0.50
Median (50th percentile)	0.51	0.59	0.69	0.52	0.42	3.20	0.45
Exceedences, %	8.8	6.5	15	3.4	0	100	2.0
Number of samples	68	93	66	59	68	48	98

Average and median nitrogen levels in all these streams as well as in Nogies Creek and the Sturgeon Lake outlet are well below the interim guideline (Figure 7.3). There were no exceedances in Nogies Creek. Only in two samples from the Sturgeon Lake outlet nitrogen concentrations were detected above 1.0 mg/L.

Reforestation Creek (P6) is completely different. This creek has extremely high nitrogen concentrations reaching as high as 8.40 mg/L (Table 7.10). Furthermore, 100% of all samples exceeded the interim guideline. Over the period of monitoring average nitrogen concentrations in the creek varied from 3.12 mg/L in 2014-2015 to 3.78 mg/L in 2013-2014 (Figure 7.3). The water in the creek is heavily contaminated with nitrogen, specifically in its nitrate form. Concentrations of nitrates ranged from 0.70 to 5.60 mg/L with the average being 2.71 mg/L.

Seasonal distribution of total nitrogen in streams of the southern part of the watershed is characterized by higher concentrations during winter due to increasing levels of nitrates as a result of higher groundwater contribution to the flow in tributaries and slow natural processes of nitrate assimilation.

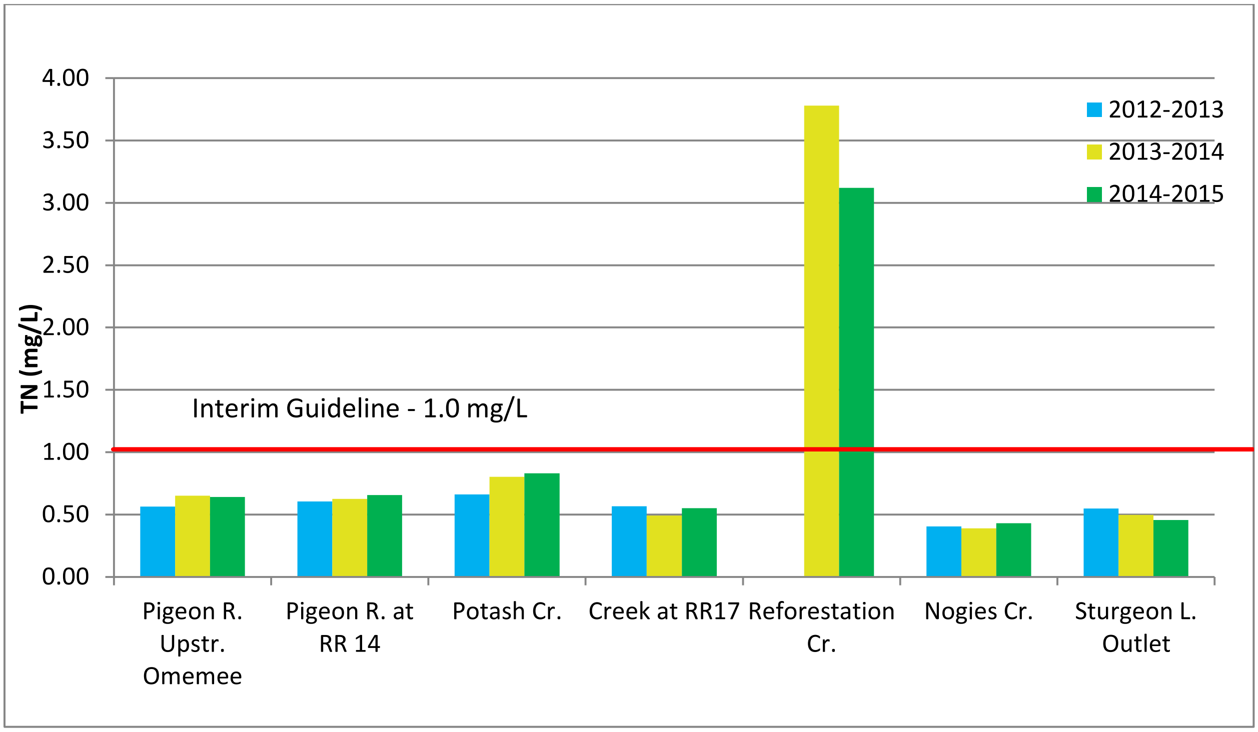

Figure 7.3. Average Total Nitrogen Concentrations in the Pigeon Lake Tributaries in 2012-2015

Organic forms of nitrogen as determined by the TKN analysis are higher during spring and summer. TKN values are always higher in summertime as a result of the increased biomass of phytoplankton in water and more organic matter entering streams from wetlands.

Looking at the watershed-wide scale, one can see that nitrogen levels are higher in the southern tributaries as opposed to Nogies Creek, situated to the North of Pigeon Lake, which has the lowest concentrations of all nitrogen forms. Extremely high nitrogen concentrations in Reforestation Creek are in sharp contrast to other streams in the watershed. Analysis of the water quality data suggests that an increase in total nitrogen levels in the creek is mainly associated with very high nitrate concentrations that likely result from the intensive agricultural activities in the subwatershed.

Total Suspended Solids

Total suspended solids (TSS) may have significant effects on aquatic organisms because of shading, abrasive action, habitat alteration and sedimentation (CCME, 2002). Suspended solids or sediments have a significant effect on community dynamics when they interfere with light transmission. Most flowing waters have considerable variation in suspended solids from day to day. Because natural variation of TSS is so great, it is not desirable to establish a fixed rigid guideline (CCME, 2002). Therefore more flexible guidelines have been established: the concentration of suspended solids 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 long term exposure (30 days and more) (CCME, 2002).

Background concentrations of total suspended solids in streams located in the study area are usually 1.0-2.0 mg/L. After significant rain events, TSS concentrations can increase quite substantially at several monitoring stations (Table 7.11). For example, high TSS levels have been observed in Potash Creek (station P3) as a result of a sharp increase in flow volume after storm events. The maximum TSS concentration detected in this watercourse is 60 mg/L, that being ten times more than the maximum in Nogies Creek, triple that found in the Pigeon River and unnamed creek at RR 17 and much higher than in other streams of the watershed (Table 7.11), however the average TSS concentration in the creek is only 4.0 mg/L.

Table 7.11. Results of Statistical Analysis of TSS Concentrations (mg/L) in the Pigeon Lake Tributaries for the Period of 2012-2015

Statistical Parameters	P1	P2	P3	P4	P5	P6	ST5
Maximum	26.0	17.0	60.0	20.0	6.0	16.0	6.4
75th percentile	3.0	2.9	3.0	3.0	2.0	5.0	1.6
25th percentile	1.0	1.0	1.0	1.0	1.0	1.0	0.8
Minimum	1.0	0.5	1.0	1.0	1.0	1.0	0.25
Average	2.9	2.8	4.0	3.5	1.8	4.2	1.4
Median (50th percentile)	2.0	2.0	1.5	2.5	1.0	3.0	1.0
Exceedences, %	0	0	2.0	0	0	0	0
Number of samples	53	44	50	30	48	35	37

Reforestation Creek has an even higher average and median TSS concentration than Potash Creek but, a much lower maximum concentration (Table 7.11). The highest observed TSS reading in the tributaries were detected during peak of flows during spring freshet. The only detected exceedance among all monitored streams was 60 mg/L in the water of Potash Creek in 2014. Average and median TSS concentrations in all monitored streams are well below the CCME guideline. The lowest TSS concentrations, as anticipated, were detected in the water of Nogies Creek, which drains forested areas with numerous lakes on Canadian Shield (station P5).

Escherichia Coli

The Provincial Water Quality Objective for *Escherichia coli (E.coli)* is based on the recreational water quality guideline established by the Ontario Ministry of Health for swimming at beaches (MOECC, 1994). *E.coli* characterizes bacteriological contamination of surface or ground water. *E.coli* was selected for the guideline because it was found that *E.coli* is the most suitable and specific indicator of fecal contamination (MOECC, 1994). The PWQO is set at 100 colony forming units per 100 mL (cfu/100 mL) and based on a geometric mean of at least five samples (MOECC, 1994).

E.coli monitoring results from 2012-2014 have revealed that majority of monitored streams in the watershed have had *E.coli* levels below the PWQO. In two streams, namely Potash Creek and Reforestation Creek, *E.coli* concentrations are a great concern (Figure 7.4). In Potash Creek, the geomean *E.coli* concentration was 158 cfu/100 mL in 2013 and 121 in 2014. Furthermore, *E.coli* concentrations exceeded the PWQO in 40% of water samples collected from the creek in 2012, in 100% of samples in 2013 and in 62.5% of samples in 2014 (Table 7.12). In Reforestation Creek *E.coli* concentrations exceeded the PWQO in 100% of samples collected in 2014 under both dry and wet weather conditions. The maximum *E. coli* concentrations in the creek varied from 920 to 1000 cfu/100 mL; that being the highest values observed in three years at five monitored locations.

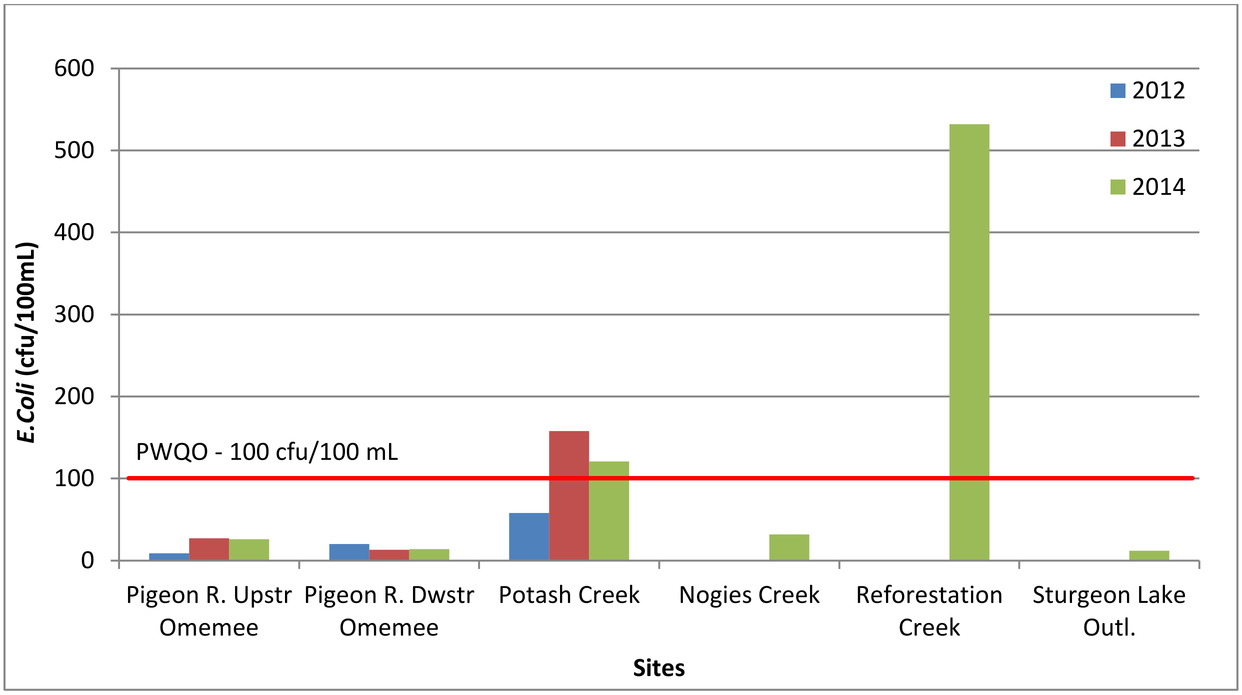

Figure 7.4. Geomean *E. Coli* Concentrations (cfu/100ml) in the Pigeon Lake Tributaries in 2012, 2013 and 2014

E.coli exceedances generally followed intensive rain events. At the same time, dry weather samples from both creeks have also shown *E.coli* concentrations in excess of the PWQO that may be the result of low water volumes during dry periods and, consequently, increased stream vulnerability to contamination from natural and human-induced sources.

Table 7.12. *E.coli* Concentrations (cfu/100ml) in the Pigeon Lake Tributaries in 2012 - 2014

Watercourse	2012		2013		2014	
	Geomean, cfu/100mL	Exceedences, %	Geomean, cfu/100mL	Exceedences, %	Geomean, cfu/100mL	Exceedences, %
Pigeon R. Upstream Omemee	9	0	27	0	26	0
Pigeon R. Downstream Omemee	20	0	13	12.5	14	0
Potash Creek	58	40	158	100	121	62.5
Nogies Creek	n/d		n/d		32	0
Reforestation Creek	n/d		n/d		532	100

7.5 Lake Water Quality

Water quality in lakes is determined by a number of abiotic and biotic factors. Among abiotic factors it is necessary to mention the hydrological regime, lake water levels, population density and shoreline development. As well, meteorological conditions play an important role in water quality. The amount of precipitation, solar radiation, number of sunny days, wind conditions, and average annual air temperature are factors that have a significant effect on water quality in lakes.

Biotic factors also play an important role in influencing lake water quality Factors such as bottom sediments and conditions at the water-sediment interface, the amount and consumption rates of dissolved oxygen in different layers of water, the amount of macrophytes, algae and phytoplankton in a lake and competition between them for nutrients, light and oxygen. Lake depth can have a considerable effect on the amount of phosphorus and nitrogen in the water and their movement through the water column.

Overall, Pigeon Lake can be characterized as a mesotrophic water body based on phosphorus concentrations in the lake water in recent years and Secchi disk depth readings. According to the Canadian Council of Ministers of the Environment (CCME) classification, a lake can be defined as a mesotrophic water body if it has total phosphorus concentration is less than 20 µg/L (0.02 mg/L) during the open water period *(CCME, 2007).* During the 2012-2015 monitoring period average phosphorus levels in Pigeon Lake at all monitoring locations were generally below the above-mentioned limit while fluctuating from 0.014 to 0.020 mg/L (Figure 7.5). Average Secchi disk depth readings usually exceeded 3.0 m and even reached 4.0 m in 2015.

Phosphorus

Pigeon Lake can be divided into two quite different parts: Southern Pigeon Lake, south from the Jacob Island – Gannon Narrows area, and Northern Pigeon, north of Jacob Island all way up to the mouth of Nogies Creek and Bald Lake Narrows. Water quality has been monitored by means of water sampling at five stations (PL1, PL2 in the southern part; PL4, PL5 in the northern part and PL3 located right near Jacob Island) (Figure 7.1).

The Northern and Southern portions of Pigeon Lake consist of different hydrographic features and hydrological regimes and thus each part is influenced by the local hydrography and hydrology. The hydrochemical regime is also influenced to some degree by abiotic anthropogenic factors including the urban area of Bobcaygeon, which is situated around the Sturgeon Lake outlet at the north-western corner of the lake, and private septic systems along the shores.

The stations PL1 and PL2 are situated in the southern part of the lake with PL1 being in close proximity to the Potash Creek mouth. Flows from Pigeon River and Potash Creek have significant effects on water quality in this portion of the lake. The water quality in the southern part of the lake is also influenced by anthropogenic factors such as agricultural runoff, urban runoff from some nearshore urban areas and private septic systems along lakeshores. The stations PL4 and PL5 represent the northern portion of Pigeon Lake and are located near the Sturgeon Lake outlet (east of Bobcaygeon) and north-east of Big Island respectively. The station PL3 is situated in the middle of the lake near Gannon Narrows which connects Pigeon Lake with Buckhorn Lake.

The shallow southern part of Pigeon Lake has higher phosphorus and nitrogen concentrations when compared to the lake's northern part. Phosphorus concentrations in this part of the lake varied between 0.009 and 0.031 mg/L at two stations during the summers of 2012-2015 (Table 7.13). The average phosphorus level near the

Potash Creek mouth (station PL1) was the highest in 2015 (0.020 mg/L). Near Floods Landing (station PL2) the average TP concentration was the highest in 2013 (0.020 mg/L). During the summer of 2012, as a result of a very dry spring and summer, phosphorus levels were lower and fluctuated in the lower range from 0.009-0.010 mg/L in the end of June to 0.025-0.029 mg/L in the end of July. Generally speaking, phosphorus levels were lower in 2012 and 2015 compared to 2013 and 2014 (Figure 7.5). It appears that high spring inflow from Pigeon River and other smaller tributaries resulted into a considerable influx of phosphorus into the lake during April – May and caused elevated TP levels during the summer of 2013.

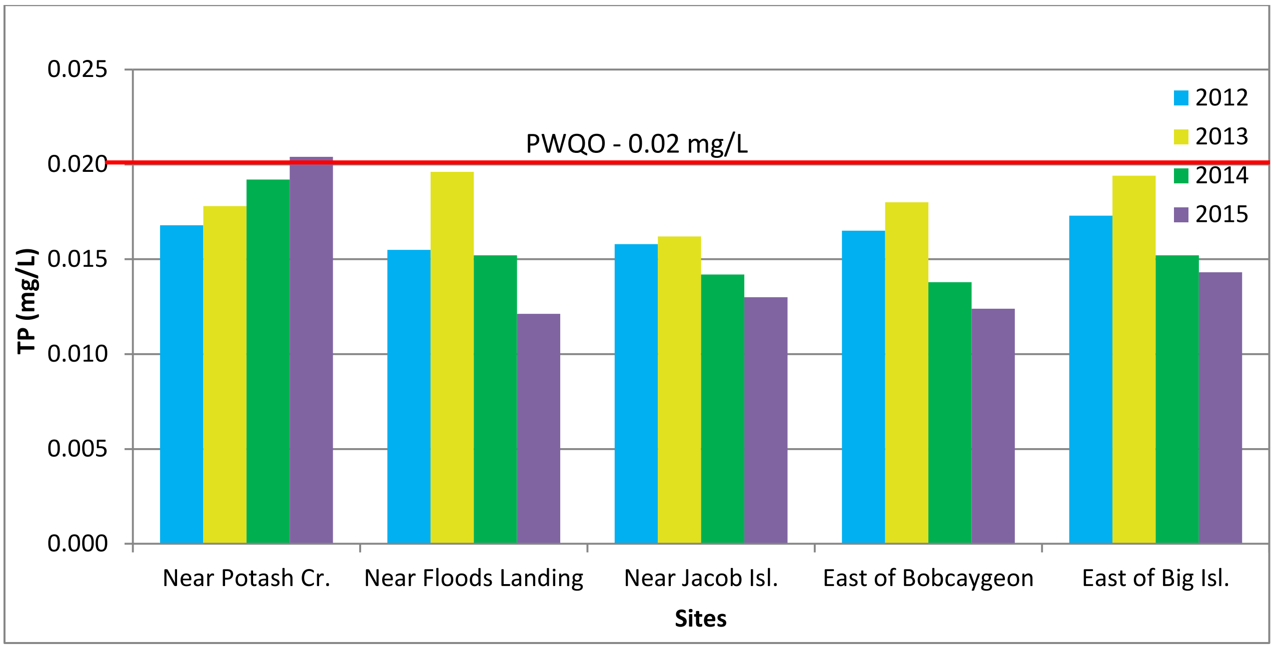

Figure 7.5. Average Phosphorus Concentrations in Pigeon Lake During the May-September Period in 2012-2014 in Comparison with the PWQO

As noted, the monitoring stations PL4 and PL5 are situated in the northern portion of the lake. Average annual phosphorus concentrations in this area ranged from 0.012 mg/L during the summer of 2015 to more than 0.019 mg/L in the summer of 2013 (Figure 7.5).

Over the four-year period, phosphorus levels in the northern part of the lake between two monitoring locations fluctuated from as low as 0.007 mg/L in May of 2015 and 0.008 mg/L in May of 2014 to as high as 0.033 mg/L in September of 2013. Phosphorus levels appear to be the highest during hot months (July-August) probably reflecting increasing algae population in summer time. The lowest TP concentrations were usually observed in May – June, just before or during the spring turnover. As well, much depends on how dry or wet each year was. For instance, 2012 was a very dry year with a small amount of flow moving into and through the lake. Phosphorus concentrations that year were lower than the next year, 2013, which was wet year with extremely high flows entering the lake from Sturgeon Lake, Nogies Creek and the Pigeon River which resulted in elevated phosphorus concentrations across the entire lake (Figure 7.5). It appears that during dry years phosphorus levels are lower while during wet years, with high inflows, TP concentrations are much higher (2014 was much drier than 2013).

The monitoring station PL3 in the central part of the lake is situated to the west of Jacob Island. Phosphorus levels generally follow a pattern similar to the northern part of the lake. Average annual phosphorus concentrations in the area ranged from 0.013 mg/L during the summer of 2015 to more than 0.016 mg/L in the summer of 2013. Over the four-year period, phosphorus levels fluctuated from as low as 0.007 mg/L in May of 2013 and 0.008 mg/L in May of 2015, to as high as 0.025 mg/L in August of 2014 and 0.027 mg/L in July of 2013. The lowest TP concentrations at the PL3 were usually observed in May. In June TP levels always increase and reach the highest values in July or August depending on the weather conditions each given year and the intensity of algae growth. In September phosphorus concentrations are typically beginning to decrease.

Table 7.13. Results of Statistical Analysis of Total Phosphorus Concentrations (mg/L) in Pigeon Lake for the Period of 2012-2015

Statistical Parameters	PL1	PL2	PL3	PL4	PL5
Maximum	0.031	0.026	0.027	0.028	0.033
75th percentile	0.021	0.019	0.018	0.020	0.022
25th percentile	0.015	0.011	0.011	0.010	0.011
Minimum	0.009	0.010	0.007	0.007	0.009
Average	0.019	0.016	0.015	0.016	0.017
Median (50th percentile)	0.017	0.015	0.013	0.014	0.014
Exceedances, %	37	26	16	32	42
Number of samples	19	19	19	19	19

The available data demonstrate that the lowest phosphorus concentrations in Pigeon Lake overall were usually observed in May and/or June, just before or after the spring turnover (Figure 7.6). After that, TP levels increase and reach the highest values in July -August, depending on the weather conditions in each given year.

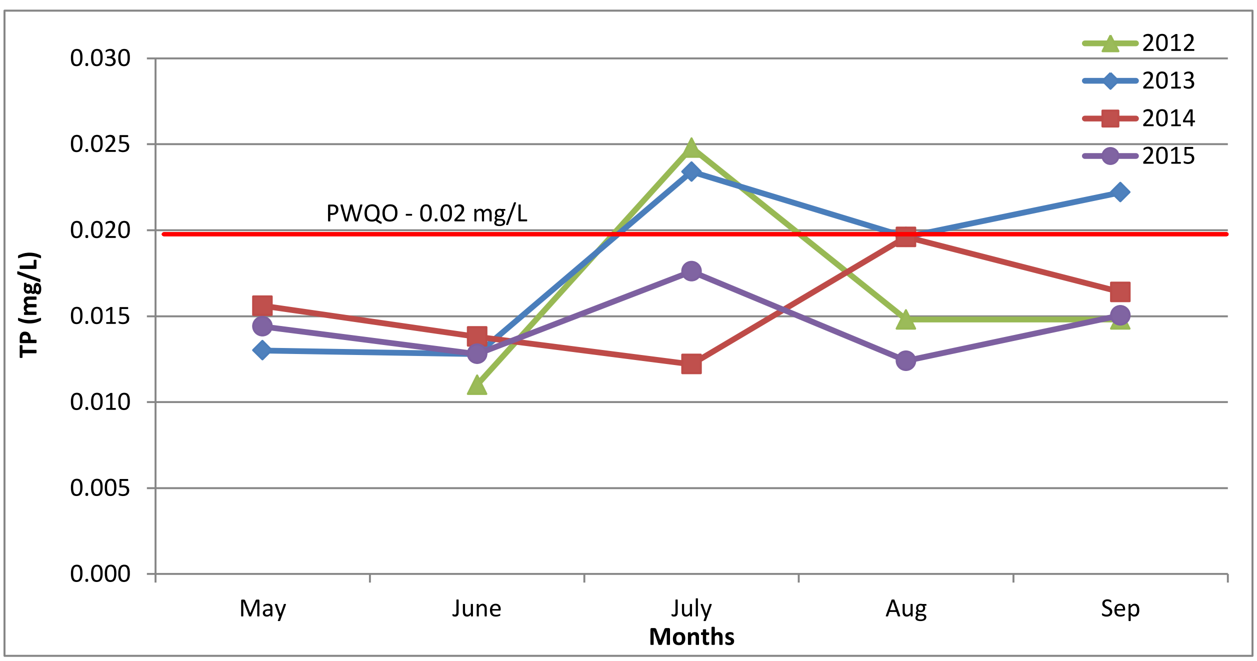

Figure 7.6. Average Monthly Phosphorus Concentrations (mg/L) in Pigeon Lake in 2012, 2013, 2014 and 2015

In September phosphorus concentrations are typically lower than in the previous two months but still higher than the May and June values. Total phosphorus levels can vary considerably between years during the same month. For example, in September they were as low as 0.015 mg/L in 2012 and as high as 0.033 mg/L in 2013 (Figure 7.6).

The long-term data collected through the Lake Partner Program (LPP) by local lake associations and volunteers since 2002-2003 demonstrate that phosphorus concentrations in the lake are quite stable since the beginning of monitoring (Figure 7.7). There are five monitoring stations in the framework of the LPP on Pigeon Lake. They are located primarily in the northern part of the lake:

- Station 3 – near Sandy Point;
- Station 12 – north-east of Bobcaygeon;
- Station 13 – north end, near Alpine Village;
- Station 15 – near Dead Horse Shoal (buoy C340), south of Big Island;
- Station 16 – south of Bottom Island.

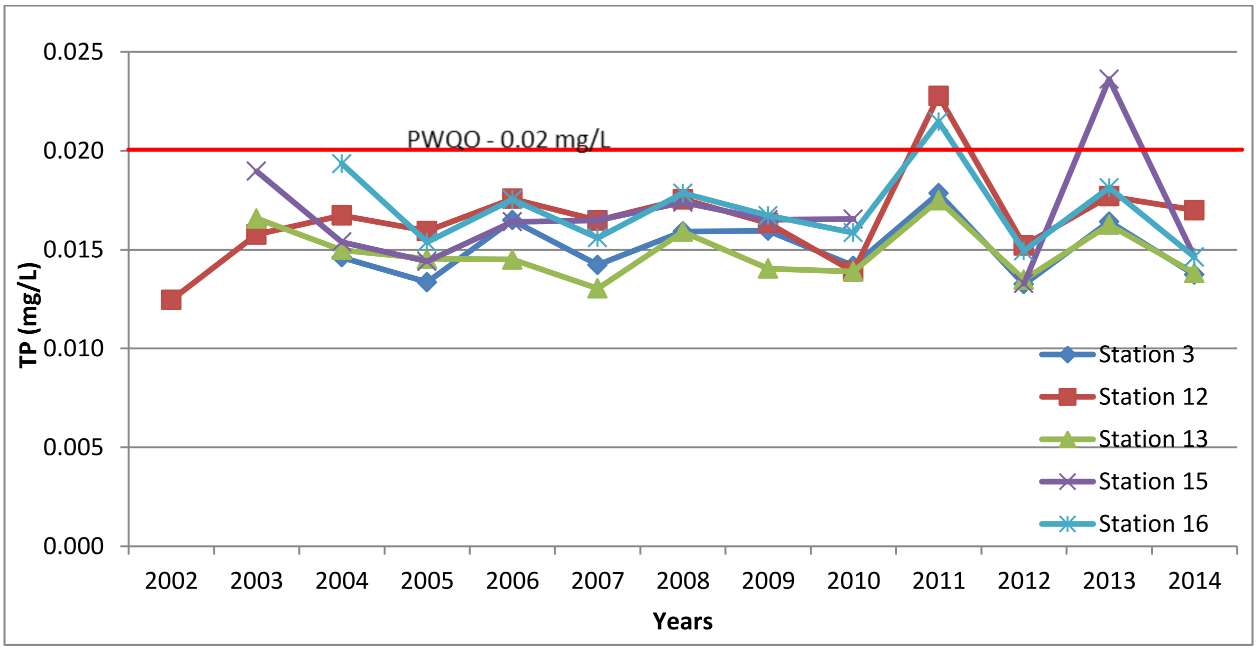

Figure 7.7. Average Annual Phosphorus Concentrations (mg/L) in Pigeon Lake for the Period of 2002 – 2014 (Lake Partner Program Data)

Since the beginning of 2000s the average annual TP concentrations at all five stations fluctuated from 0.013 to 0.18 mg/L. They exceeded the PWQO at three stations (# 12, # 15 and #16) in 2011 and 2013 (Figure 7.7). In 2011 a large widespread blue-green algae bloom occurred in Sturgeon and Pigeon lakes at the end of July The 2013 LPP data correlates very well with our own data (Figures 7.5 and 7.7). A basic statistical analysis performed for the two monitoring periods (2002-2008 and 2009-2014) has shown that phosphorus concentrations at all five monitoring stations does not indicate much change between the datasets (Table 7.14). Average and median values were practically the same over the two periods. The number of exceedances increased at station 12 (from 13% in 2002-2008 to 21% in 2009-2014), but decreased at stations 13, 15 and 16 from 11, 30 and 27% in 2003-2008 to 8, 23 and 17% in 2009-2014 correspondently. During the period of monitoring the number of samples significantly varied between years and between stations, and were often taken on different dates and months and that could affect the results of statistical analysis.

Table 7.14. Results of Statistical Analysis of Total Phosphorus Concentrations (mg/L) in Pigeon Lake During the 2002-2014 Monitoring Period (Lake Partner Program Data)

Statistical Parameters	Station #3		Station #12		Station #13		Station #15		Station #16	
	2004-08	2009-14	2002-08	2009-14	2003-08	2009-14	2003-08	2009-14	2004-08	2009-14
Maximum	0.022	0.025	0.028	0.041	0.022	0.026	0.025	0.030	0.027	0.036
75th percentile	0.017	0.018	0.019	0.019	0.018	0.017	0.021	0.020	0.021	0.019
25th percentile	0.014	0.013	0.012	0.013	0.012	0.013	0.014	0.014	0.013	0.014
Minimum	0.007	0.008	0.008	0.009	0.007	0.008	0.007	0.009	0.008	0.008
Average	0.015	0.015	0.016	0.017	0.015	0.015	0.017	0.017	0.017	0.017
Median (50th percentile)	0.016	0.015	0.017	0.016	0.015	0.015	0.017	0.017	0.017	0.016
Exceedences, %	13	14	13	21	11	8	30	23	27	17
Number of samples	31	36	38	29	37	36	23	22	22	29

Nitrogen

In Pigeon Lake total nitrogen concentrations fluctuated in the range of 0.26 – 0.95 mg/L (Table 7.15). The lowest TN levels among five stations were observed at the station PL4, 0.34-0.64 mg/L with an average of 0.43 mg/L. The highest TN concentrations were observed at the station PL2, 0.54-0.95 mg/L, with an average of 0.73 mg/L and median of 0.75 mg/L (Table 7.15).

Overall, nitrogen concentrations are much higher in the southern portion of the lake (Figure 7.8). At stations PL1 and PL2, which are under the influence of t runoff from agricultural fields south of the lake, they varied from 0.54 mg/L in July of 2014 to 0.95 mg/L in June of 2013 with averages at both stations recorded at 0.73 mg/L (Table 7.15). The lowest nitrogen levels were observed in 2014, while the highest concentrations were detected in 2013, which coincided with a very wet year with potential of an increase in runoff entering the lake.

Table 7.15. Results of Statistical Analysis of Total Nitrogen Concentrations (mg/L) in Pigeon Lake for the Period of 2012-2015.

Statistical Parameters	PL1	PL2	PL3	PL4	PL5
Maximum	0.90	0.95	0.94	0.64	0.76
75th percentile	0.77	0.78	0.55	0.49	0.50
25th percentile	0.650	0.67	0.42	0.38	0.38
Minimum	0.57	0.53	0.26	0.34	0.30
Average	0.72	0.73	0.50	0.44	0.46
Median (50th percentile)	0.73	0.72	0.46	0.40	0.45
Exceedences, %	0	0	0	0	0
Number of samples	19	19	19	19	19

At the station PL3, located in the middle of the lake, total nitrogen concentrations were much lower and varied from 0.26 to 0.94 mg/L with average and median concentrations being at 0.49 and 0.46 mg/L, correspondently, which reflected results observed in the northern portion of Pigeon Lake (Table 7.15). The highest total nitrogen levels were detected in 2013, while the lowest levels were observed in 2012, differing from the southern Pigeon Lake stations.

In the northern part of Pigeon Lake total nitrogen concentrations fluctuated in the range of 0.30-0.76 mg/L. The lowest total nitrogen concentrations in the northern part of the lake were observed in 2012, when the three stations had levels ranging from0.33-0.34 mg/L in August to 0.40-0.45 mg/L in June-July. In 2013 and 2014 nitrogen concentrations were higher, ranging from 0.26-0.37 mg/L to 0.49-0.94 mg/L. The highest concentrations were observed in 2015 resulting in average concentrations of 0.53 mg/L (Figure 7.8).

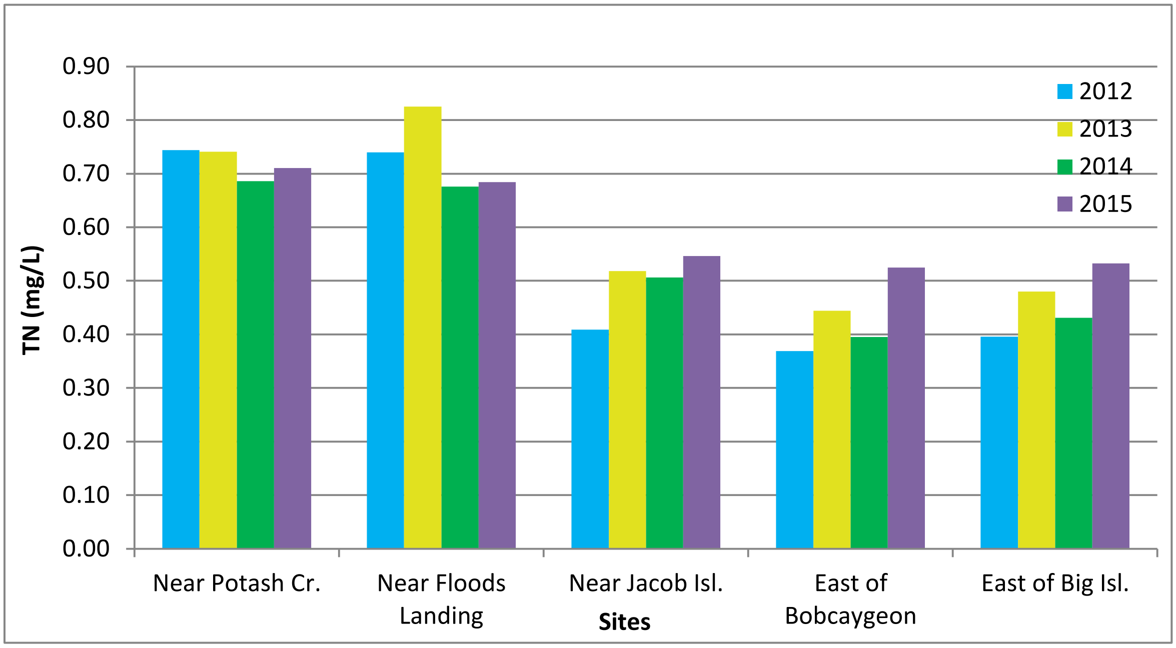

Figure 7.8. Average Total Nitrogen Concentrations (mg/L) in Pigeon Lake During the May-September Period in 2012-2014

Seasonal dynamics in total nitrogen levels are characterized by higher concentrations in May and September in Southern Pigeon Lake. In Northern Pigeon Lake the highest total nitrogen levels were observed in August-September, while the lowest concentrations in both parts of the lake were often detected in July.

Organic nitrogen (total Kjeldahl nitrogen minus ammonia) constitutes most of the total nitrogen amount in the lake water, ranging from 57% to 99% of total nitrogen amount and averaging at 92%. Nitrate levels tend to be higher in May and/or September, up to 0.21 and 0.18 mg/L correspondingly. During the summer months nitrate concentrations are often below the laboratory detection limit (0.02 mg/L) or in the range just above the limit – 0.02-0.05 mg/L.

Dissolved Oxygen

Dissolved oxygen (DO) is one of the most important parameters in natural water. It is extremely vital for fish and other forms of aquatic life. Major sources of dissolved oxygen in water are the atmosphere and photosynthesis by aquatic vegetation and algae (CCME, 1999). DO in lakes is consumed mainly for oxidation of organic matter at the sediment-water interface and within the water column as well as for bacterial, plant and animal respiration (CCME, 1999). Excessive input of phosphorus and nitrogen into lakes can lead to over-abundant development of aquatic vegetation and/or algae. The resulting plant die-off and decomposition causes an accelerated depletion of DO levels in the hypolimnion (deep water layers) affecting the well-being of aquatic organisms.

Extremely low DO levels have another negative effect on lake ecosystems. When a deficit of dissolved oxygen in the near-bottom layers of lake water occurs, processes of phosphorus desorption from lake sediments can be initiated and can have a significant effect on phosphorus concentrations in water. Acute deficit of dissolved oxygen in combination with low pH values creates a reducing environment (negative Eh values) in both bottom sediments and the water – sediment interface that causes the intensive process of desorption of previously adsorbed phosphorus from sediments. As well, low redox potential can lead to mineral dissolution of iron-phosphorous, manganese-phosphorous and aluminum-iron-phosphorous minerals present in the lake sediments. As a result, elevated concentrations of phosphorus as well as iron and manganese can be observed in the bottom layer of the lake water.

The PWQOs have several numerical limits for the dissolved oxygen, which depend on the type of water biota and temperature of water. For the warm water biota, the objective varies from 4 mg/L at 25 °C to 7 mg/L at 0 °C and the percent of DO saturation stays at 47% (MOECC, 1994). For the cold water biota the objective varies from 5 mg/L at 25 °C to 8 mg/L at 0 °C and the percent of DO saturation varies from 54 to 63% (MOECC, 1994). The CWQGs for the Protection of Aquatic Life have somewhat more stringent DO limits. For warm water organisms the lowest acceptable DO concentration is 5.5 mg/L and for the cold water organisms the lowest acceptable concentration is 6.5 mg/L (CCME, 1999).

The dissolved oxygen regime in Pigeon Lake is characterized by predominantly high DO concentrations in the upper layers of the lake during both the spring – summer and autumn periods (Figures 7.9 and 7.10). In Northern Pigeon Lake, oxygen levels in the surface layer have varied in a narrow range of concentrations (7.84 – 9.62 mg/L or 88 – 105% of saturation) that demonstrates a stable regime of DO at the two northern monitoring locations.

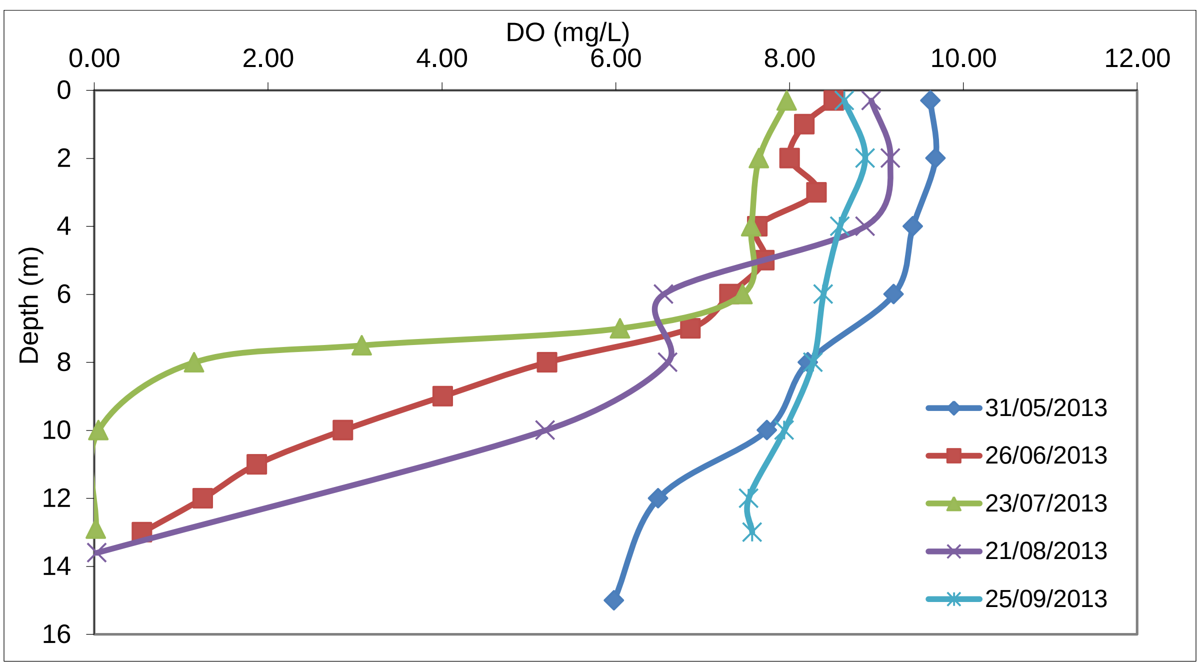

Figure 7.9. Dissolved Oxygen Profiles in Pigeon Lake (Station PL4) in May-September 2013

In Southern Pigeon Lake dissolved oxygen concentrations in the surface layer varied in a much wider range (from 6.04 to 12.05 mg/L or 76 – 143% of saturation) that reveals a rather vulnerable unstable DO regime with oxygen oversaturation occurring often and sharp declines in concentrations as a result of DO consumption by decaying organic matter and by aquatic plants at night time. The southern part of the lake has over-abundant aquatic vegetation.

In the bottom layers of three stations (PL1, PL2 and PL3) with water depths from 1.5 to 4.8 m, oxygen levels were often lower (4.2 – 9.45 mg/L or 47 – 114% of saturation) in summer months but never dropped below the PWQO.

At the station PL5 with a water depth of 10.2 m a deficit of dissolved oxygen was often observed near the lake bottom during summer months (June and July) when DO concentrations varied in the range of 0.1 – 3.69 mg/L, whereas at a depth of 9.0 m, oxygen concentrations always stayed above 4.0 mg/L

At the deepest station, PL4, which has a depth of 13.1 m, a severe deficit of oxygen in the hypolimnion was observed every year during the June – August period. In June – July of each year DO concentrations in the near bottom layer of water from a depth of 10.0 m and deeper were in the range of 0.02 – 3.37 mg/L or 0.2 – 36% of saturation. In July of 2013 oxygen deficit was detected starting at a depth of 7.5 m (3.08 mg/L) and at the depth of 10.0 m DO was technically absent (0.03 mg/L). In August of each year, the situation improved, with dissolved oxygen being virtually absent only in the water layer below 12.0 m. For example, in August 2013 and August 2014 DO readings at 12.0 m were as low as 0.03 and 0.06 mg/L correspondingly that is just 0.2 – 0.5% of saturation (Figures 7.9 and 7.10). During August 2015 oxygen concentrations at the depths below 10.0 m varied from 0.07 to 4.91 mg/L. Similarly severe dissolved oxygen depletion in the deep water area were observed during July – August in 1971, when DO concentrations were close to 0.0 mg/L below the water depth of 12.0 m (OWRC, 1971).

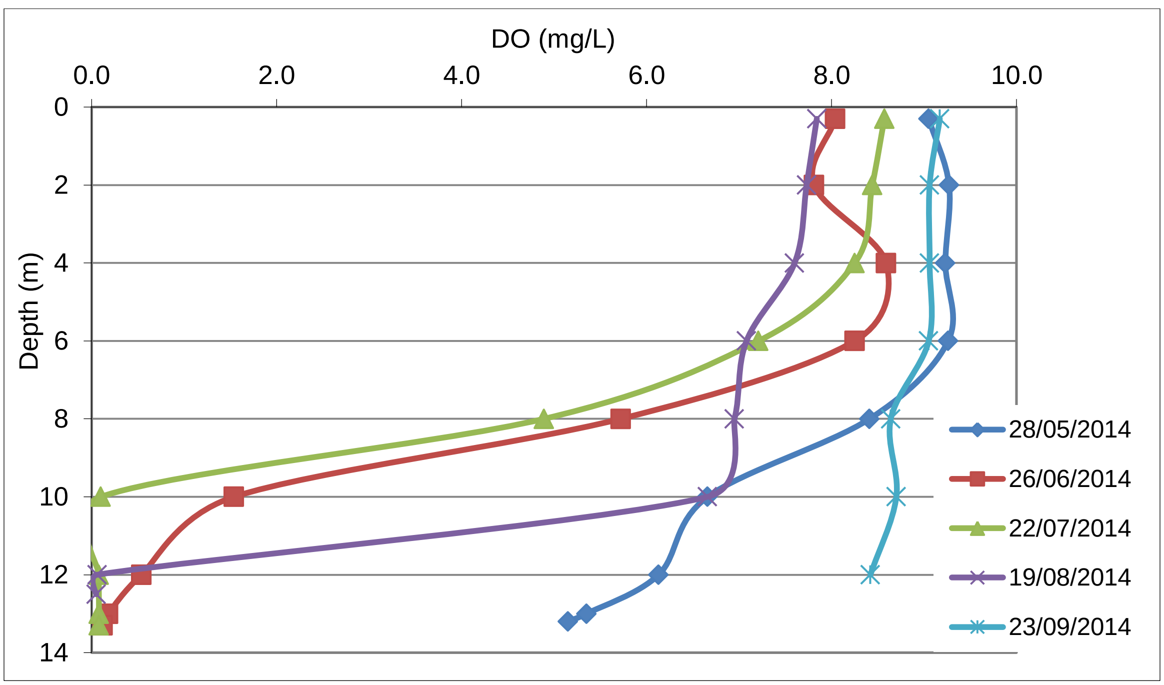

Figure 7.10. Dissolved Oxygen Profiles in Pigeon Lake (Station PL4) in May-September 2014

Escherichia Coli at Public Beaches

The Haliburton, Kawartha, Pine Ridge (HKPR) District Health Unit monitors bacteriological contamination at one public beach, which is located on Pigeon River in Omemee, just several kilometers upstream of Pigeon Lake (Figure 7.11). There are three other public beaches on the lake, two are located in Emily Provincial Park and the other is on the Northern part of Pigeon Lake at Crowes Line. The latter is monitored by the Peterborough County-City Health Unit. In order to ensure that the lake beaches are safe for swimming, Health Unit inspectors collect water samples for *Escherichia coli* analysis every week from the beginning of June until the end of August.

The Peterborough Health Unit's *E.coli* data for 2013-2014 demonstrate that the beach at Crowes Line has good bacteriological water quality. The Omemee beach has serious problems with water quality and swimming safety (Table 7.16).

During the last four years the Omemee beach has had the worst water quality among the four beaches (Figure 7.12). *E.coli* concentrations at that beach exceeded the PWQO (100 cfu/100 mL) in 40% of samples in 2011, in 75% of samples in 2012 and in 64% of samples in 2014, and often resulted in beach posting (Table 7.16). In 2013 *E.coli* concentrations were detected above the PWQO in 100% of samples. As a result, the annual geometric mean exceeded 100 cfu/100 mL during the four recent years. The most likely source of contamination in that location is the local Canada goose population. The other three beaches had low *E.coli* levels that only occasionally exceeded the provincial objective (Table 7.16).

Table 7.16. *E.coli* Concentrations (cfu/100ml) at the Pigeon Lake/River Beaches in 2011 - 2014

Beach	Lake or River	2011		2012		2013		2014	
		Geomean, cfu/100mL	Exceed-ences, %	Geomean, cfu/100mL	Exceed-ences, %	Geomean, cfu/100mL	Exceed-ences, %	Geomean, cfu/100mL	Exceed-ences, %
Crowes Line	Pigeon L.	n/d	n/d	n/d	n/d	11.5	0	19.5	7
Emily Park North	Pigeon R.	n/d	n/d	n/d	n/d	65.0	18	30.3	18
Emily Park South	Pigeon R.	n/d	n/d	n/d	n/d	7.9	0	22.9	36
Omemee	Pigeon R.	121	40	178	75	655	100	177	64

While *E.coli* concentrations can be quite high at some beaches, they are usually very low at open water sampling locations according to the Kawartha Lake Stewards Association (KLSA) data (KLSA, 2012, 2013, 2014 and 2015). On Pigeon Lake KLSA volunteers collect water samples for *E.coli* analysis since 2005. Currently they monitor 14 sites across the lake and take samples six times per season.

During the last five years of monitoring, *E.coli* concentrations exceeded the PWQO in only six samples from five different stations (2011 one sample, 2013 one sample and 2014 four samples). In total more than 400 samples were collected over the five-year period. All other samples were well below the PWQO, mainly in the range of 1 – 50 cfu/100 mL. Many samples returned results below the method detection limit. The annual geometric mean varied from 1 to 48 cfu/100 mL at different stations (KLSA, 2012, 2013, 2014 and 2015).

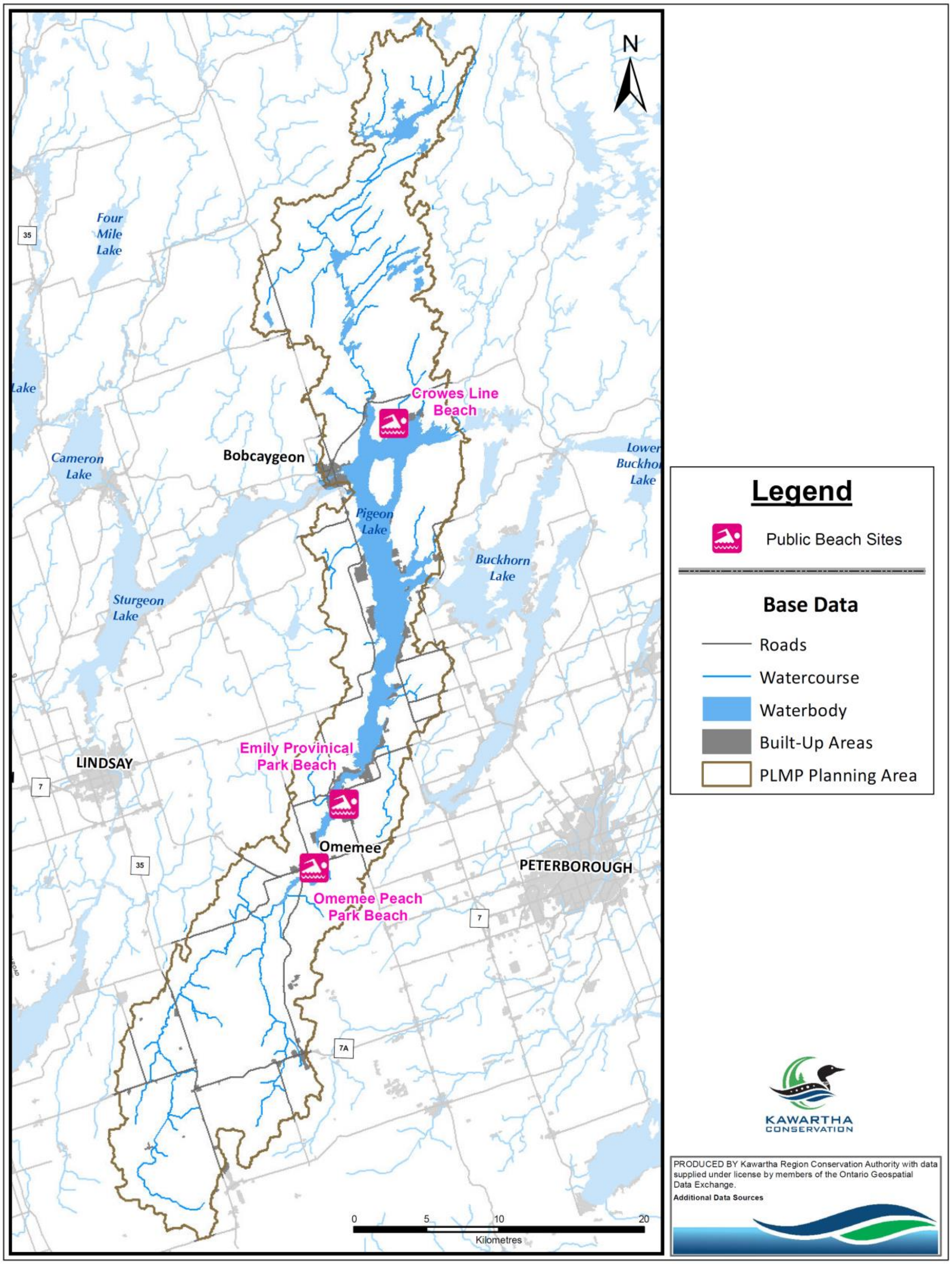

Figure 7.11. Public Beach Locations within Pigeon Lake

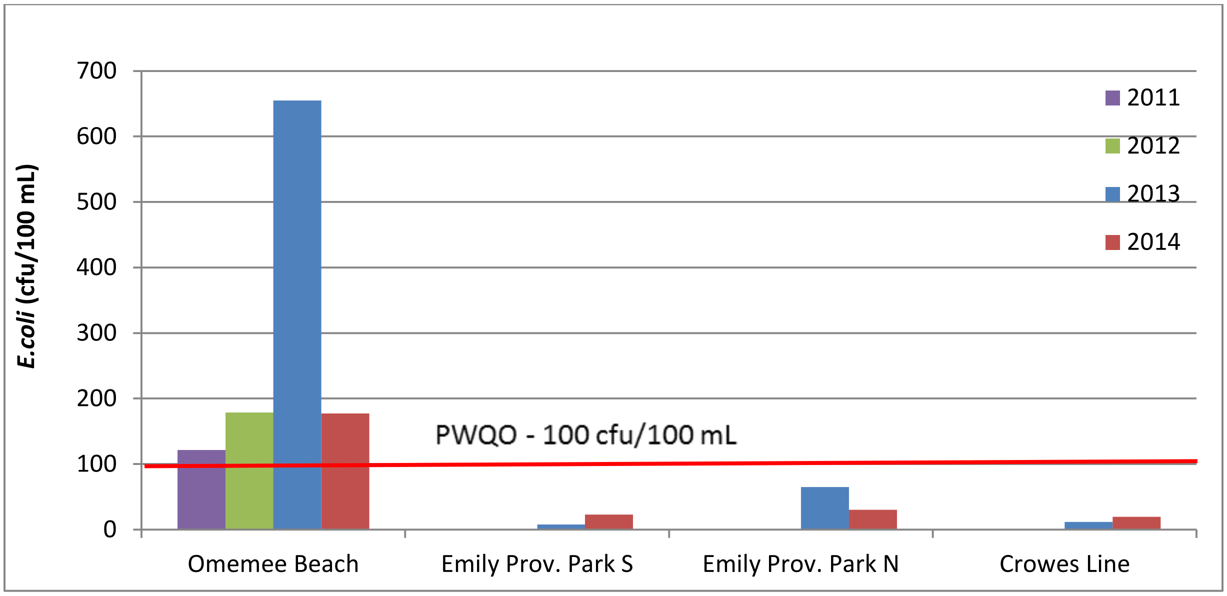

Figure 7.12. Annual Geometric Mean *E.coli* Concentrations (100cfu/100ml) at the Pigeon Lake Beaches

7.6 Sources of Phosphorus and Nitrogen

Phosphorus and nitrogen are the two most significant nutrients in aquatic ecosystems. Without nutrients, there would be no aquatic life in watercourses and lakes. However, because of increasingly intensive human activities during the last century nutrients have been entering natural water bodies in excessive amounts. As a result, phosphorus and nitrogen have become responsible for the process of eutrophication and overabundant development of macrophytes and phytoplankton in many lakes and rivers across Canada, including Pigeon Lake. Other chemical elements such as copper, iron, manganese, molybdenum, zinc and some others, called micronutrients, are also vital for the development of aquatic vegetation. They are usually present in small, but sufficient quantities such that only phosphorus and nitrogen concentrations are the strongest drivers of algal and vegetation growth and, consequently, the rate of eutrophication.

As explained, phosphorus and nitrogen enter Pigeon Lake from various sources. Sources include runoff from agricultural fields and urban areas, shoreline development and recreational activities, wastewater treatment plants, industrial discharges, and atmospheric deposition. It is impossible to determine a single source of nutrients that is responsible for the entire process of eutrophication; rather this process is a consequence of many factors and causes, most of them having a human origin.

All nutrient sources can be separated into two large groups: point source and non-point source. Point sources of nutrients include industrial and municipal sewage outflows, individual septic tanks, single wastewater discharge pipes from farms, factories, etc. Non-point sources include nutrients that are entering water bodies with urban runoff, agricultural runoff, and atmospheric deposition (wet and dry) as well as natural sources such as shoreline and riverbank erosion, groundwater discharges, wild waterfowl, local geological and soil conditions etc.

Pigeon Lake receives nutrient input from many of the above-mentioned sources. In order to quantify nutrient load into the lake, all sources have been separated into six major categories:

1) Inflow from Sturgeon Lake;
2) River flow and surface water runoff including:

2a) Pigeon River flow;
2b) Nogies Creek flow;
2c) Local stream and surface water flow;
3) Atmospheric deposition on water surface of the lake;
4) Direct urban runoff into the lake;
5) Septic systems along the shoreline and
6) Municipal point source – Bobcaygeon WWTP.

A detailed description and characteristics of the above-mentioned categories of phosphorus and nitrogen sources are provided below.

River Flow and Surface Water Runoff

More than 97% of the total volume of water is entering Pigeon Lake as surface or river flow (Table 6.7). The river flow is a derivative of precipitation, which is the main and determinative source of water in our physiographical zone. Approximately 33% of the total annual precipitation amount enters the lakes as surface runoff. This 33% can be separated into two components: instantaneous surface runoff and shallow groundwater runoff. Groundwater runoff or discharge includes precipitation infiltrated into shallow aquifers as well as water from deeper aquifers. Approximately 67% of the precipitation amount eventually returns to the atmosphere through the processes of evaporation and evapotranspiration.

Rivers and streams collect runoff from their corresponding drainage basins and eventually deliver all of their water into the lakes. Watercourses in the Pigeon Lake watershed have a distinct seasonal distribution of flow volume as can be seen from the annual hydrographs (Figure 6.3). Even a quick analysis of a typical annual hydrograph demonstrates that the largest portion of flow enters the lake during the spring period (40 – 55% of the total annual flow) followed by winter (30 – 35%) and finally by the summer-autumn period (15 – 25%). Consequently, the highest concentration of phosphorus and nitrogen in streams is usually observed during periods of high water levels and discharges that occur during spring freshet, winter thaws and after intensive rain events in spring, summer and fall. Due to these hydrological particularities, the largest portion of the nutrient load is delivered into the lake during the springtime. Under high flow conditions, phosphorus concentrations in some streams within the study area have been observed as high as 0.66-2.19 mg/L or up to 73 times above the PWQO.

River flow incorporates phosphorus from both natural and anthropogenic sources. As a result, natural surface water always has some amount of phosphorus, even in the most pristine natural environments.

Natural sources of phosphorus and nitrogen include shoreline and riverbank erosion, groundwater discharges, lake sediments, local bedrocks and soils, wild waterfowl, fallen tree branches and leaves, and remnants of other organic materials.

Anthropogenic sources of nutrients in surface water include urban runoff and agricultural runoff. Urban areas are a source of significant amounts of nutrients that can substantially pollute local watercourses. As a result of a high percentage of impervious surfaces in urban areas, and, consequently, low infiltration rates, rainfall and water from snowmelt enter adjacent streams and lakes faster and in larger volumes thus transporting larger amounts of pollutants that can be found in urban environments.

Agricultural sources of nutrients in surface water include manure, chemical fertilizers, milkhouse wastewater discharge, cropland erosion and livestock operations. Manure and chemical fertilizer field applications along with soil erosion are probably the most significant sources of phosphorus and nitrogen among the above-mentioned agricultural activities. It is very important to promote and apply advanced techniques in modern agricultural land management.

Unrestricted access of livestock to watercourses is an additional source of nutrients and can also increase bacteriological contamination of surface water (*E.coli*, Total coliform, Fecal coliform etc.) and erosional processes along the riverbanks.

Atmospheric Deposition

Atmospheric deposition of phosphorus and nitrogen includes wet deposition (rain, snow, dew) and dry deposition (dust etc.). Air circulation and precipitation can bring nutrients into the lake from both local sources, such as wind erosion of bare ground, construction sites, local industrial emissions, and locations thousands of kilometers away.

Concentrations of phosphorus and nitrogen in precipitation samples vary significantly during the year. Usually the highest concentrations are observed in the spring season and the lowest during late fall-winter. Atmospheric deposition of phosphorus and nitrogen was calculated as a sum of the number of precipitation volumes collected in two-week periods multiplied by phosphorus or nitrogen concentrations in the corresponding rain and snow samples.

Urban Runoff

Urban runoff is one of the main human-generated sources of phosphorus, nitrogen and other contaminants entering Pigeon Lake. Urban centers have large impervious areas paved with asphalt and concrete as well as many building roofs. Due to the high percentage of impervious surfaces, urban areas have higher runoff coefficients and, as a result, generate much larger volumes of stormwater runoff into adjacent streams and lakes. As a result, the rapid rainwater or snowmelt runoff carries large quantities of phosphorus and nitrogen as well as other pollutants, which can easily contaminate water in nearby streams and lakes. According to multiple research data, high-density urban areas generate nutrients and other pollutants at a much higher rate per unit area than agricultural lands. In order to mitigate this, all new urban developments are required to be serviced by stormwater management facilities such as stormwater ponds, constructed wetlands or other SWM controls. Yet, a substantial portion of urban areas around both lakes do not have stormwater treatment facilities, thus making them a significant source of pollutants including phosphorus and nitrogen.

To calculate phosphorus loading from urban areas, a phosphorus export coefficient of 132 kg/km^2/year, based on the MOECC research data from 2006 SWAMP studies, has been accepted (Hutchinson Environmental Sciences, 2012, MOECC, unpublished data). This value is very close to our own data obtained in the framework of the urban stormwater monitoring program in the Port Perry urban area, when an average TP export coefficient of 133 kg/km^2/year was derived from water quality data collected in 2006-2009 (KRCA, 2010). This value can be slightly adjusted annually depending on the amount of precipitation in each hydrologic year.

Urban areas intersecting the Pigeon Lake shoreline occupy 3.16 km^2 of the watershed. As well, rural or semi-urban developments intersecting the lake's shoreline occupy 11.57 km^2. These areas include Bobcaygeon, Victoria Place and a number of other urban and semi-urban subdivisions and hamlets adjacent to the lake's shoreline that generate direct urban runoff into the lake.

Septic Systems

Nearshore septic systems can be a significant source of phosphorus and nitrogen loading to the adjacent water bodies. There has been a considerable scientific discussion over the recent decades about phosphorus loading from septic systems and whether some portion of it can be retained in soils. While the Ontario Ministry of the Environment has recognized that the degree of retention may vary with soil type and particle size, it has consistently held the position that all of the phosphorus deposited in septic systems within 100 m from a water body eventually migrates to lake ecosystems. Specifically, it relates to the Canadian Shield areas. Given that the ecological state of Canadian Shield lakes was a high priority for the Ministry, it recommended a cautious approach, adhering to the "precautionary principle" and assumed that 100% of phosphorus from septic systems within 100 m from the shoreline will reach the nearest water body (Paterson et al., 2006). This approach reflects the predominance of thin, organic or sandy soils and tills on the Precambrian Shield, the fractured nature of the bedrock, and the predominance of aging septic systems that were designed for hydraulic purposes (*i.e.,* to ensure fast infiltration) rather than for nutrient retention (MOECC, MNR, and MMAH, 2010).

At the same time, there is a considerable list of scientific literature on septic systems and phosphorus behaviour in/under leaching beds and in septic plumes. According to multiple studies there is clear evidence that phosphorus concentrations in plumes from septic tile beds are usually much lower than in effluent from septic tanks. The percent of phosphorus retention can vary from 23% to 99% (Robertson et al., 1998). It was shown that the movement of phosphorus from septic tank – tile bed systems may be retained to some degree depending on soil type and thickness. It was also shown that phosphorus retention in the vadose zone (the layer of soil between the land surface and the groundwater table) is mostly achieved due to reactions of chemical precipitation (Zanini et al., 1998).

It was also shown that phosphorus from a nearshore septic system can and will reach the adjacent water body (Robertson, 1995; Harman et al., 1996; Zurawsky et al., 2004; Zanini et al., 1998). The question is how far and how fast the phosphorus plume can travel and what is the possible average/maximum phosphorus concentration in the plume? That is why it is important to note that there is a substantial difference in degree of phosphorus retention in calcareous and non-calcareous soils. Phosphates have much higher mobility and form long distinct plumes with higher phosphorus concentrations (0.5-5.0 mg/L) in shallow groundwater located under and down gradient of septic systems placed on calcareous soils (Robertson et al., 1998). Additional data have shown that the percent of retention on calcareous soils in the vadose zone varies from 23 to 84%, with an average of 51%. On non-calcareous soils such as those found on the Canadian Shield (Muskoka region) phosphorus retention in the vadose zone can be much higher, up to 75-99% under some specific conditions (Robertson, 2003).

In general, there are two approaches to determining septic system phosphorus loading into water bodies. The first assumes that 100% of phosphorus from septic systems near the lake shoreline eventually will reach the lake (MOECC, MNR, and MMAH, 2010). However, the Handbook's authors recognize that it is mainly related to Canadian Shield areas with very thin or no soils, and fractured bedrock underneath. Another approach is that some of the phosphorus from septic tanks, which can be quite substantial, is retained in the soil. The level of irreversible attenuation (retention) depends on many factors including soil type and thickness, chemical composition of soil, distance to the shore, depth of saturated zone, etc. (Robertson, 2008). As a result, it is very difficult to determine one single average percent of attenuation for the entire lake shoreline. Trent University researchers believe that it is unrealistic to assume that 100% of phosphorus from septic tanks can reach the lake or stream; the coefficient of phosphorus retention will depend on condition, size and maintenance of the septic system (Dr. Paul Frost, personal communications). As well, new septic systems do not immediately add phosphorus to the nearby waterbody; it may take years for the phosphorus plume to reach the lake or stream depending on the distance from the lakeshore or river bank.

Pigeon Lake is surrounded by predominantly calcareous soils underlined by limestone formations. As a result, and taking into consideration the above-mentioned information, it is reasonable to assume that phosphorus attenuation (retention) in septic systems around the lakes is somewhere near 50%. Therefore, until new data and methods of estimation become available, it has been recommended by the CKLMP Science and Technical Committee to use a 50% retention rate in all future calculations of septic system phosphorus loading within the Kawartha Conservation watershed. It was also recognized that in cases where septic systems are malfunctioning for various reasons, virtually all phosphorus and nitrogen from septic tank effluent can ultimately reach nearby water bodies.

According to the previous research data, a phosphate plume from a septic system can extend for 70-75 m (Robertson and Harman, 1999). There are approximately 1,560 houses with private septic systems within 75 metres of the Pigeon Lake shoreline which is a major factor to consider when phosphorus loading to the lakes littoral zone is in question. Property usage values from Table 7.17 have been used in phosphorus loading calculations. The water usage number of 200 L/day/capita was used for the septic phosphorus loading calculations (Paterson et al., 2006).

The average phosphorus concentration in septic tank effluent according to the most recent data is 8.2 mg/L based on 174 samples (Hutchinson, 2002; Paterson et al., 2006). Other researchers demonstrate similar data, 7.5 mg/L (weighted average from 64 samples) and 8.1 mg/L (average from five septic tanks) (Robertson et al., 1998). The Lakeshore Capacity Assessment Model uses 9.0 mg/L (MOECC, MNR, and MMAH, 2010). Applying a 50% retention factor to the value of 8.2 mg/L we can calculate that 4.1 mg/L of phosphorus in the septic system effluent will reach Pigeon Lake.

Table 7.17. Septic System Usage Values for Shoreline Properties
(Paterson et al., 2006)

Development Type	Usage (capita years·yr^{-1})
Permanent residence	**2.56**
Extended seasonal residence (cottage with winter access)	**1.27**
Seasonal residence (cottage – no winter access)	**0.69**
Resorts (serviced, housekeeping cabins)	**1.18**
Trailer parks	**0.69**
Campgrounds/tent trailers/RV parks	**0.37**
Youth Camps	**125 grams of P·$capita^{-1}$·yr^{-1}**

The average nitrogen concentration in regular septic tank effluent is 45 mg/L (OMOE, 1982). Approximately 25% of the nitrogen can easily be attenuated while effluent is passing through soils and shallow aquifers on its way to the closest water body. The remaining nitrogen amount (in nitrate form) and taking into consideration the possible extension of the plume from conventional septic systems will reach the lake (Harman et al., 1996, MPCA, 1999).

As more accurate data from new studies for all components becomes available, it will be possible to refine current calculations. Meanwhile, Kawartha Conservation's "Blue Canoe" program was initiated during summer of 2012. In the framework of this program, Kawartha Conservation staff's role was to conduct surveys among shoreline residents and collect information on septic systems including type, age, distance from the lake etc. These new endeavours can help to better understand septic system effects on water quality in Pigeon Lake.

Municipal Point Sources

One municipal point source of phosphorus and nitrogen, namely the Bobcaygeon Wastewater Treatment Plant, releases its final wastewater effluent into Pigeon Lake near the Sturgeon Lake outlet. The plant is situated in the eastern part of Bobcaygeon at the end of the small peninsula between the Big Bob Channel and Pigeon Lake.

The Bobcaygeon Wastewater Treatment Plant was built approximately 42-43 years ago in the early 1970s. The plant serves the Village of Bobcaygeon with a total serviced population of approximately 2,500 people (Ontario Clean Water Agency, 2013). While the Bobcaygeon WWTP is usually referred as a single plant, in reality it consists of two separate wastewater treatment plants at the same location with combined effluents at the release point into the lake.

The Bobcaygeon WWTP was designed and approved to treat wastewater at an annual average daily flow rate of 3,055 m^3/day (Ontario Clean Water Agency, 2015). The plant’s effluent is released year round on a daily basis. The average daily flow in 2012 was 1,958 m^3/day or 64% of capacity. It was a slight decrease in an average flow from 2011, when it was 2,015 m^3 per day. The average daily flow in 2013 was 2,373 m^3/day or 78% of designed capacity. It was 415 m^3/day (21%) more than the previous year. In 2014 the average daily flow was 2,406 m^3/day or 79% of capacity. The Bobcaygeon WWTP treated a total of 714,774 m^3 of raw sewage in 2012, 866,286 m^3 in 2013 and 875,892 m^3 in 2014 (Ontario Clean Water Agency, 2013, 2014, 2015).

The MOE Certificate of Approval limit requires that phosphorus concentrations in the effluent have to be less than 1.0 mg/L. The monthly average loading limit is 1.3 kg/day (Ontario Clean Water Agency, 2013). In order to maintain the loading limit when the average daily flow is in excess of 1,300 m^3/day, the compliance limit for total phosphorus concentrations in the effluent needs to be reduced accordingly. As a result, the adjusted total phosphorus monthly average loading limit can vary and over the three years sometimes was as low as 0.24-0.35 kg/day (Ontario Clean Water Agency, 2015). The average phosphorus concentrations in the plant’s final effluent was 0.059 mg/L in 2012 and translates into TP loading of 0.118 kg/day, 0.098 mg/L or 0.234 kg/day in 2013, and 0.074 mg/L or 0.169 kg/day in 2014 (Ontario Clean Water Agency, 2013, 2014, 2015).

The MOE Certificate of Approval limit for total ammonia concentrations in the effluent is 20 mg/L. The average ammonia concentration in the plant’s final effluent was 0.474 mg/L and translates into loading of 0.98 kg/day in 2012, 0.501 mg/L (1.375 kg/day) in 2013 and, finally, 1.037 mg/L (2.37 kg/day) in 2014 (Ontario Clean Water Agency, 2013, 2014, 2015).

The MOE Certificate of Approval limit for Total Suspended Solids concentrations in the effluent is 25.0 mg/L. Average TSS concentrations in the plant’s final effluent were 6.67 mg/L in 2012 that translates into TSS loading of 13.12 kg/day, more than 9.05 mg/L or 22.90 kg/day in 2013, and around 6.41 mg/L or 15.42 kg/day in 2014 (Ontario Clean Water Agency, 2013, 2014, 2015).

Annual phosphorus loads from the Bobcaygeon WWTP were calculated as a sum of daily loads, which, in turn, have been calculated as the daily average phosphorus concentration found in the final effluent from the plant multiplied by the daily volume of effluent. The initial numbers of the daily flow and average phosphorus concentrations have been provided by the City of Kawartha Lakes Public Works Department.

7.7 Phosphorus Load

The three year average total phosphorus load into Pigeon Lake is 29,160 kg (Table 7.18). The highest phosphorus load was in 2013-2014, when about 36,061 kg was loaded into the lake. The lowest loading was observed in 2014-2015, when only 25,436 kg entered the lake as a result of low flow during the spring 2015. The phosphorus load into the lake is distributed between the six major sources:

1) Sturgeon Lake flow brings into Pigeon Lake on average 23,201 kg of phosphorus annually. The flow from Sturgeon Lake is the largest source of phosphorus for Pigeon Lake (Table 7.18).

2) The river flow phosphorus loading into Pigeon Lake was 3,046 kg or 11.7% of the total phosphorus loading into the lake in 2012-2013, 4,039 kg or 11.2% in 2013-2014 and 3,139 kg or 11.7% kg in 2014-2015 (Table 7.18). The average three-year river flow phosphorus loading was 3,408 kg. The largest individual source of phosphorus among streams was the Pigeon River, which loaded 1,335 kg, 11,429 kg and 1,286 kg into the lake in 2012-2013, 2013-2014 and 2014-2015 correspondingly.

3) Atmospheric deposition (wet and dry) of total phosphorus on the lake's water surface was 483 kg in 2012-2013, 671 kg in 2013-2014 and 414 kg in 2014-2015. The average atmospheric load over the three year period was 523 kg.

4) Shoreline urban stormwater phosphorus loading into Pigeon Lake was estimated at approximately 984 kg in 2012-2013, 996 kg in 2013-2014, and 825 in 2014-2015.The average load over the three-year period was 935 kg.

5) Septic systems. Phosphorus loading from private septic systems around the lakes was estimated at 1,027 kg annually. Total amount includes 612 kg from year-round houses, 201 kg from summer cottages, 112 kg from trailer parks and campgrounds, 8.8 kg from houses with holding tanks (some grey water) and 94 kg from failed systems.

6) Bobcaygeon Waste Water Treatment Plant. Only 67 kg of phosphorus is released annually with the plant's treated effluent into Pigeon Lake.

Calculated average and annual phosphorus loadings into Pigeon Lake are presented in Table 7.18. A breakdown of the average phosphorus load between its major sources during the 2012-2015 monitoring period is presented at Figure 7.13.

The Sturgeon Lake flow is the largest source of phosphorus for Pigeon Lake. It transports almost 80% of the total phosphorus load into the lake (Figure 7.13). Between years, the phosphorus load from Sturgeon Lake and all the watersheds upstream varied from 19,970 kg (78.5%) to more than 29,247 kg (81.1%). The phosphorus amount that enters the lake with the flow from Sturgeon Lake is generated outside the study area (Figure 7.1).

The Sturgeon Lake watershed occupies 1028 km^2 and the upstream watersheds combined (the Gull River, Burnt River, Corben Creek, Balsam and Cameron lakes, Lake Scugog) occupy 3761 km^2. Combined, all those watersheds are almost seven times larger than the Pigeon Lake watershed itself, which occupies 711 km^2. At the same time, the Pigeon Lake watershed accounts only for 9.4% of the water volume entering the lake, but contributes 14.9% of the total phosphorus load.

Table 7.18. Pigeon Lake Phosphorus Loads for 2012-2013, 2013-2014 and 2014-2015 Hydrologic Years

Sources of Phosphorus	2012-2013		2013-2014		2014-2015		Average	
	TP, kg	TP, %	TP, kg	TP, %	TP, kg	TP, %	TP, kg	TP, %
Sturgeon Lake	20,385	78.5	29,247	81.1	19,970	78.5	23,201	79.6
River flow as:								
Pigeon River	1,335	5.1	1,429	4.0	1,286	5.1	1,350	4.6
Nogies Creek	704	2.7	936	2.6	464	1.8	701	2.4
Local streams and overland flow	1,007	3.9	1,674	4.6	1,389	5.5	1,357	4.7
Atmospheric deposition	483	1.9	671	1.9	414	1.6	523	1.8
Shoreline urban runoff	984	3.8	996	2.8	825	3.2	935	3.2
Septic systems	1,027	4.0	1,027	2.8	1,027	4.0	1,027	3.5
Bobcaygeon WWTP	59	0.2	81	0.2	61	0.2	67	0.2
Total Load	**25,983**	**100**	**36,061**	**100**	**25,436**	**100**	**29,160**	**100**

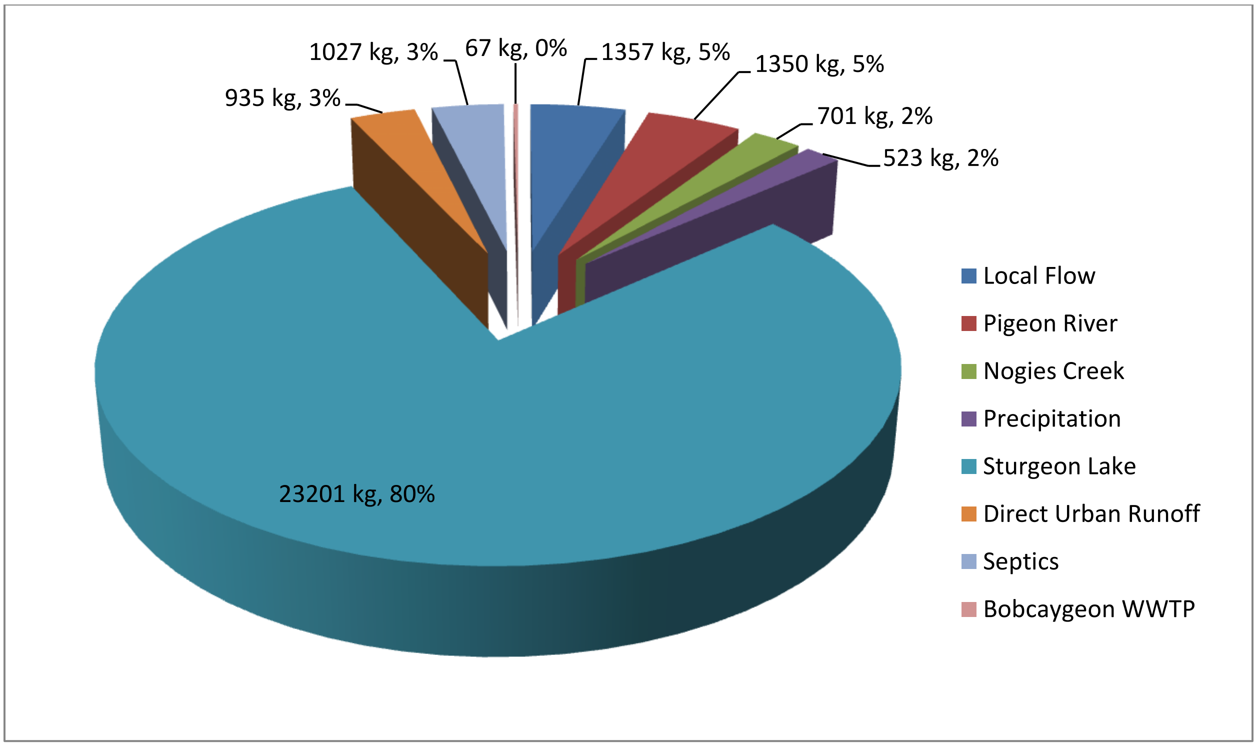

Figure 7.13. Average Phosphorus Load into Pigeon Lake from Different Sources During 2012-2015 Monitoring Period

It is important to remember that Sturgeon Lake is the largest source of phosphorus not because it has very high phosphorus concentrations in the water, but because a very large volume of water from the upstream watersheds outside the planning area enters Pigeon Lake. When one looks at the Pigeon Lake water inflows, it can be seen that approximately 90% of the total lake water inflow originates from Sturgeon Lake (Table 6.7).

A total of 2707 kg or 9.3% of the total phosphorus load enters the lake with the Pigeon River flow and local surface runoff from the Pigeon Lake subwatershed (Table 7.17). Approximately 701 kg (2.4%) of phosphorus comes from Nogies Creek flow, while 3.2% of phosphorus enters Pigeon Lake with from shoreline urban runoff.

This is an entirely human-generated phosphorus as well as phosphorus from shoreline septic systems, which accounts for up to 3.5% of the total load. Close to 2% of phosphorus enters the lake via different types of precipitation, such as rain, snow, hail, dew, etc. Finally, the Bobcaygeon wastewater treatment plant annually generates around 67 kg of phosphorus that is slightly above 0.2% of the total phosphorus load with variations from 59 to 81 kg over the three-year period.

Average phosphorus loading from river flow and surface runoff into the lake is 3408 kg annually or approximately 12% of the total load. Distribution of the total river flow phosphorus load between different tributaries and subwatersheds is shown in Table 7.19. The most significant sources, as noted, are Pigeon River and Nogies Creek. The least amount of phosphorus enters the lake from the Eels Creek subwatershed, which generates on average 73 kg annually (although it is the second smallest subwatershed).

Table 7.19. Phosphorus Load into Pigeon Lake with River Flow in 2012-2013, 2013-2014 and 2014-2015 Hydrologic Years

Watercourse / Subwatershed	2012-2013		2013-2014		2014-2015		Average	
	TP, kg	TP, %	TP, kg	TP, %	TP, kg	TP, %	TP, kg	TP, %
Pigeon River	1,335	43.8	1,429	35.4	1,286	41.0	1,350	39.6
Nogies Creek	704	23.1	936	23.2	464	14.8	701	20.6
Eels Creek	73	2.4	98	2.4	48	1.5	73	2.1
Potash Creek	93	3.0	173	4.3	103	3.3	123	3.6
Reforestation Creek	417	13.7	643	15.9	682	21.7	581	17.0
Pigeon L. Subwatershed	424	13.9	760	18.8	556	17.7	580	17.0
TOTAL	**3,045**	**100**	**4,039**	**100**	**3,139**	**100**	**3,408**	**100**

The local subwatersheds in the study area include Pigeon River, Nogies Creek, Potash Creek and Reforestation Creek as well as the Pigeon Lake subwatershed. Among local subwatersheds, the Pigeon River subwatershed, which is the biggest (274 km^2), generates the largest amount of phosphorus, 1350 kg annually. It is followed by Nogies Creek subwatershed (701 kg) and the Reforestation Creek subwatershed (581 kg). The Pigeon Lake subwatershed (areas around the lake drained by many small streams) generated 580 kg of phosphorus. In addition, 935 kg of phosphorus enters the lake from urban areas within the subwatershed for 1515 kg in total.

In the course of further analysis, phosphorus loading from the local subwatersheds was split between several categories of total phosphorus sources in order to determine how much phosphorus is entering the lake from natural sources/processes and how much is the result of human activities, primarily agricultural and urban runoff as well as loading from shoreline septic systems around the lake. In order to determine phosphorus loadings from natural sources and from agricultural fields, loading coefficients from the CANWET model were used. The MOE Phosphorus Loading Tool was also utilized for calculations (Hutchinson Environmental Services, 2012).

Estimated TP loads from three major land use categories, namely agricultural runoff, urban runoff and natural sources, as well as from shoreline septic systems and the Bobcaygeon WWTP are presented in Table 7.20.

Table 7.20. Phosphorus Load into Pigeon Lake from Local Source Categories

Source / Category of Sources	TP Load, kg	% of Local TP Load	% of Total Load
Local Natural Sources	2,287	42.1	7.8
Local Urban Runoff	1,007	18.5	3.5
Local Agricultural Runoff	1,049	19.3	3.6
Shoreline Septics	1,027	18.9	3.5
Bobcaygeon WWTP	67	1.2	0.2
Total from Local Sources	5,437	100	18.6

7.8 Nitrogen Load

The three year average total nitrogen load into Pigeon Lake is 1,355,188 kg. The highest loading into the lake was in 2012-2013 with 1,621,719 kg of nitrogen delivered from all sources. The lowest loading was observed in 2014-2015, which was as low as 962,533 kg, primarily as a result of lower spring flow. The total nitrogen load into Pigeon Lake can be distributed between the five major sources:

1) **Sturgeon Lake flow** brings into the Pigeon Lake on average 1,159,530 kg of nitrogen annually. The flow from Sturgeon Lake is the largest source of nitrogen for Pigeon Lake (Table 7.21).

2) **The river flow** total nitrogen loading into Pigeon Lake was 124,199 kg in 2012-2013, 153,208 kg in 2013-2014 and 124,562 kg in 2014-2015. The average load over the three year period was 133,990 kg (Table 7.22)**.** The largest source of nitrogen is the **Pigeon River**, which transported 51,701 kg, 59,701 kg and 56,155 kg in 2012-2013, 2013-2014 and 2014-2015 respectively. Nitrogen load with **local stream flow** was 46,226 kg, 62,153 kg and 46,392 kg in the 2012-2013, 2013-2014 and 2014-2015 hydrologic years correspondingly. The average nitrogen load from local tributaries over the three year period was 51,590 kg.

3) **Atmospheric deposition** (wet and dry) of total nitrogen on the lake's water surface was 40,268 kg in 2012-2013, 46,209 kg in 2013-2014 and 39,678 kg in 2014-2015. The average atmospheric load over the three year period was 42,052 kg (Table 7.21).

4) **Shoreline urban stormwater** nitrogen loading into Pigeon Lake was estimated at approximately 9,283 kg in 2012-2013, 9,943 kg in 2013-2014 and 8,236 in 2014-2015.The average load over the three-year period was 9,334 kg (Table 7.21).

5) **Septic systems.** Nitrogen loading from private septic systems around the lake is estimated at 10,283 kg annually.

Some nitrogen enters Pigeon Lake with the Bobcaygeon Wastewater Treatment Plant effluent. Unfortunately, the plant does not monitor concentrations of nitrites, nitrates and organic nitrogen in the effluent, but only ammonia. As a result, an exact amount of nitrogen released annually from the plant is unknown.

Calculated average and annual nitrogen loadings into Pigeon Lake are presented in Table 7.21. A breakdown of the average nitrogen load between its major sources during the 2012-2015 monitoring period is presented in Figure 7.14.

As mentioned, the flow from Sturgeon Lake is the largest source of nitrogen for Pigeon Lake. On average, it contributes more than 85% of the nitrogen load into the lake (Figure 7.14). The Pigeon River watershed is the second largest source of nitrogen for the lake that contributes more than 4% of the total nitrogen load due to quite a large catchment area. Almost 4% of nitrogen enters the lake with local flow (Potash Creek, Reforestation Creek, Eels Creek and Pigeon Lake subwatersheds).

Table 7.21. Pigeon Lake Nitrogen Loads for 2012-2013, 2013-2014 and 2014-2015 Hydrologic Years

Sources of Nitrogen	2012-2013		2013-2014		2014-2015		Average	
	TN, kg	TN, %	TN, kg	TN, %	TN, kg	TN, %	TN, kg	TN, %
Sturgeon Lake	1,437,146	88.6	1,261,669	85.2	779,774	81.0	1,159,530	85.6
River flow as:								
Pigeon River	51,701	3.2	59,701	4.0	56,155	5.8	55,852	4.1
Nogies Creek	26,272	1.6	31,353	2.1	22,015	2.3	26,547	2.0
Local streams and overland flow	46,226	2.9	62,153	4.2	46,392	4.8	51,590	3.8
Atmospheric deposition	40,268	2.5	46,209	3.1	39,678	4.1	42,052	3.1
Shoreline urban runoff	9,823	0.6	9,943	0.7	8,236	0.9	9,334	0.7
Septic systems	10,283	0.6	10,283	0.7	10,283	1.1	10,283	0.8
Total Load	**1,621,719**	**100**	**1,481,311**	**100**	**962,533**	**100**	**1,355,188**	**100**

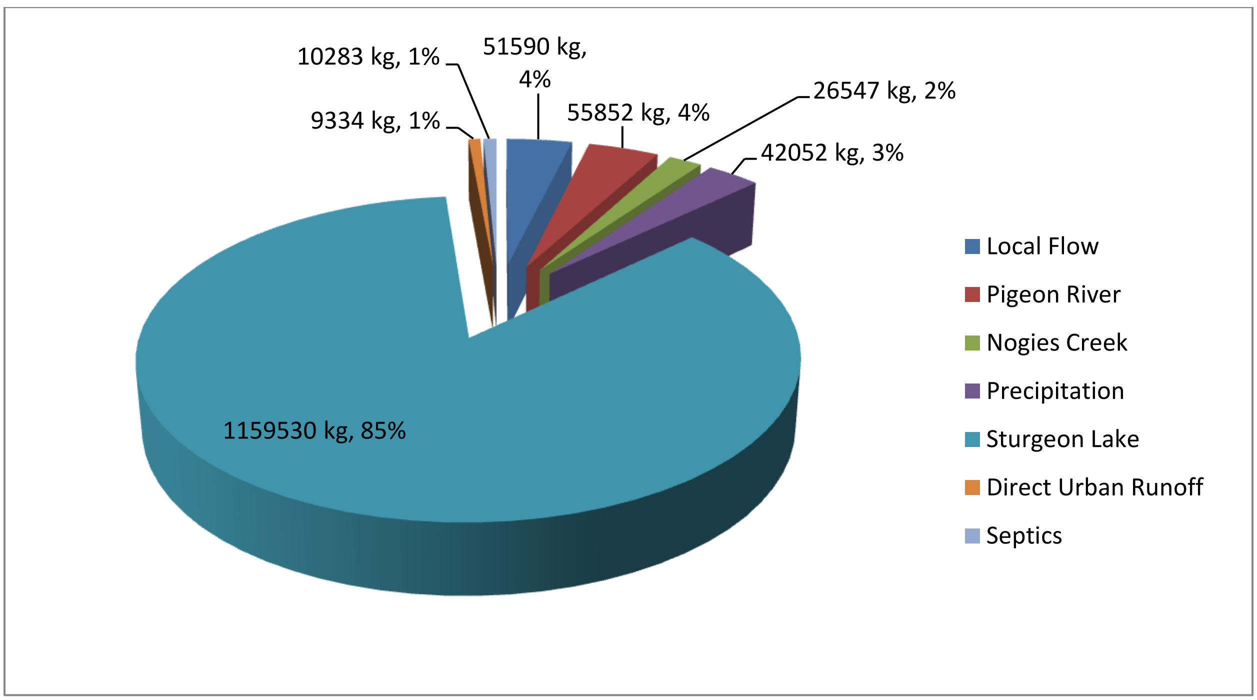

Figure 7.14. Average Nitrogen Load into Pigeon Lake from Different Sources During 2012-2015 Monitoring Period

Average annual nitrogen loading with the river flow and surface runoff into the lake is 133,990 kg. A breakdown of the river flow nitrogen load between the tributaries and subwatersheds is shown in Table 7.22. The Pigeon River contributes 41.7% of the nitrogen load within the river flow category, while Nogies Creek contributes almost 20% and Reforestation Creek subwatershed despite being the smallest subwatershed (15.3 km^2) in the study area generated 17009 kg or 12.7%. Similar to Phosphorus, the Eels Creek subwatershed generates the least amount of nitrogen, from 2292 to 3265 kg annually. This subwatershed is the second smallest (19.3 km^2) within the study area.

Table 7.22. Nitrogen Load into Pigeon Lake with River Flow in 2012-2013, 2013-2014 and 2014-2015 Hydrologic Years

Watercourse / Subwatershed	2012-2013		2013-2014		2014-2015		Average	
	TN, kg	TN, %	TN, kg	TN, %	TN, kg	TN, %	TN, kg	TN, %
Pigeon River	51,701	41.6	59,701	39.0	56,155	45.1	55,852	41.7
Nogies Creek	26,272	21.2	31,353	20.5	22,015	17.7	26,547	19.8
Eels Creek	2,702	2.2	3,265	2.1	2,292	1.8	2,753	2.1
Potash Creek	4,440	3.6	8,520	5.6	5,567	4.5	6,176	4.6
Reforestation Creek	18,801	15.1	18,250	11.9	13,977	11.2	17,009	12.7
Pigeon L. Subwatershed	20,283	16.3	32,119	21.0	24,556	19.7	25,653	19.1
TOTAL	**124,199**	**100**	**153,208**	**100**	**124,562**	**100**	**133,990**	**100**

8.0 Aquatic Ecosystems

8.1 Summary of Observations, Key Issues, and Information Gaps

OBSERVATIONS

- ***Aquatic habitat conditions vary between the north and south sections of the lake.*** The north end of Pigeon Lake (north of Gannons Narrows) can be characterized as relatively deep (>3 metres) open water conditions, consisting of steep and narrow nearshore areas with coarse substrates. This area of the lake contains the deepest basin within the lake (approximately 13m depth) that thermally stratifies in the summer months, providing cold water habitat in relatively small water volumes. The south end of the lake is relatively shallow (<3 metres), broad nearshore areas that are dominated by large tracts of marsh wetlands and extension colonization of submerged aquatic plants. These areas are particularly important areas of biological productivity.

- ***Lake tributaries provide important ecological pathways to-and-from the lake**. T*here are approximately 35 tributaries that drain directly into Pigeon Lake. Many of these, including the Bobcaygeon River, Nogies Creek, Pigeon River, and Eels Creek have been documented as providing spawning habitat for important migratory lake-dwelling fish species such as walleye, muskellunge and/or white sucker. For the most part, there is unimpeded access along most lake-tributary pathways. Notable exceptions are the dams located at Bobcaygeon and Omemee which impede access to aquatic habitat within Sturgeon Lake and Pigeon River, respectively.

- ***Pigeon Lake and its tributaries support diverse fish communities that are typical of Kawartha Lake aquatic ecosystems**.* Approximately 38 fish species have been documented within the core Pigeon Lake management planning area, most of which are common throughout all of the Kawartha Lakes. The fish community structure in the lake has changed over time through intentional stocking, range extensions, unintentional introductions, non-native species invasions, and changes in lake-wide habitat conditions. According to recent netting (2013), the large-bodied nearshore fish community in Pigeon Lake consists of warm- and cool-water species including bluegill, black crappie, walleye, common carp, largemouth bass, smallmouth bass, pumpkinseed, muskellunge, yellow perch, brown bullhead, and rockbass. Sensitive coldwater fish species have been documented in the deeper northern basin of Pigeon Lake (Lake Herring), and within the headwater of several tributaries (Brook Trout). No known fish species listed as Special Concern, Threatened or Endangered have been documented.

- ***There have been recent changes to fish community composition.*** There is an apparent increase in the relative abundance of several panfish species, particularly bluegill and black crappie. This is not unique to Pigeon Lake and is a Kawartha Lakes wide phenomenon. Further, the data may indicate a decreasing trend in muskellunge and walleye relative abundance, although this should be interpreted with caution as data points are limited and other metrics suggest a stable walleye population.

- ***The lake supports a significant recreational fishery with the most targeted species being bass, (largemouth bass and smallmouth bass), walleye, muskellunge, and panfish (black crappie, pumpkinseed, and bluegill).*** The Kawartha Lakes are heavily fished, and support one of the largest inland lake recreational fisheries in Ontario. According to most recent data (2005), Pigeon Lake is among the top fifteen lakes in Ontario in terms of angler activity, has been relatively consistently fished over the last decade at 115,000 angling hours per year. The most sought-after species for anglers has shifted within the past 30 years, from predominately walleye to bass and walleye. Also during this time, fish harvested by anglers has shifted from walleye to bass and bluegill.

KEY ISSUES

- ***Establishment of non-native, invasive aquatic species that alter the aquatic ecosystem****.* Pigeon Lake has been exposed to a variety of non-native aquatic species, including fish (e.g., common carp, bluegill, black crappie), invertebrates (e.g., zebra mussels, rusty crayfish, spiny water flea), and aquatic plants (e.g., common reed, Eurasian water milfoil). In addition to these existing non-native species, there are others that are at immediate risk of becoming established (e.g., round goby). Proliferations of non-native species are considered invasive when they have negative ecological and economic impacts. The interconnected nature of the Kawartha Lakes, along with high recreational usage, facilitates the spread of invasive species. Pigeon Lake is particularly susceptible being one of the tri-lakes with unimpeded access Buckhorn Lake and Chemong Lake, as well as Big Bald and Little Bald Lake. Northern pike have recently become established in upstream Balsam Lake, and their relative biomass is increasing in that lake which may lead to future negative impacts for native muskellunge populations if populations expand into Pigeon Lake or neighbouring Tri-lakes.

- ***Loss and fragmentation of aquatic habitat along the shoreline, and small-to-medium sized tributaries****.* A significant portion of the shoreline on the lake, particularly in the north end, has been altered through development. Many areas have been hardened with concrete, armourstone and other non-natural materials which can have impacts for the nearshore area and can reduce aquatic habitat potential. Aquatic habitat loss and fragmentation is evident along some small to medium-sized tributaries (Pigeon Lake Tribs., Reforestation Creek, and Pigeon River), particularly in their headwaters due to land being converted to agricultural production. Stream benthic macroinvertebrate communities suggest a slight degree of stream habitat degradation, although data indicates Pigeon Lake tributaries are faring better than those within neighbouring Sturgeon Lake.

- ***Climate change has the potential to continue to alter aquatic ecosystem conditions****.* The impacts of climate change will emanate from well beyond the watershed, but they can affect physical and biotic attributes and ecological functions within the watershed. Climate change trends can be considered a large factor influencing the productive capacity of fisheries. Water temperature increases associated with climate change can influence factors such as year-class strength, recruitment, growth and survival of fishes. It is generally predicted that on a provincial scale increases in water temperatures will favour the production of warm-water fishes, while reducing production of cool/coldwater fishes. Coldwater fishes in particular, are sensitive to increasing water temperatures that can lead to reduced populations (or elimination) of lake herring which are already limited in Pigeon Lake, and Brook Trout which are confined to limited sections of some of the lake's tributaries.

INFORMATION GAPS

- ***Limited understanding of how stressors such as climate change, cumulative development and invasive species will impact the aquatic ecosystem.*** Aquatic habitat and aquatic communities within both lakes have been altered throughout the years in response to various pressures. It is important to have a comprehensive understanding of how these stressors interact within both lakes and their watersheds, for example, by determining lake capacity thresholds. Moreover, no known standards exist for determining what constitutes a "healthy aquatic ecosystem" that is specific to the Kawartha Lakes.

- ***Limited understanding of coldwater aquatic habitat and communities.*** Coldwater fishes are present within Pigeon Lake (e.g., lake herring, trout-perch, and burbot), and its tributaries (brook trout, and sculpin species), however there is limited reliable data on important metrics such as species composition, relative abundance, and habitat occupancy. Routine netting programs (aside from the recently implemented Broad-scale Netting program), within the Kawartha Lakes have typically not focused on assessing coldwater fish populations. Coldwater species are sensitive to ecosystem change and as such are useful as indicator organisms in monitoring programs.

- ***Limited understanding of small-bodied fish communities.*** Sampling practice has largely been focused on tracking large-bodied fish species that are important in supporting the recreational fishery, therefore little is known regarding the status of small-bodied fish communities. These fishes are important components of the aquatic ecosystem in both lakes and their tributaries. The Broad-scale Monitoring program will, over time, contribute to these data for Pigeon Lake. Obtaining a more thorough understanding of their diversity and population trends will be beneficial towards a comprehensive characterization of the aquatic ecosystem.

- ***Limited understanding of fish spawning habitat and recruitment dynamics.*** Much of the existing data relating to fish spawning habitat within Pigeon Lake, and its tributaries, is relatively dated (pre-2006). This is particularly true when considering the ecosystem shifts that have occurred in the Kawartha Lakes since the data collection period with respect to changes in fish community (e.g., increase in panfish) and changes to aquatic habitat (e.g., increase in clarity, wild rice proliferation). Recruitment is currently monitored through collecting information such as age structures and analyzing year class strength. However, due to netting catchability only adult fish are assessed, representing recruitment in previous (e.g., 2+) years. Thus it may be beneficial to obtain more detailed information on early recruitment to immediately capture any major changes in population dynamics, particularly for species significant to the recreational fishery (e.g., walleye, muskellunge).

8.2 Introduction

This chapter provides an overview of important components of the aquatic ecosystems of Pigeon Lake by characterizing its lake-based and tributary-based elements, and their interconnectedness.

An aquatic ecosystem is life within water bodies and their relationship to, and connection with, living and non-living components. Maintaining healthy aquatic ecosystems is integral in maintaining healthy lakes.

Communities and individuals who rely on the lakes benefit from healthy aquatic ecosystems through the goods and services they provide such as: quality recreational opportunities, clean water, biodiversity and other lake-based functions. Local municipalities rely on healthy aquatic ecosystems to support their lake-based economies (the foundation of which is tourism), and to provide high quality lifestyle opportunities for residents, cottagers and visitors.

The key aquatic ecosystem components that are critical in supporting the above-mentioned benefits are characterized below. A particular emphasis is placed on aquatic life (communities of species, particularly fishes) and aquatic habitats (features and functions that maintain life) that exist/interact within the lakes and their tributaries.

8.3 Lake Ecosystems

8.3.1 Aquatic Habitat

The abundance, composition and productivity of aquatic communities are dependent on the quality and availability of habitats in a lake. Changes in habitat can affect aquatic communities by, for example, creating favourable conditions for one species that in turn shifts aquatic community composition or available prey resources. Physical habitat includes all spatial and temporal extents of lake morphology, hydrology, substrate type and physical cover, nutrient, optical and thermal features of an aquatic ecosystem. These habitat components differ among zones of a lake; most obviously between the shallow nearshore zones (depths ~ 1 – 3 m) and deeper offshore zones (depths > 3 m). This section will characterize the lake-based aquatic habitat of Pigeon Lake specific to aquatic communities, and describe recent changes observed in the abiotic and biological habitat components detailing potential consequences for the resident aquatic communities.

Defining the Aquatic Habitat in Pigeon Lake

Pigeon Lake, with a surface area of 55 km^2, is one of the larger lakes in the series of connected Kawartha Lakes. Pigeon Lake is long and narrow, having a distinctive "north-south" orientation that was exaggerated (particularly in its south half) by the regulation of seasonal water level fluctuations and flows to render the Trent and Severn watersheds united and navigable. The unique lake shape consists of three general areas for characterization purposes: a Northern section (top-third of the lake), a Central section (middle-third), and a Southern section (bottom-third). These spatially explicit areas provide variable aquatic habitat differing in local drainage, hydrology, nutrient loadings, clarity, and substrate and physical cover and ultimately affect aquatic communities and biological productivity.

Bathymetry highlights the difference in habitat across the lake (Figure 8.1). The Northern section consists of relatively deep basins that have water depths ranging from 6-13 m, and has relatively narrow and steep nearshore areas. The maximum depth of the lake (approximately 13.1 m) exists in this section within the north-east basin. In contrast, the Southern section of the lake consists of relatively shallow waters ranging from 1-3m in depth, and has gradually sloping nearshore areas that extend from shore-to-shore. The Central section has water depths that range from 3-6 m and nearshore slopes that are intermediary between the Northern and Southern sections.

Vegetative cover and substrate conditions are also important physical characteristics of aquatic habitat that have implications for the productivity of aquatic communities. Generally, macrophytes are expected to increase nearshore productivity (Jude and Pappas, 1992). In addition, macrophytes increase the structural complexity of the littoral habitats which has been shown to increase fish species richness and influences predator–prey interactions (Crowder and Cooper, 1982; Eadie and Keast, 1984). The only lake-wide aquatic vegetation survey conducted on Pigeon Lake was conducted in the early 1970's (OMNR and OMOE, 1976). The survey characterized the Southern section of Pigeon Lake, below Gannon's Narrows, as having prolific plant growth due to extremely shallow waters and rich organic substrates. The vegetation at that time in this section was largely dominated by *Vallisneria americana* (tapegrass) and covered an area of 1620 ha, with other common species being *Myriophyllum* sp. (milfoils), *Chara* sp. (muskgrasses), and *Potamogeton richardsonii* (Richardson's pondweed). In the northern portion of the lake, the survey found that macrophytes occupied a total of 160 ha, and were largely confined to the mouths of Nogies Creek and Eels Creek, Tait's Bay, Back Channel, and some sections of the shoreline, particularly on the west side. In recent years (since approximately 2010), wild rice (*Zinzania* sp.) has proliferated extensively in the southern section of the lake and field surveys conducted in August 2015 by Kawartha Conservation suggest that it now covers approximately 600-730 ha, or 10-15% of the total lake surface area. The lake also has several lacustrine, shallow marsh wetlands, many of which are considered significant at a provincial level (see Chapter: Terrestrial Natural Heritage).

Nutrients, in particular phosphorus and nitrogen, are common elements that have a primary influence on the biological productivity of lakes. Nutrient concentrations are influenced by local hydrology and drainage, as well as land use, and internal lake-system dynamics. Pigeon Lake is situated at the "upper-middle" of the Kawartha Lakes systems and current water quality data indicates that it is a meso-eutrophic, or moderately productive lake (see Chapter: Water Quality). As such, it can be reasonably expected to support "moderate" amounts of biological life. Nutrient concentration are slightly lower in Northern section of the lake, likely due to local inputs of relatively nutrient-poor waters from Nogies Creek, Eels Creek, and Little Bald Lake which drain relatively undeveloped lands off the Canadian Shield. The Middle section has similar nutrient concentrations as in the Northern section, likely due to the fact that the main flow through of water in the lake is from Sturgeon Lake (90% of total yearly inputs; see Chapter: Water Quantity) to Buckhorn Lake through Gannon's Narrows. In the Southern section of the lake, nutrient concentrations are slightly higher, likely due to local inputs of relatively nutrient-rich waters from Pigeon River, Reforestation Creek, and Potash Creek which drain extensive agricultural lands, but is also likely due to the lower flushing rate from this section being slightly away from the main flow of water through the lake.

Nutrient loadings are inherently linked to water clarity, which also plays an important role in determining habitat quality. Water clarity can be a limiting factor to aquatic organisms (e.g., walleye) that rely on visual cues for predation and/or predator detection. It is also important for the production and distribution (spatially and at depth) of aquatic plants by limiting the amount of light available for photosynthesis. In following the same spatial pattern as phosphorus concentrations within Pigeon Lake, the Northern section has the clearest water (4 m average, open water Secchi depth) whereas the Southern section has less-clear waters (2 m Secchi depth).

Thermal regime is another important habitat component with strong links to aquatic communities. Water temperature is a crucial habitat component for all fish communities, with each species having preferred thermal habitat conditions for reproduction, survival and growth. Thermal conditions across Pigeon Lake were assessed from 2012-2015 on a monthly basis from May to October. Surface water temperatures averaged 20.2^{o}C (maximum = 25.3; minimum = 15.1), indicating a warmwater/coolwater thermal regime. Thermal regime not only affects the suitability of aquatic habitat, but also accessibility to habitat due to the vertical thermal structure. During most of the year, Pigeon Lake is well-mixed. From June through August, however, the vertical thermal structure temporarily stratifies in the Northern section. This permits relatively colder water to exist at depth within these areas of the lakes. For example, in August 2013 water temperatures within the deep north-western basin of Pigeon Lake ranged from 22.8^{o}C at the surface to 16.0^{o}C near the bottom substrate (approximately 13 m). However, one would not expect any sizable amount of cold water habitat because lake morphology limits the amount of volume available within the deep, cold areas of the basins.

Another physical limnological attribute that may enhance or limit access to aquatic habitat are adequate dissolved oxygen concentrations to support aquatic respiration. Summer dissolved oxygen concentrations appear relatively stable in the surface waters and are somewhat uniform with depth. However, as discussed in ***Chapter: Water Quality***, there are occasional oxygen reductions in the bottom waters of the deep basins during periods of temporary stratification (Figure 7.10).

Recent Changes in Kawartha Lakes Aquatic Habitat and Consequences for Aquatic Communities

Over the last 50 years, major land use changes within the Kawartha Lakes region have included land clearing for agriculture, increasing urbanization along the shoreline and hardening of the shoreline/lake interface. Changes in shoreline development and land use patterns can have wide-spread implications for aquatic habitat. In addition, changes in nutrient inputs from watershed sources have also likely played a role in affecting aquatic habitat.

Over recent decades, modest increases in water clarity have occurred in Pigeon Lake a result of reduced nutrient loadings starting in the late 1970s. Phosphorus levels in the lake have been reduced by approximately 30% since that time, and at present average levels are below the Provincial Water Quality Objectives limit of 20 µg/L. The observed decline in nutrient inputs, along with the arrival of zebra mussels (*Dreissena polymorpha*) in the mid-1990s, have led to a modest, yet statistically significant increased clarity in the lake water in many Kawartha Lakes (Robillard and Fox, 2006). In Pigeon Lake Secchi depth measurements taken in 1972 and 1976 averaged approximately 2 m, whereas from 2012-2015 they averaged approximately 3 m. These observed changes in Pigeon Lake are quite modest compared to dramatic increases in Secchi depth observed in other Kawartha Lakes (e.g., Sturgeon Lake and Rice Lake). Increases in water clarity typically translate into an increase in the maximum depth of macrophyte colonization.

Climate change is also a continuing stressor affecting thermal and hydrologic lake conditions. Neighbouring Sturgeon Lake has shown a slight increase of ~1^{o}C in sustained summer (June, July and August) water temperatures. Such changes in water temperature over time are becoming increasingly recognized as factors that influence year-class strength, recruitment, growth and survival of fishes. For example, in eastern Lake Ontario, it has been predicted that an increase in water temperature of 1^{o}C above the mean would result in an almost 2.5-fold increase in the relative recruitment of smallmouth bass, whereas coolwater species would experience a 2.4-fold decline in relative recruitment (Casselman et al., 2002).

Changes in thermal regime may also affect the availability of deep, cold waters within the deep basins of the Northern section of Pigeon Lake. Currently, lake herring (a coldwater fish) is considered rare in the Kawartha Lakes, however, recent surveys have captured lake herring in low numbers within the Northern section. The presence of lake herring indicates marginal summer profundal habitat for coldwater species. Changes in thermal attributes (absolute values and vertical structure) may compromise accessibility and/or suitability of deep-water habitat for these uncommon species - for example by deepening the thermocline thus reducing the available volume of cold, hypolimnetic aquatic habitat.

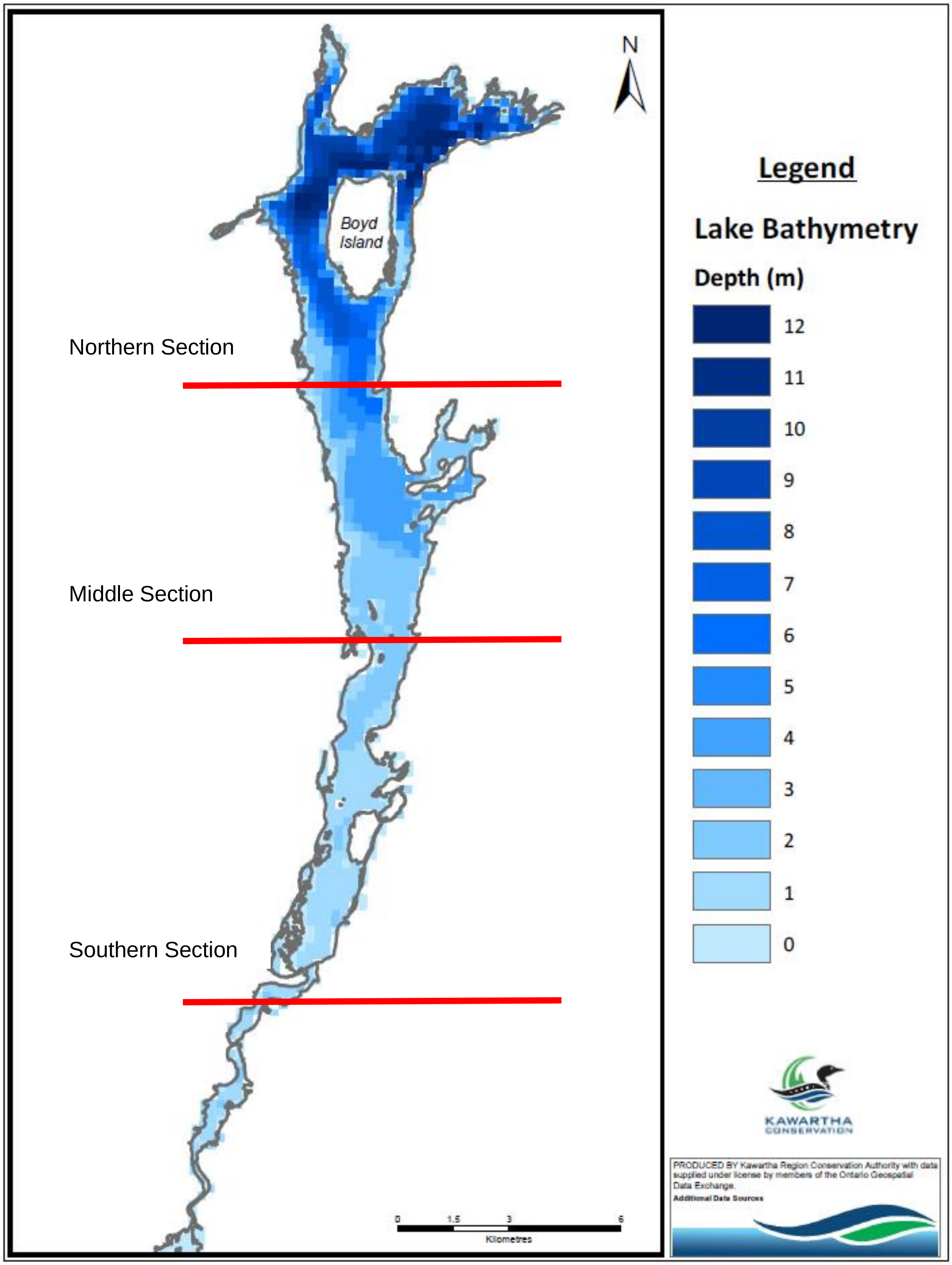

Figure 8.1: Bathymetric map of Pigeon Lake, showing three sections of the lake with varying aquatic habitat conditions.

8.3.2 Fish Communities

Assessing the Fish Community

As part of the Science and Research Branch of the Ministry of Natural Resources and Forestry (MNRF), the Kawartha Lakes Fisheries Assessment Unit (KLFAU) has been assessing the fish community of the Kawartha Lakes since the late 70`s (Rice Lake, Lake Scugog, Balsam Lake, Pigeon Lake, Buckhorn Lake and Chemong Lake). The KLFAU implements various provincially standard fisheries assessment methodologies, which is then uses to comment on population indices within individual lakes, the observed trends through time, and make comparisons among lakes. Over the years, the KLFAU has implemented a variety of programs. In this report, we draw on information from the KLFAU Nearshore Community Index Netting (NSCIN) program, KLFAU End of Spring Trap Netting program (ESTN), KLFAU Creel Surveys and the provincial Broad-Scale Monitoring (BSM) program. The methodologies of these are described in the following sections.

KLFAU NSCIN

Nearshore Community Index Netting (NSCIN) is a standard live release trap netting program designed to evaluate relative abundance and other attributes of fish species that inhabit the nearshore zone of Ontario lakes. The NSCIN program has been implemented in the Kawarthas since 1992, intermittently surveying on six lakes (Balsam, Buckhorn, Chemong, Pigeon, Rice, Scugog). Pigeon Lake has been sampled in 2005, 2009, and 2013. The field sampling season is from Aug 1st to whenever the surface water temperature cools to 13 degrees Celsius (usually late September in south-central Ontario). Standardized six foot trap nets are used, sampling sites are randomly selected, and each net set it approximately 24 hour. In order to test for statistical difference between years or lake characteristics, a minimum sample size of 30 sets per lake is recommended and a target for the KLFAU NSCIN program. In Pigeon Lake, species targeted by the NSCIN program include bluegill, black crappie, brown bullhead, common carp, largemouth bass, muskellunge, pumpkinseed, rock bass, smallmouth bass, white sucker, walleye, and yellow perch.

KLFAU ESTN

End of Spring Trap Netting (ESTN) is a standard live release trap netting program designed to estimate the relative abundance of a fish stock, and provide other biological measures to assess the status of walleye populations in Ontario. Under the ESTN protocol, Pigeon Lake has been sampled in 2001, 2004, 2008 and 2012. ESTN is an adaptation of the Nearshore Community Index Netting (NSCIN) program that was designed to provide trend through time information on nearshore fish communities. The ESTN method was proposed because the population density of walleye is better reflected when trap netting is completed in late spring and early summer, rather than during the NSCIN period of August and early fall. The field survey occurs in late spring when surface waters reach 12 degrees Celsius and may continue until the surface temperature reaches 18 degrees Celsius. This temperature window allows the post-spawning redistribution of walleye from spawning sites and ensures that sampling is completed before fish leave the nearshore zone for deeper water. In most parts of Ontario, the sampling window begins in mid-May and extends to mid-June (4 week sampling period). A standardized six foot spring-haul trap net is set and left to fish overnight. A minimum sample size of 30 sets per lake is recommended where higher precision is required (e.g., KLFAUs statistically testing for differences between years or lake characteristics). In Pigeon Lake, species targeted by the ESTN program include bluegill, black crappie, brown bullhead, common carp, largemouth bass, muskellunge, pumpkinseed, rock bass, smallmouth bass, white sucker, walleye, and yellow perch.

KLFAU Open water Angler Surveys

The Kawartha Lakes Fisheries Assessment Unit (KLFAU) periodically conducts angler (creel) surveys of the open water angler fishery on the interconnected waters of Pigeon, Buckhorn, and Chemung Lakes (collectively referred to as Tri-lakes). The purpose of the angler survey is to estimate the total fishing effort and harvest, and to collect biological information from the harvested fish. The Tri-lakes are typical of the Kawartha Lakes with walleye, smallmouth bass, largemouth bass, muskellunge, and panfish species in the fish community. Pigeon Lake has been surveyed in this manner in 1981, 1983, 1985, 1989, 1992, 1997, 2001, 2005, 2009 and 2013. The KLFAU has traditionally surveyed the portion of the open-water season from the opening of walleye season through Labour Day. This period represents most of the fishing activity and is used as an index of the entire open water season. On each survey day, the boat crew travels either Pigeon Lake, or Buckhorn and Chemung Lakes and interviewed boat angler parties at random. Interviews determined the number of anglers fishing, fishing trip duration, and the number of fish of each species caught and kept or released. Estimates of angler hours (ang-hrs), catch, harvest and catch rate (number of fish per ang-hr) can then be calculated and reported.

Ontario Broad-Scale Fish Community Monitoring (BSM)

The Broad-scale method uses a combination of two types of gillnets: "large mesh" that target fish larger than 20 cm in length, the size range of interest to anglers; and, "small mesh" that target smaller fish (size range of interest to large fish). Surveys are conducted when surface water temperature is greater than 18 degrees Celsius, and concluded when temperature drops below 18 degrees Celsius. Ideally, it is recommended that sampling take place during the four to six week period of maximum summer water temperature. All Small mesh sets must fish overnight (target duration is 18 hours) and include both crepuscular periods (i.e., set no later than one hour before sunset and lifted no earlier than one hour after sunrise).

General Species Composition

Pigeon Lake's fish community composition reflects its cool/warmwater thermal regime and mesotrophic nutrient status. Approximately 27 fish species have been formally documented within Pigeon Lake (Table 8.1), as indicated by historical records from the 1970's stored by the Royal Ontario Museum and recent netting data from 2009-2013 MNRF BSM and KLFAU surveys. Coldwater species including trout-perch, lake herring, and burbot are present but observations are rare and in very low relative abundance. The deeper northern basin and temporal stratification is presumed to have historically supported these species. Historically, the large-bodied fish species in Pigeon Lake were most represented by muskellunge, smallmouth bass, pumpkinseed and yellow perch populations. However, the large-bodied fish community structure has become increasingly altered over time due to intentional stocking, range extensions of species native to the Great Lakes basin, unintentional introductions and non-native species invasions.

In Pigeon Lake, bluegill and black crappie are the most recent additions to the fish community, and *Lepomis* sp. (bluegill and pumpkinseed) hybrids have been observed in recent surveys. Within the last two decades, bluegill (1990's) and black crappie (2000's) have become established in the Kawartha Lakes system, and now dominate fish community composition on most of the Kawartha Lakes. Both species are non-native the Kawartha Lakes but are to eastern and central North America, preferring the warm shallow waters of large and small lakes that have abundant aquatic vegetation. Bluegill populations in the Kawartha Lakes established in a progressive manner, beginning with Rice Lake in the 1970's. They were first captured in Buckhorn Lake in 1983, Lake Scugog in 1990, and Balsam Lake in 1993 (OMNR 2008). Black crappie were first detected in sampling programs on Rice Lake is 1985, and it was more than 10 years before they were sampled in another Kawartha Lake (Buckhorn in 1996), and by 1999 they were sampled in both Lake Scugog and Balsam Lake (OMNR 2008). Common carp were accidentally introduced into the Great Lakes system approximately 100 years ago and have been present in Pigeon Lake since at least the 1970s. Walleye were intentionally introduced to the Kawartha Lakes region in the 1930s to provide recreational angling opportunities. Largemouth bass and rock bass are native to the Trent River system and the construction of locks and canals between waterways have allowed these species to expand their ranges into Pigeon Lake. Tiger muskellunge (northern pike and muskellunge hybrid) have apparently also been observed in Pigeon Lake (Deacon, 1996; OMNR unpublished data), however no tiger muskellunge or northern pike has ever been observed in recent netting surveys or caught by anglers participating in creel surveys. At this time, it cannot be concluded that northern pike (or hybrids) are present and/or establishing in the lake. Northern pike have expanded along the Trent-Severn Waterway from Lake Simcoe into the Kawartha Lakes and have now become established in Balsam Lake.

The existing fish community in Pigeon Lake, as indicated by the most recent nearshore netting (NSCIN 2013), is similar to Buckhorn and Chemong Lakes in that it primarily consists of the family groups Centrarchidae and Percidae (Figure 8.2). However, the relative biomass of the fish community in Pigeon Lake is relatively low; it is the lowest of the tri-lakes and second-lowest of all sampled Kawartha Lakes. Recent fish community composition, from highest relative biomass to lowest, includes bluegill, black crappie, walleye, common cap, largemouth bass, smallmouth bass, pumpkinseed, muskellunge, yellow perch, brown bullhead, and rock bass (Figure 8.3). Over half of the relative biomass of fish is comprised of two recent additions the fish community: bluegill (33%), and black crappie is (21%). The fish community also includes small-bodied forage fish species such as minnows, darters, shiners and trout-perch. Little is known about the status of these small-bodied species within Pigeon Lake because routine monitoring (using large trapnetts) does not efficiently catch them. Historic records from other Kawartha Lakes and their tributaries indicate the potential for a diverse community.

Table 8.1. Fish species found in Pigeon Lake based on records from ROM, and recent observations from MNRF BSM and KLFAU. All recent observations are from the most recent sampling event, unless otherwise noted.

Fish Species	Historical Observation ROM*	Recent Observation	
		BsM**	KLFAU***
Banded Killifish	X		
Black Crappie [1]		X	X
Blackchin Shiner	X	X (2009)	
Bluegill [1]		X	X
Bluntnose Minnow	X	X	
Brassy Minnow	X		
Brook Stickleback	X		
Brown Bullhead	X	X	X
Burbot	X		
Central Mudminnow	X		
Common Carp [1]	X	X	X
Creek Chub	X		
Fathead Minnow	X		
Golden Shiner	X	X	X
Lake Herring	X	X (2009)	
Largemouth Bass [1]	X	X	X
Lepomis sp. (Hybrid) [1]		X	
Muskellunge	X	X	X
Northern Redbelly Dace	X		
Pumpkinseed	X	X	X
Rock Bass	X	X	X
Smallmouth Bass	X	X	X
Spottail Shiner	X		
Trout-perch		X (2009)	
Walleye [1]	X	X	X
White Sucker	X	X	X
Yellow Perch	X	X	X
TOTAL (27)	**23**	**18**	**13**

Royal Ontario Museum (ROM) data obtained 2006.
****MNRF most recent BsM netting (2012), unless otherwise noted.***
******MNRF KLFAU most recent index netting (2013)***
[1] denotes species that are non-native to the Kawartha Lakes region.

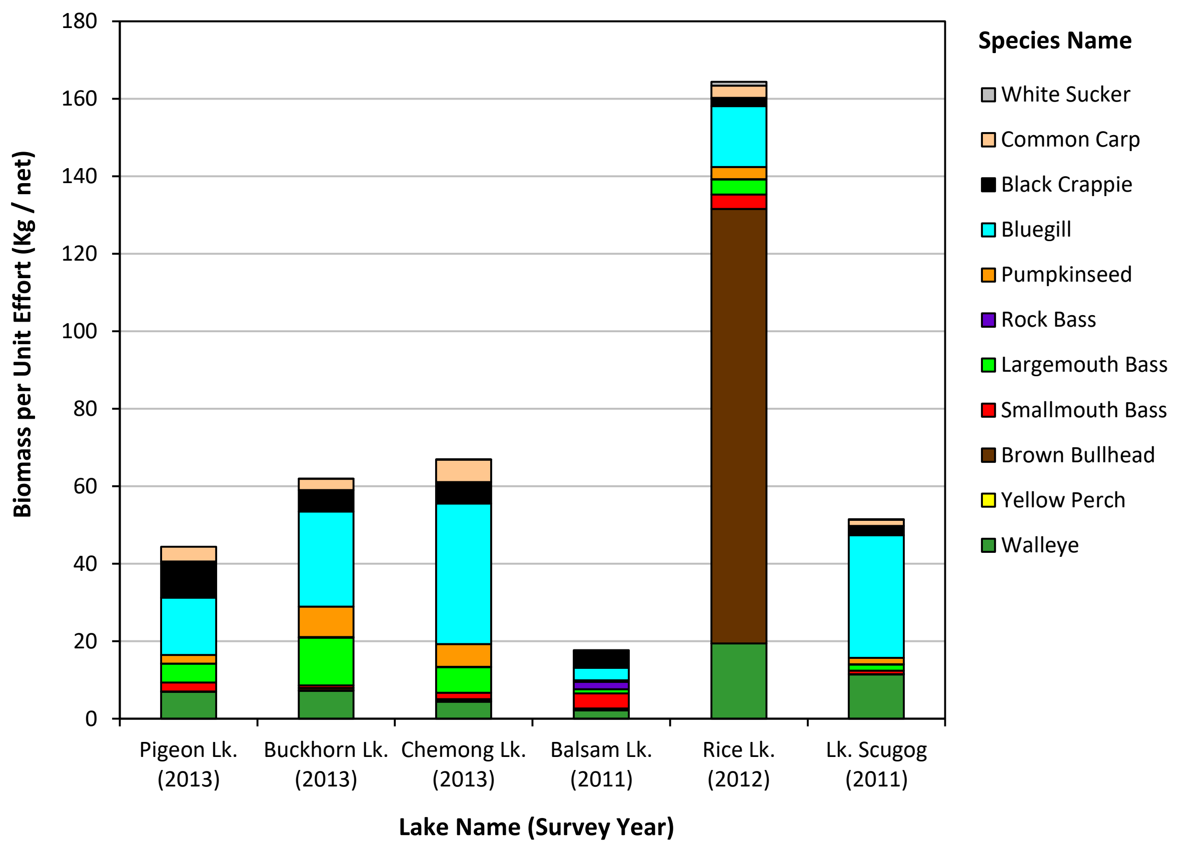

Figure 8.2: Relative biomass (Kg per net lift) of species caught in the Nearshore Community Index Netting program lead by the Kawartha Lakes Fisheries Unit (Ontario Ministry of Natural Resources and Forestry, Science and Research Branch). Surveys are designed to assess those fish species that inhabit the nearshore zone of the lake in the late summer and early fall (i.e. the so-called warmwater and coolwater fish communities of temperate lakes).

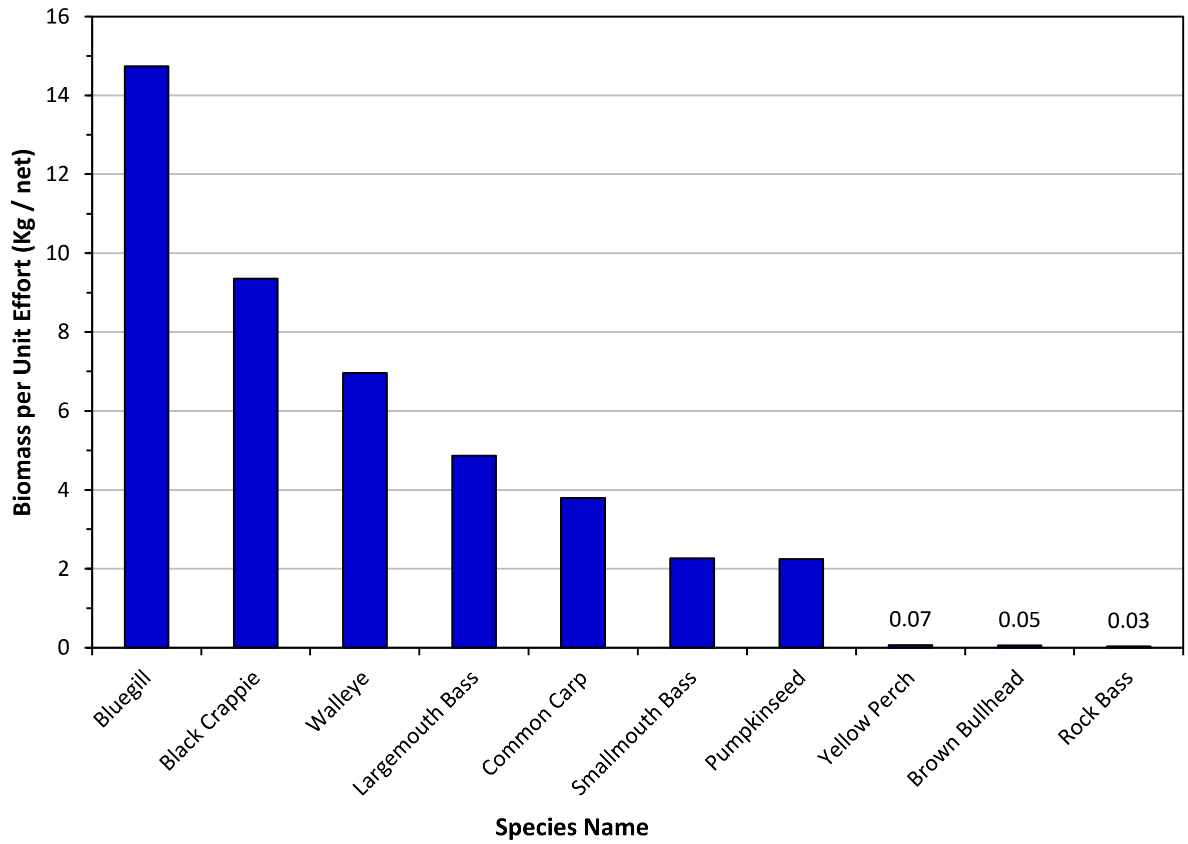

Figure 8.3: Relative biomass (Kg per net lift) of species caught in the Pigeon Lake Nearshore Community Index Netting Survey (2013) lead by the Kawartha Lakes Fisheries Unit (Ontario Ministry of Natural Resources and Forestry, Science and Research Branch). The survey is designed to assess those fish species that inhabit the nearshore zone of the lake in the late summer and early fall (i.e. the so-called warmwater and coolwater fish communities of temperate lakes).

Changes in Pigeon Lake fish communities

A standardized, long-term (i.e., pre-1990's) fish community dataset does not exist for Pigeon Lake, unlike data on Balsam Lake, Rice Lake, and Lake Scugog which extends back into the late 1970's and early 1980's. Since that time, as documented by Robillard and Fox (2006), the Kawartha Lakes have experienced a regional-scale decline in the relative abundance of walleye and an increase in the relative abundance of largemouth bass and smallmouth bass. These changes were associated with reductions in phosphorus concentration and increases in water clarity and summer temperature. It is likely that the fish community in Pigeon Lake has responded in a similar fashion to these regional-scale changes.

Figure 8.4 shows the trends in the relative abundance of large-bodied species caught during the KLFAU ESTN efforts on Pigeon Lake, from 2011 to 2012. In general, there is an observed decreasing trend in walleye and an increase in panfish relative abundance. This is not uncommon to the rest of the Kawartha Lakes that are routinely monitored. Smallmouth bass and largemouth bass show an increasing trend, although they only making up 4% of the total catch per unit effort in the most recent ESTN survey. Walleye and muskellunge show a declining trend but are likely stable, as the trend is not statistically significant and further, an analyses of the walleye age structure does not show a significant decline in year class strength (proxy for recruitment). The relative abundance of bluegill, pumpkinseed, and black crappie have increased over the past decade (bluegill now makes up the largest proportion of the total catch per unit effort), but only the pumpkinseed trend is significant. In terms of yellow perch, both ESTN and NSCIN data suggest a decreasing and low relative abundance, however this is presumed to be related to catchability (i.e., both trapnetting programs do not best capture population metrics for perch).As the BSM program continues on Pigeon Lake, better estimates of perch and other small-bodied fishes will be obtained that will more accurately characterize their populations.

Status of the Pigeon Lake Recreational Fishery

Pigeon Lake is located within the Kawartha Lakes area which supports a significant recreational fishery. The Kawartha Lakes are a popular recreation destination because of their proximity to urban centres (e.g., GTA) and their desirable sportfish species (e.g., walleye, muskellunge). Pigeon Lake is a competitively fished lake with multiple tournaments per year (Kerr, 2009). According to a 2005 survey of recreational fishing (OMNR 2009), Pigeon Lake is among the top 15 of lake in Ontario in terms of angler effort.

Since the late 1970’s, the KLFAU has conducted creel surveys on six Kawartha Lakes, providing detailed information on angler profile, effort, catch, and harvest. Figure 8.5 shows the trend in targeted angler effort on Pigeon Lake (expressed as total hours spent fishing during the open water season), from creel surveys conducted periodically from 1981 to 2013 by the KLFAU. During this sample period, estimates of total angler effort were highest in the late 1980’s, with a peak of 228,000 angler hours in 1989. Since the early 2000’s, angler effort has remained relatively stable at approximately 110,000 angler hours. The decline in angler activity over the years is not unique to Pigeon Lake, and has been experienced in all Kawartha Lakes as well as most of Ontario’s other lakes. In terms of species targeted, there is an apparent overall shift in species targeted, moving from walleye to panfish and bass. This trend is also observed on the rest of the tri-lakes, and in the Kawartha Lakes as whole.

Figure 8.6 shows the trend in species-specific yield (i.e., harvest) by anglers from the same creel survey as indicated above. During the period of record, although overall angler effort has decreased, there has been no apparent trend in overall angler harvest. The average harvest on Pigeon Lake has been 3.44 kg/ha, with the last two surveys being above this average (5.64 kg/ha in 2009, and 3.61 kg/ha in 2013). However, a shift can be observed in the species-specific harvest which corresponds to the shift in angler effort. There is a statistically significant decrease in walleye harvest, and an increase in bluegill and largemouth bass and smallmouth bass harvest.

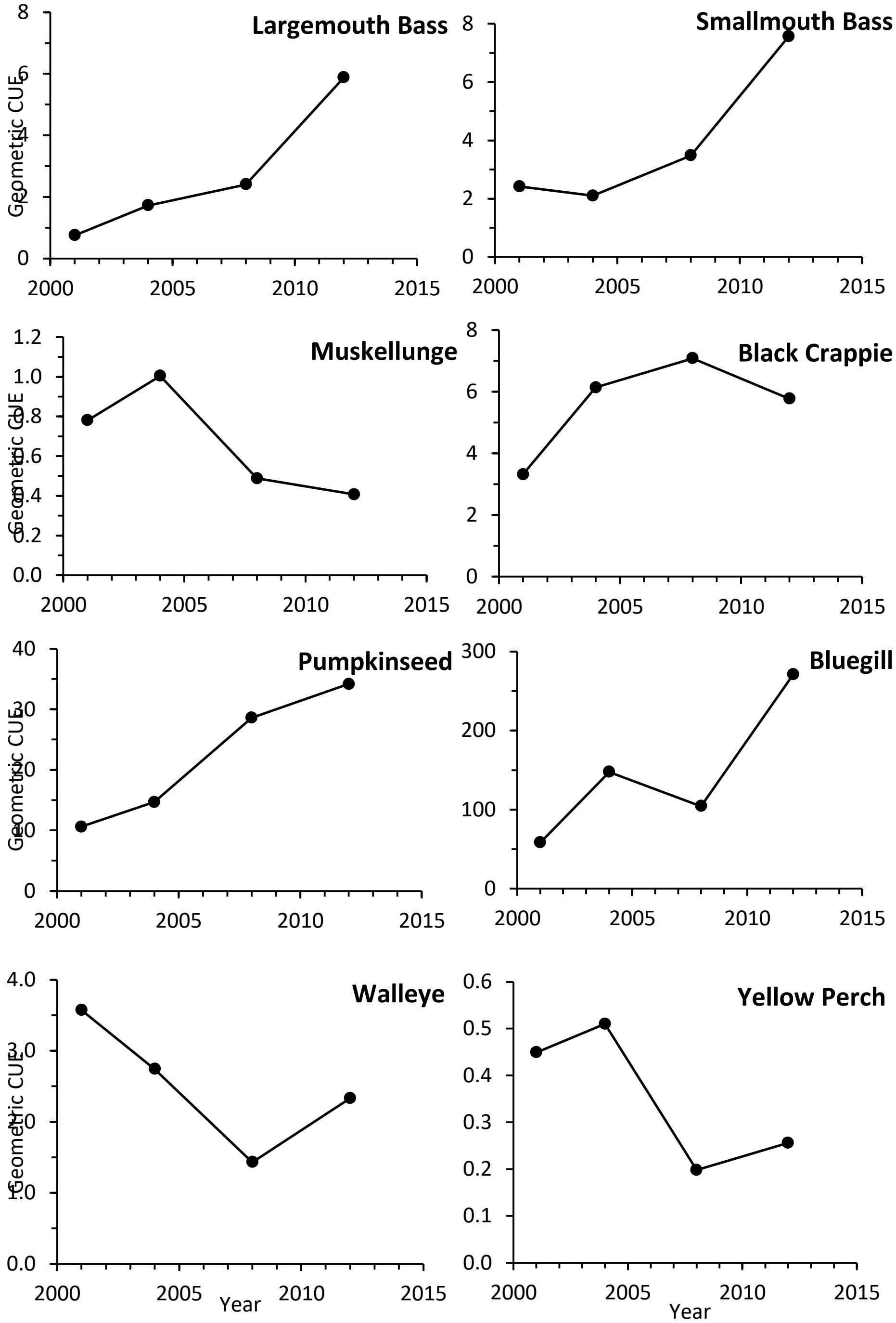

Figure 8.4: Trend in relative abundance (as represented by geometric mean catch per unit effort (CUE)) of species caught during the Kawartha Lake Fisheries Assessment Unit`s End of Spring Trap Netting efforts on Pigeon Lake from 2001-2012 (Ontario Ministry of Natural Resources and Forestry, Science and Research Branch).

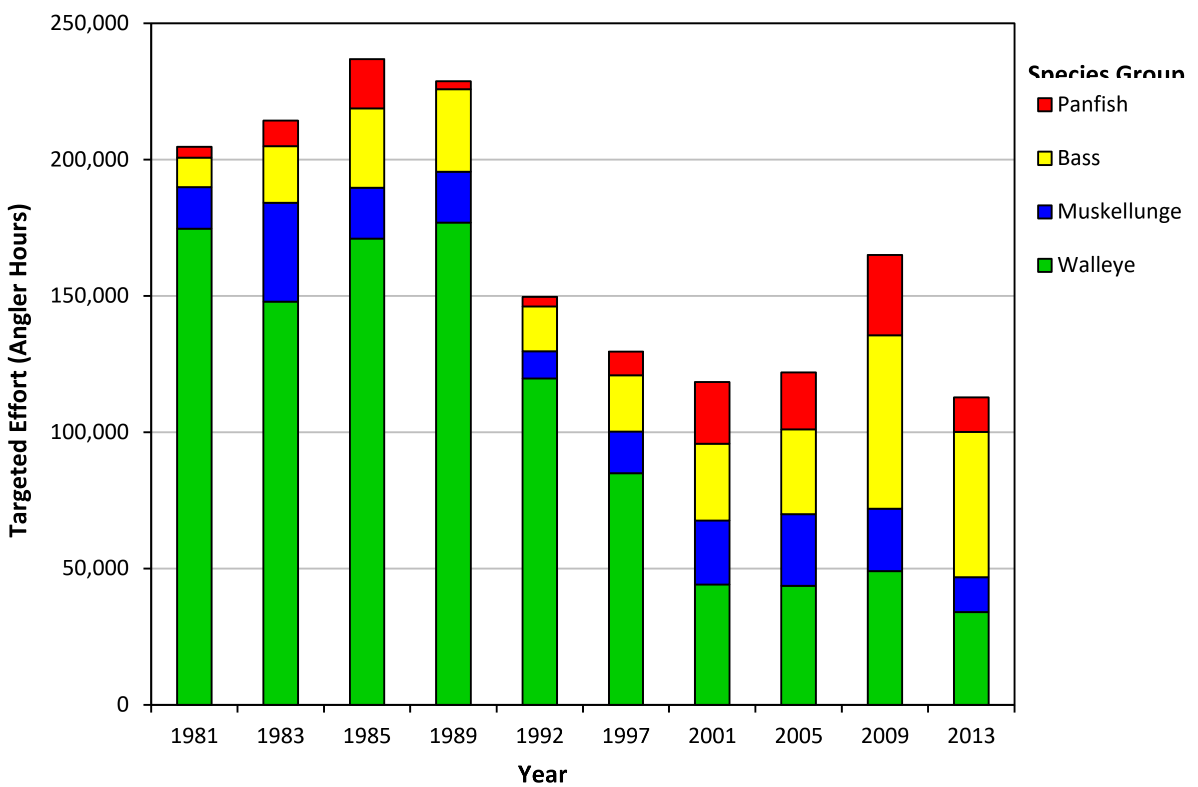

Figure 8.5: Targeted effort (angler hours per species group) of boat anglers on Pigeon Lake during the open water season. Estimates are generated from Creel Surveys that were conducted periodically from 1981-2013 by the Kawartha Lakes Fisheries Assessment Unit (Ontario Ministry of Natural Resources and Forestry, Science and Research Branch).

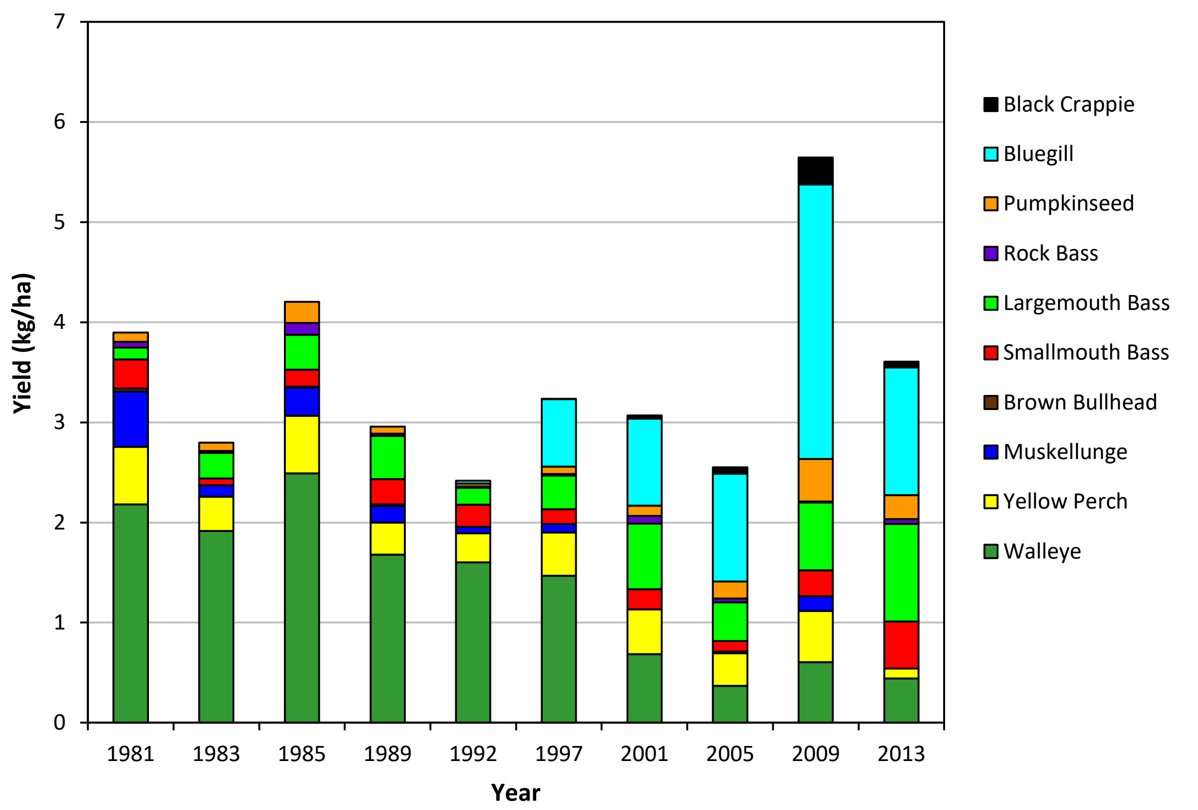

Figure 8.6: Pigeon Lake species specific yield (kg per ha) by boat anglers on Pigeon Lake during the open water season. Estimates are generated from Creel Surveys that were conducted periodically from 1981-2013 by the Kawartha Lakes Fisheries Assessment Unit (Ontario Ministry of Natural Resources and Forestry, Science and Research Branch).

8.3.3 Exotic and Invasive Species

In the Pigeon Lake ecosystem, several types (e.g., plants, invertebrates, fish, etc.) of aquatic invasive species are now well established that have altered, or are altering our natural communities. An exotic species is one that has been moved from its native habitat to a new area, whereas an invasive species is an exotic species that has proliferated to the extent that it causes widespread negative environmental, social, or economic impacts.

Due to the interconnectedness of lakes within the Trent-Severn Waterway watershed, the Kawartha Lakes facilitate the proliferation of exotic species, if they become established. Further, the lakes are particularly susceptible to exotic species transfer because they are recreational hotspots (e.g., boating corridor, fishing, watersports, etc.) that are close to large population centres such as the Greater-Toronto-Area. There are several pathways of exotic species introductions, including Intentional introductions (e.g., pest management, fish stocking, etc.), accidental introductions (e.g., dumping aquariums, hitch a ride, etc.), and natural dispersal through connected waterbodies.

Within Pigeon Lake, there are several exotic and invasive species that are now part of the aquatic ecosystem. Many exotic species have been established for several years and are now considered “naturalized” because they have integrated into ecosystem functions (e.g., common carp, walleye, Eurasian watermilfoil, etc.). According to an exotic species tracking project (EDDMAPS, 2015), at least 24 aquatic exotic invertebrate, plant, and fish species have been formally observed and reported within the Trent-Severn Waterway, 17 of which have been documented within the Kawartha Lakes subwatershed (Table 8.2, and Appendix 6).

Table 8.2: Exotic species found within the Kawartha Lakes subwatershed, from EDDMAPS.

Aquatic Invertebrates	banded mysterysnail
	Chinese mysterysnail
	rusty crayfish
	spiny waterflea
	zebra mussel
Aquatic Plants	common water hyacinth
	curly-leaved pondweed
	Eurasian water-milfoil
	European common reed
	European frog-bit
	flowering-rush
	purple loosestrife
	yellow iris
Fishes	oscar
	rainbow smelt
	red-bellied pacu
	round goby

8.4 Tributary-Based Ecosystems

8.4.1 Aquatic Habitat

Figure 8.7 shows the best-available mapping of the watercourse network within the core PLMP planning area. When combined, the watercourse network totals approximately 900 km in length, all of which can be considered as probable aquatic habitat that directly supports or contributes to aquatic life. The majority of the stream network (approximately 83% or 747 km of total length) flows through natural lands, primarily through coniferous forest, mixed forest, deciduous swamp, and thicket swamp. Approximately 11% or 99 km flows through agricultural areas, primarily croplands and to a lesser degree pasturelands. The remainder of the network (7%) flows through developed areas, mainly through areas of rural development and under roads.

Figure 8.8 shows the watercourse network, and Table 8.3 lists their respective lengths by stream order. Stream ordering, as introduced by Strahler (1957), is a method of classifying the branching complexity and size of the stream network. First-order streams are watercourses with no tributaries; second-order streams begin when two first-order streams meet; and so on proceeding in a downstream manner. As outlined in the River Continuum Concept (Vannote et al., 1980), stream ordering is a useful approach to help classify watercourse reaches that exhibit similar biological properties. Stream orders within the PLMP planning area range from one to five. The majority of watercourses (over 75% by length), are small first- and second-order streams. These "headwaters" are typically small, ill-defined and inconspicuous ephemeral or intermittent stream corridors that usually dry up during extended dry periods (e.g., during summer and winter). Headwaters are typically far-removed from the lake, but serve an important function by providing seasonal aquatic habitat when flow does occur, as well as conveying food, nutrients, and water flow that are used by aquatic life residing downstream in the larger and more identifiable watercourses. These larger streams sections, of third-, fourth-, and fifth-orders, comprise 25% of the total length of the stream network. These sections typically flow continuously, thus providing aquatic habitat year-round.

Table 8.3. Length of Streams Within Each Subwatershed by Strahler Order

Subwatershed	Stream Length	1st order	2nd order	3rd order	4th order	5th order
Nogies Creek	326	47	31	11	2	9
Pigeon River	258	47	24	13	11	5
Pigeon Lake Tribs.	126	63	30	7		
Fleetwood Creek	109	54	22	8	16	
Eels Creek	32	48	22	31		
Potash Creek	29	47	12	8	33	
Reforestation Creek	18	53	39	9		
Stream Order Total	**899 km**	**50%**	**27%**	**11%**	**7%**	**5%**

Within the PLMP planning area, there are approximately 35 tributaries that drain directly into Pigeon Lake. All of these provide important aquatic habitat pathways to-and-from the lakes. The aquatic habitat within these tributaries helps maintain functioning aquatic communities within the lakes by providing spawning habitat for lake-based migratory fishes, providing a corridor for the movement of aquatic organisms, water flow, food and energy transport which all contribute to the aquatic biodiversity of the lake basins, among other functions. The outlet sections of these tributaries are transitional areas between the lotic flowing water "stream-like" environments and the lacustrine still-water “lake-like” environments. These transitional areas are biodiversity hot-spots.

Many fish species in Pigeon Lake migrate up lake tributaries in late winter/early spring to reproduce (e.g., walleye, muskellunge and white sucker). Many tributary-dwelling fish species migrate to the lake and to refuge pools during seasonal dry periods and to avoid stream freeze-up during winter months. Therefore, unimpeded access both along tributaries, as well as to-and-from the lake is critical to maintain healthy fish populations in the lakes. Typically, the larger stream sections connected to the lake are most important in terms of providing habitat for lake-dwelling communities. In terms of watercourses flowing directly into Pigeon Lake, Nogies Creek and Pigeon River are the largest, entering the lake as 5^{th}-order streams into the north end and south end respectively. The next largest to enter the lake, as a 4^{th}-order stream, is Potash Creek that enters near Yankee Line on the east side of the lake.

Figure 8.9 shows the approximate locations of spawning habitats for three important top predator fish: muskellunge, smallmouth bass, and largemouth bass (OMNRF, 2006). Muskellunge in particular have been observed migrating up several tributaries to access spawning habitat. There are several spawning habitats along the shoreline of the lake, associated with wetland vegetation. Populations in Pigeon Lake have been found using habitat up Pigeon River (to Omemee, as well as upstream of Omemee dam), Nogies Creek outlet, Eels Creek, an unnamed tributary in the north-west end of the lake, and several unnamed tributaries (including Bears Creek) that flow into the Blind Channel. Maintaining migratory access to these areas is critical to maintaining healthy populations of these fish species. Access to aquatic habitat can be fragmented by man-made obstructions including dams, weirs, and perched or blocked culverts, as well as by natural obstructions such as steep river channels and fast flowing waters. Not only do such features impede migration, but they can also isolate populations and limit their access to suitable resident habitat.

Figure 8.9 shows the location of all known, man-made in-stream barriers within the PLMP study area, as identified from provincial mapping (dams) and Kawartha Conservation thermal regime surveys (perched culverts). There are over 40 such barriers, most of which do not interfere within migration to and from the lake. The dam and lock structures at Bobcaygeon provide a great degree of habitat isolation from Pigeon Lake to Sturgeon Lake, but does facilitate some movement (albeit limited, and mostly in a downstream manner) of aquatic organisms between each lake. Most other barriers are private pond dams located on small headwater tributaries of Pigeon River and Fleetwood Creek, and other areas located well upstream of the lake. One exception is Omemee dam on Pigeon River, which isolates lower Pigeon Lake from its upstream waters of the Pigeon River. Other notable “upstream dams” are on Nogies Creek: two on the mid reaches that bound a provincial fish sanctuary, and one on the upper reaches that provides water level control for Crystal Lake.

The transitional zones between aquatic and terrestrial environmental are called the riparian area. Natural riparian areas encompass a range of vegetation types (i.e., forest, wetland, meadow), and provide similar benefits along tributaries as do natural shorelines around lakes. These include: stabilizing stream banks, reducing erosion, moderating water temperatures, filtering contaminants, providing cover and spawning habitat for fishes, and supplying nutrients and food for the watercourse (Gregory et al., 1991). To characterize riparian areas within PLMP planning area, 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)].

Various studies have investigated the minimum riparian buffer width necessary to maintain the ecological integrity of watercourses, often ranging from 5 metres to 300 metres depending on the functions they provide (OMAFRA, 2003) (Figure 8.10). 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). In general, a 30 m width of natural vegetation on both sides of the watercourse is of sufficient size to provide beneficial functions such as aquatic habitat, bank stability, and sediment removal. Studies in southern Ontario have demonstrated that that stream degradation occurs (e.g., loss of sensitive species) when riparian vegetation amounted to less than seventy-five percent of the total stream length (Environment Canada, 2013). Thus, as a general guideline, it is recommended that to help maintain the ecological integrity of the aquatic ecosystem, at least 75 % of the total length of watercourses should have natural riparian areas, preferably as wide as 30m, on either side of the top of bank-full stage.

Table 8.4 lists the percentages of 30 metre riparian areas consisting of natural, agricultural or developed lands along all tributaries within the study area, by stream order. At 85% existing natural riparian areas, the watercourses within the PLMP meet recommended guidelines. Natural riparian areas by stream order range from 80-100%, and are more extensive along larger (higher-order) stream sections and are reduced along smaller streams to accommodate agricultural land use. Developed riparian areas account for 0-4% and tend to exist along tributaries that are nearer to the lake.

Table 8.4. Riparian Land Use (30 m on Both Sides) by Strahler Order for all Subwatersheds Combined

Stream Order	Riparian Area Size (ha)	Natural (%)	Agriculture (%)	Developed (%)
1st order	2894	80	16	4
2nd order	1433	85	11	4
3rd order	613	96	2	1
4th order	309	98	1	1
5th order	73	100	0	0
All Combined	5321 ha	85 %	12 %	3 %

Table 8.5 lists the percentages of 30 m riparian areas by subwatershed. Natural riparian area coverage ranges from 69-98%, agricultural areas ranges from 0-22%, and developed lands ranges from 2-19%. Three of the seven subwatersheds within the planning area do not meet minimum ecological requirements. They include the Pigeon Lake Tribs., Pigeon River, and Reforestation Creek subwatersheds. Reforestation Creek would require the least amount of additional natural cover (1 ha) to achieve the 75% guideline, whereas the Pigeon Lake Tribs. Subwatershed would require the most (77 ha).

Water temperature plays an important role in the overall health of aquatic ecosystems, affecting rates of productivity, timing of reproduction and movement of aquatic organisms (Caissie, 2006). Fish and other aquatic organisms often have specific temperature preferences which can ultimately determine their distribution within watercourses. 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). Thermal habitat is often categorized into three broad types: warmwater, coolwater and coldwater. Warmwater designations imply that the watercourse is known to contain, or is likely to support, warmwater fishes (e.g., bluntnose minnow, fathead minnow, largemouth bass, etc.). Coolwater and coldwater designation implies that these watercourses are known to contain, or are likely capable of supporting, coldwater fishes (e.g., brook trout, mottled sculpin, etc.). Coldwater streams are particularly sensitive to land use impacts.

This is due to the relatively narrow habitat requirements of coldwater fishes (e.g., the need for stable groundwater discharge areas, clean cold water, high levels of dissolved oxygen, etc.).

Table 8.5. Riparian Land Use (30m on Both Sides) in Subwatersheds of the Pigeon Lake Watershed

Subwatershed	Riparian Area Size (ha)	Natural (%)	Agriculture (%)	Development (%)	Natural riparian needed to achieve 75% of length
Nogies Creek	1841	98%	0%	2%	-
Pigeon River	1715	74%	22%	4%	1% (17 ha)
Pigeon Lake Tribs.	1289	69%	11%	19%	6% (77 ha)
Fleetwood Creek	710	85%	10%	5%	-
Eels Creek	206	96%	1%	2%	-
Potash Creek	204	83%	14%	3%	-
Reforestation Creek	126	74%	22%	4%	1% (1 ha)
All Combined	6091 ha	83%	11%	7%	-

In summer of 2014 and 2015 the thermal regime of the watercourses was assessed at all third-order and fourth-order stream-road crossings to identify any potentially sensitive areas. In total, 63 sites were sampled by taking spot-measurements of water temperature following the module outlined in the Ontario Stream Assessment Protocol (Stanfield, 2010) with slight modifications to the time of collection as per Chu et al. (2009). The data from these surveys were used to assign a thermal regime status of coldwater, coolwater, or warmwater to each sample site, based on the relationships between air temperatures and water temperatures observed in streams across southern Ontario and the types of resident fishes (Stoneman and Jones, 1996). According to available data prior to this survey, sensitive coldwater habitat/fish communities are known to occur in Pigeon River, Fleetwood Creek, Potash Creek, and depending on sources Reforestation Creek (OMNR Coldwater Streams Strategy). As shown in Figure 8.11, almost 2/3rds of the sample sites have a coolwater or coldwater thermal regime which means these locations are likely capable of supporting coldwater aquatic communities. This sampling substantiates, to a certain degree, the existing classification of all tributaries. However, the warmwater thermal regime classifications of sites within the lower reaches of the main channel of Fleetwood Creek suggest that these areas may no longer be able to support coldwater aquatic communities. This is likely due to the presence of various on-line ponds along the main channel, the open water of which gradually warm downstream waters from coldwater to warmwater classifications.

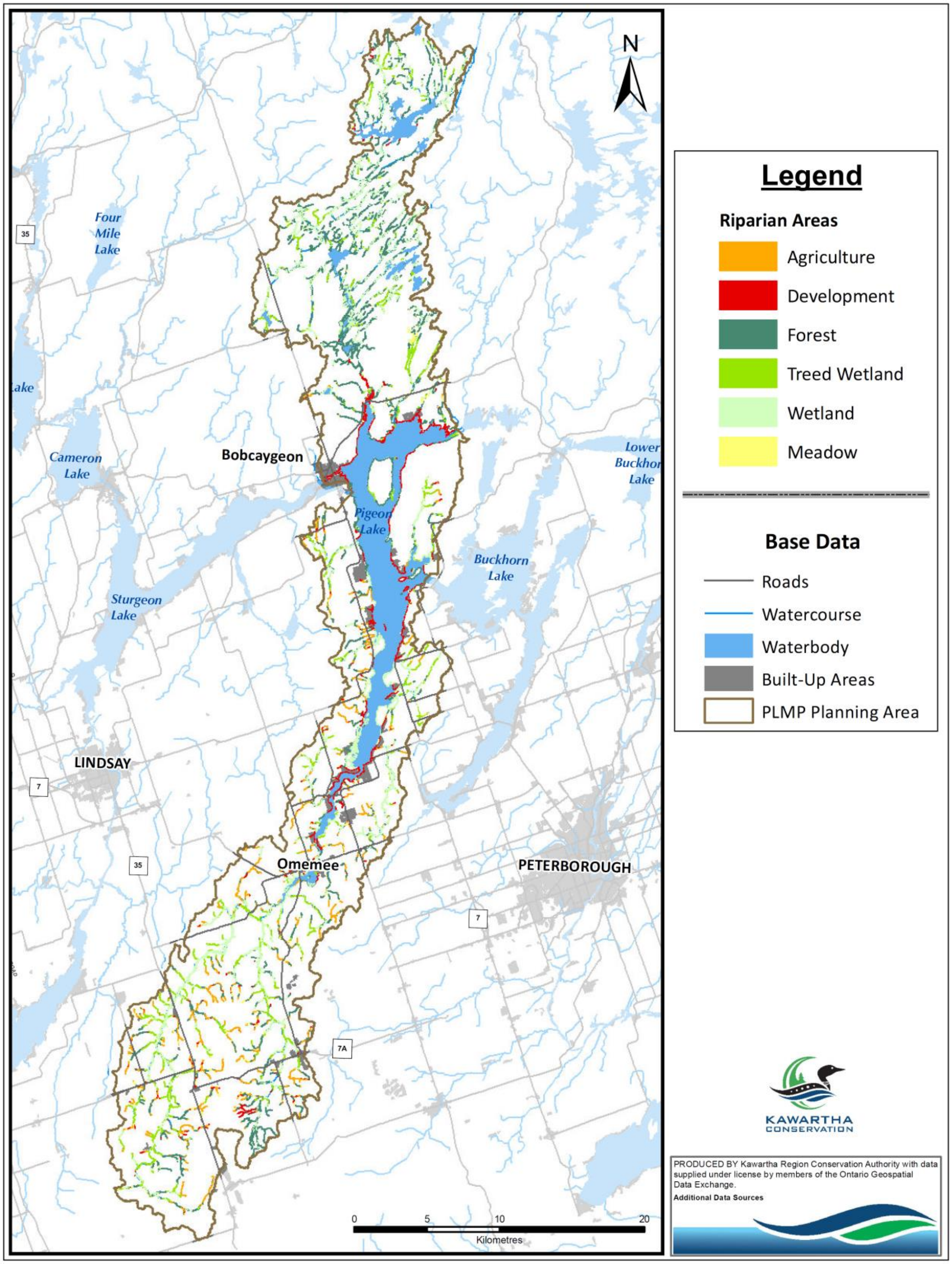

Figure 8.7. Land Use Along Stream Corridors and Lake Shoreline in the Pigeon Lake planning area

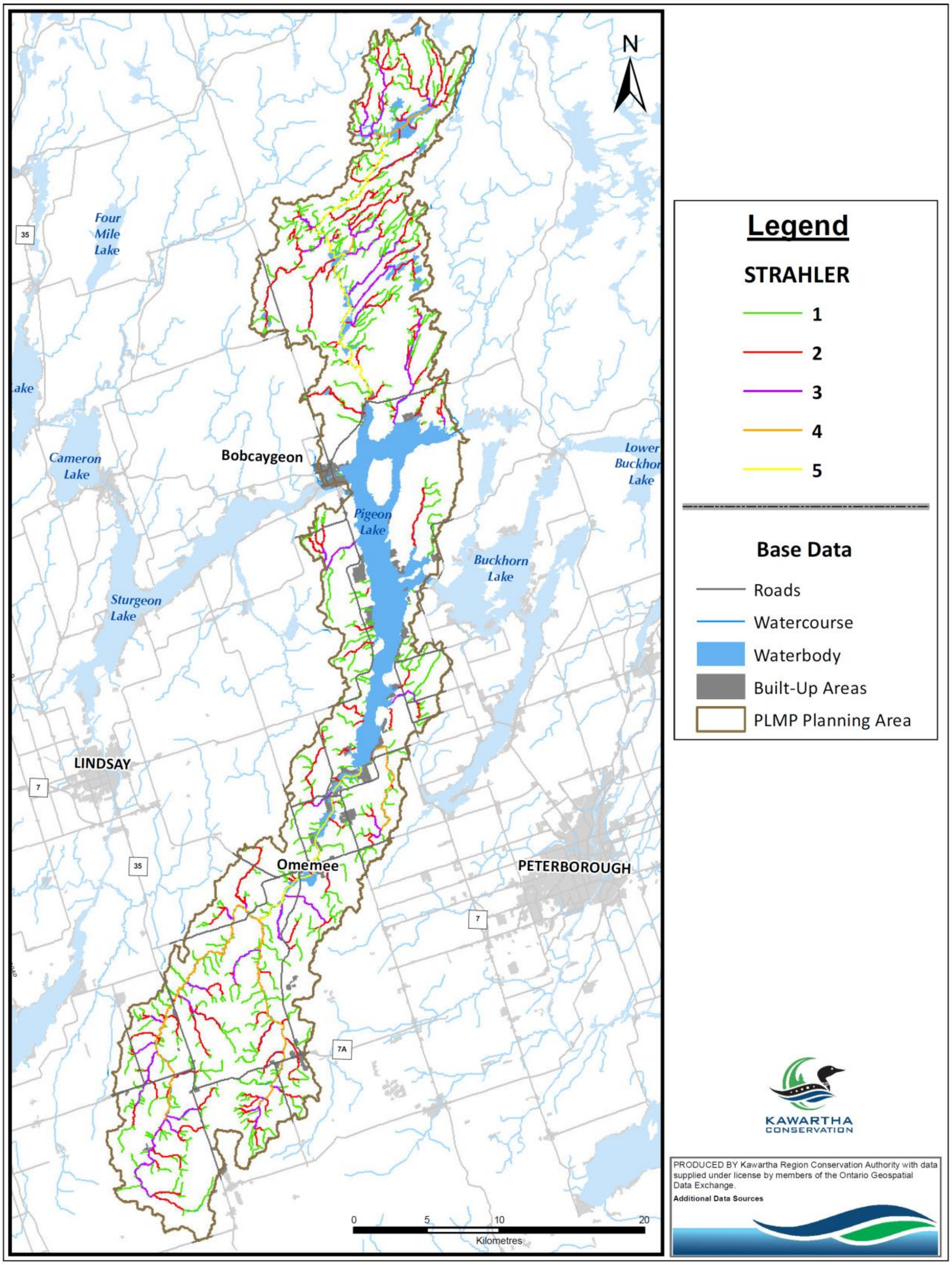

Figure 8.7. Watercourse Network by Strahler Order

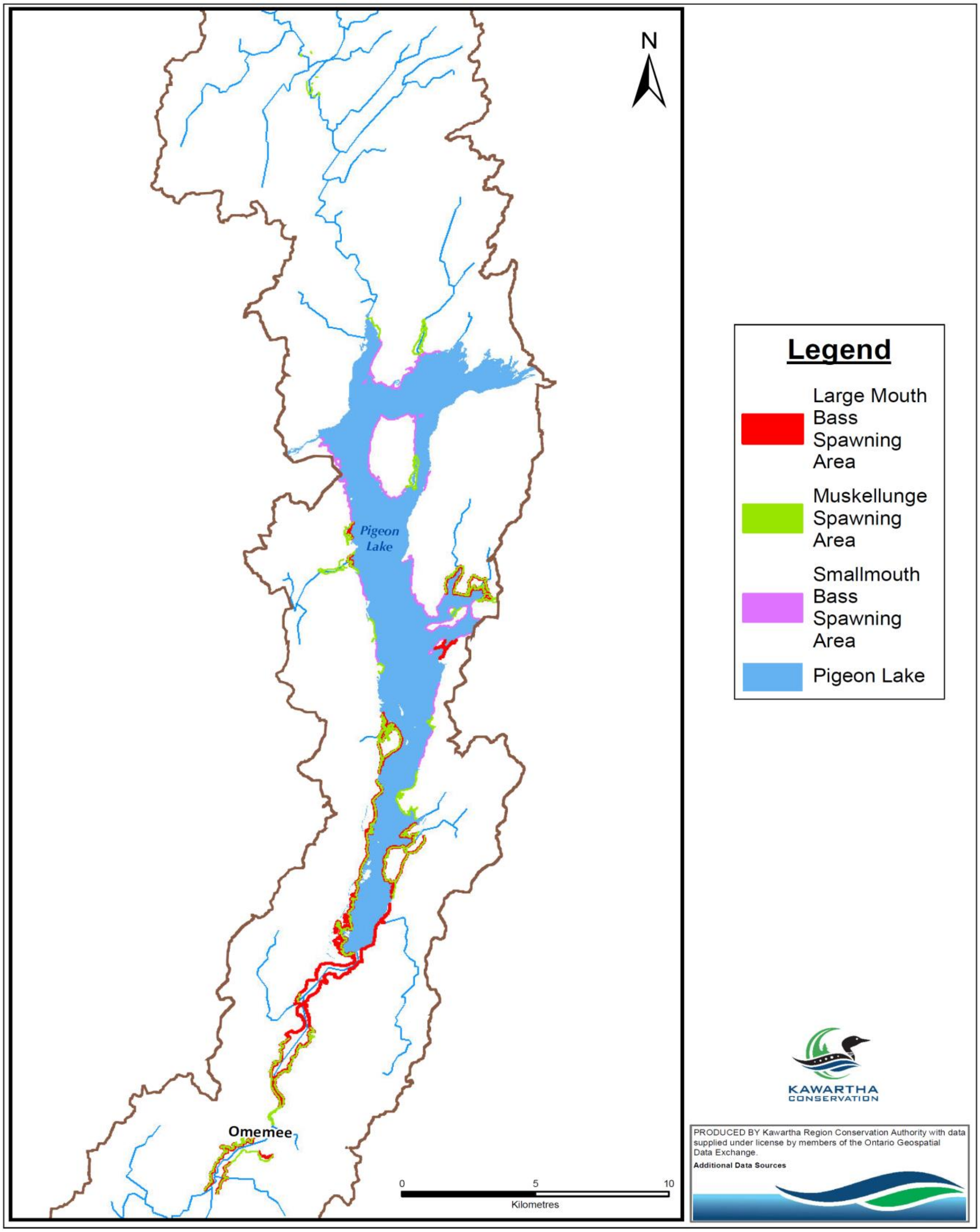

Figure 8.8. Muskellunge, Smallmouth Bass, Largemouth Bass Spawning Areas

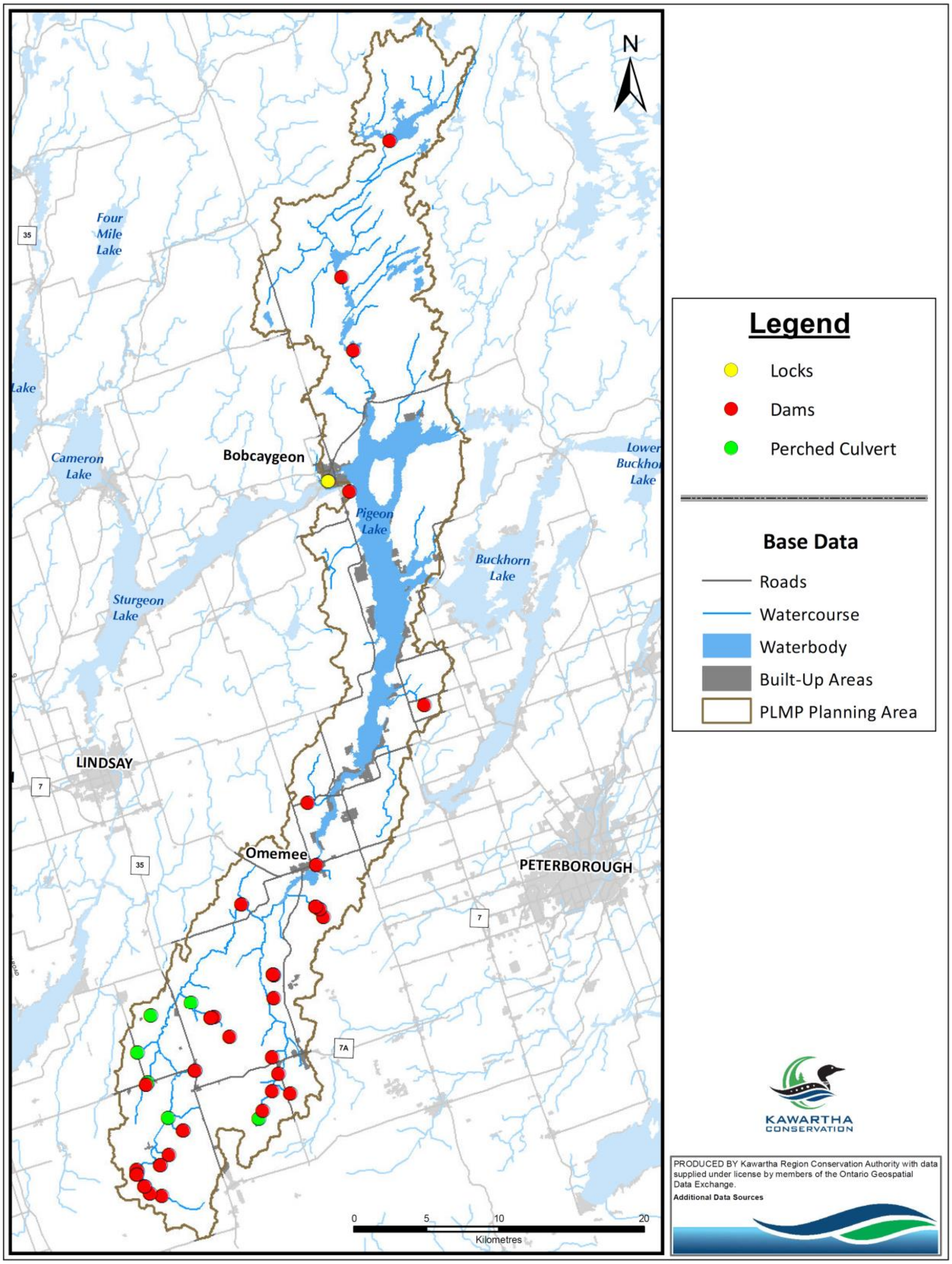

Figure 8.9: Locations of dams and other in-stream barriers within the core planning area.

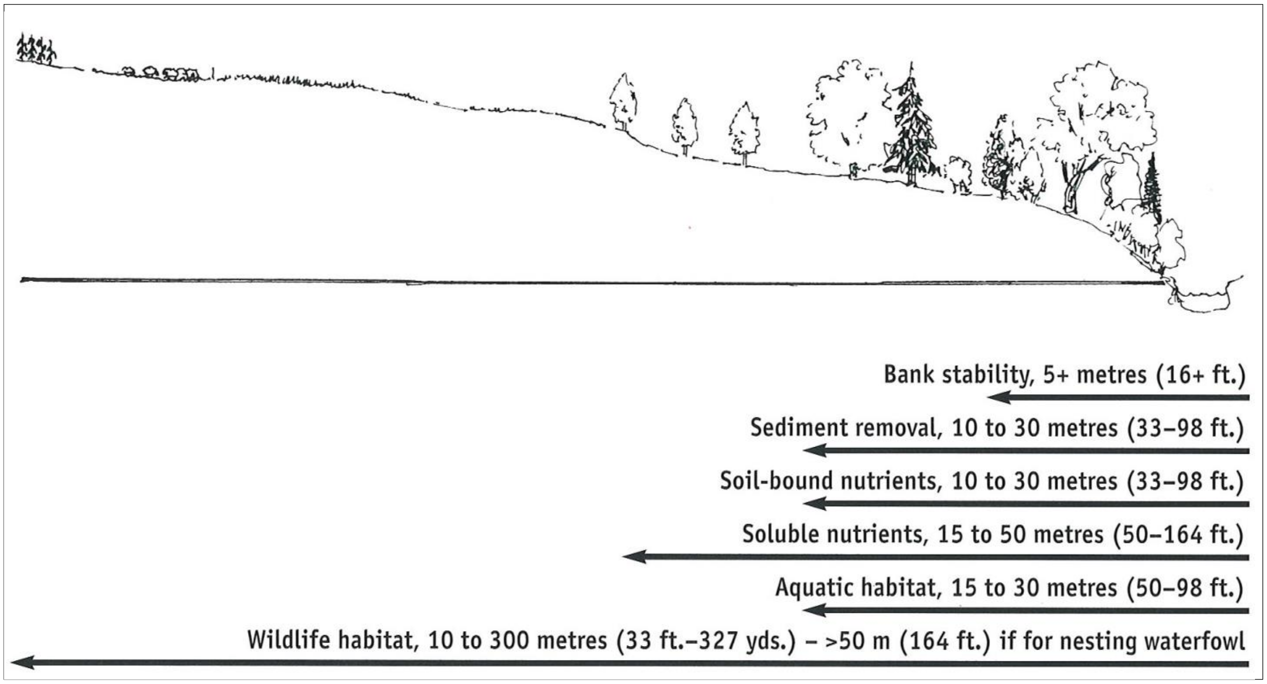

Figure 8.10. Summary of Important Functions of Natural Riparian Areas by Width

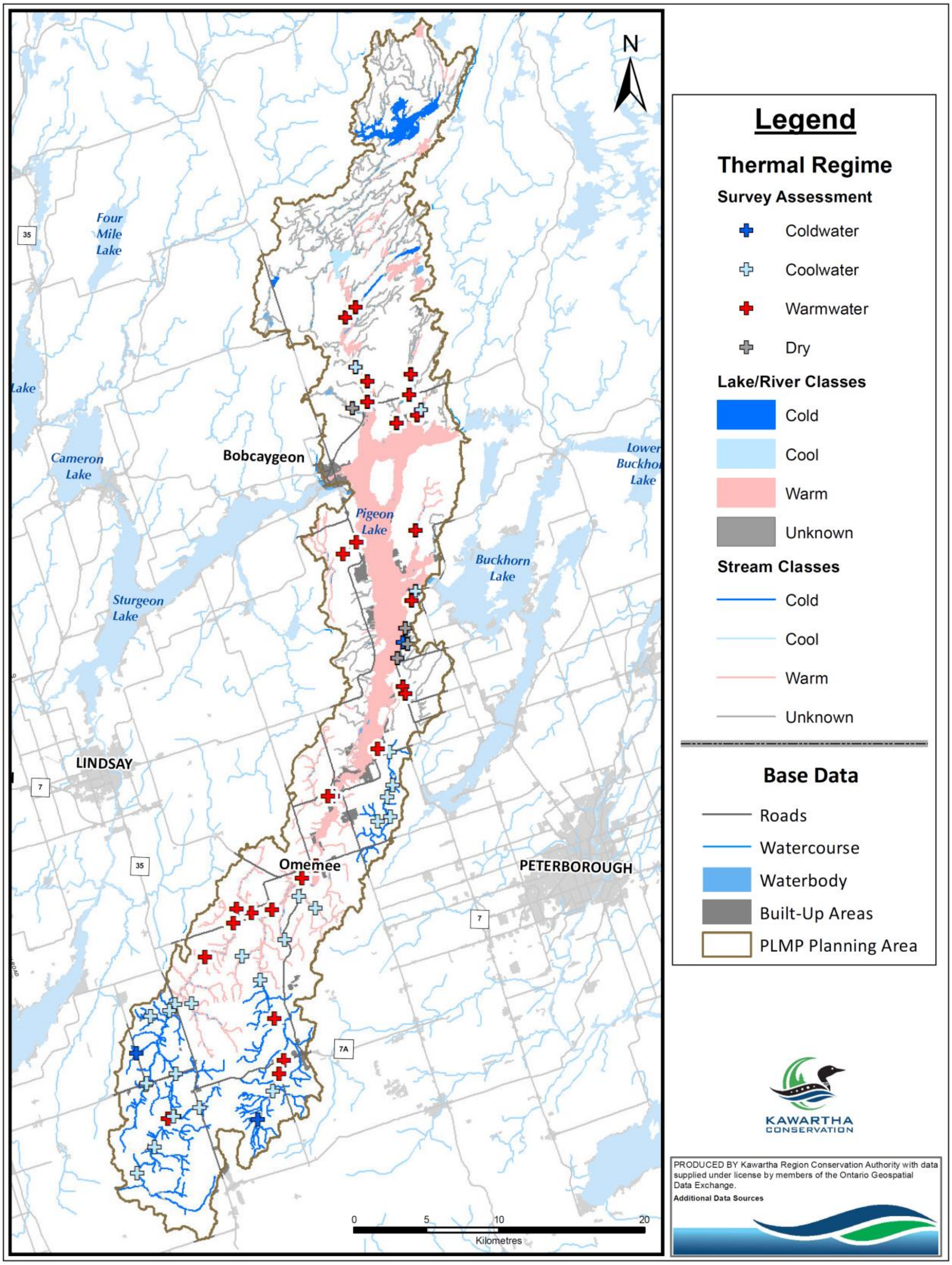

Figure 8.11. Thermal Regime Designations

8.4.2 Fish Communities

Within the tributaries of the PLMP planning area, approximately 34 unique fish species have been documented (Table 8.6). By subwatershed, 22 species have been found in Nogies Creek, 20 in the Pigeon River, 19 in Fleetwood Creek, 11 in Reforestation Creek, 9 in Potash Creek, and 3 in Bears Creek. There is no known sampling in the Eels Creek, or Pigeon Lake Tribs. subwatersheds so there are no formal fish records. Fish species records by subwatershed are found in Appendix 3. Data was summarized from historical OMNR Stream Surveys in 1973 and 1976, Kawartha Conservation PLMP sampling in 2015, and data exported from the OMNR Aquatic Resources Areas in 2006. Most of the documented fish species are considered common to the area, and the majority are considered warmwater fish except for three coldwater species: brook trout, mottled sculpin, and slimy sculpin. There are no fish species that are considered to be at risk, meaning classified as Special Concern, Threatened or Endangered.

Table 8.6. Documented Fish Species in Pigeon Lake Tributaries

Blackchin Shiner	Common Shiner	Northern Redbelly Dace
Blacknose Dace	Creek Chub	Pearl Dace
Blacknose Shiner	Fallfish	Pumpkinseed
Bluegill	Fathead Minnow	Rock Bass
Bluntnose Minnow	Golden Shiner	Slimy Sculpin
Brassy Minnow	Iowa Darter	Smallmouth Bass
Brook Stickleback	Largemouth Bass	Spottail Shiner
Brook Trout	Logperch	White Sucker
Brown Bullhead	Longnose Dace	Yellow Bullhead
Burbot	Mottled Sculpin	Yellow Perch
Central Mudminnow	Muskellunge	
Common Carp	Northern Pike	

Of all documented species within the PLMP planning area, many are not considered native to this area: northern pike, bluegill, rock bass, largemouth bass, and common carp. All these species are native to the Lake Ontario drainage basin, but due to the physical isolation of the Kawartha Lakes from Lake Ontario (i.e., pre Trent-Severn Waterway) these species traditionally had no access to Pigeon Lake. According to OMNR (2008), largemouth bass were deliberately introduced into the Kawartha Lakes in the mid-19th century; rock bass and then bluegill expanded their range from the construction of locks and canals and, more recently, northern pike have expanded their range from neighboring waterways via the canal system. Largemouth bass, rock bass, bluegill, and common carp are now considered "naturalized" in the Kawartha Lakes, because they have been here for long time periods and have integrated with the aquatic communities of the lakes. Northern pike, on the other hand, can be considered an invasive species due to its ability to outcompete and displace native muskellunge populations.

To determine if fish communities within tributaries have changed over time, historical OMNR mid-1970s sample sites were re-sampled in 2015 by Kawartha Conservation. Figure 8.12 shows the locations of sample sites.

Unfortunately, for the historical sites it is unknown what type of gear was used to sample the site, as well as how much effort (e.g., how large an area sampled over how much time) was put in to catch fish. It is known, however, at which road/stream intersection the sampling occurred. In 2015, sampling was conducted using two techniques. In “wadeable” flowing stream sections, a single-pass electrofishing method, as outlined in the Ontario Stream Assessment Protocol (Stanfield, 2010), was used to determine fish species composition. In wadeable sluggish stream sections, triple-pass seine netting was employed from the shore to catch fish. Table 8.7 provides a summary of this historical vs. present comparison. There were 8 historical sites that were re-sampled in 2015 within the subwatersheds of Pigeon River (5 sites), Fleetwood Creek (2 sites), and Reforestation Creek (1 site). All fish species documented at comparison sites are found in Appendix 4.

Table 8.7. Comparison of Fish Species Richness and Similarity Between Same Sites Sampled in 2015 and in 1970s

	Richness (# species)		Similarity (%)
	2015	1973/76	2015 vs. 1973/76
PR-02	6	3	29%
PR-04	5	4	13%
PR-05	2	5	0%
PR-06	5	3	33%
PR-10	5	2	17%
PR-11	11	8	36%
PR-12	2	2	33%
Ref-01	3	4	40%
ALL SITES	**19**	**19**	**58%**
Unique Species	largemouth bass white sucker brassy minnow slimy sculpin bluegill	brown bullhead longnose dace mottled sculpin pearl dace iowa darter	

When examining all fish species caught from both time periods, two measures were used: species richness (an index of taxa diversity), and % similarity (how many species were common to both sampling events). These measures provide insight into whether any major shifts in community composition have occurred. Since there were relatively few sites in each subwatershed, for comparison purposes results from each site and each subwatershed were pooled together. In terms of species richness, 19 unique species were recorded during each of the sampling periods. There was 58% similarly between the species of fishes found between sampling events. This suggests that fish communities, based on our sampled sites, remain relatively dissimilar. However, many of the unique fish species in both sampling events are relatively common in Kawartha Lake tributaries, particularly largemouth bass, white sucker, brassy minnow, and pearl dace, and were likely present but were just not captured within the subwatersheds. Furthermore, slimy sculpin, mottled sculpin, iowa darter, and longnose dace are bottom-dwelling fish species that can be difficult to capture particularly when in low abundance. Of all the unique species, bluegill is likely the only new addition to the fish community within the tributaries to become established since the mid-70s.

8.4.3 Benthic Macroinvertebrates

Benthic Macroinvertebrates (benthos) have been widely utilized in biological assessments to characterize water quality and aquatic ecosystem health. Sampling for benthos is advantageous because they are abundant in most streams, serve as primary food source for fish, respond to ecosystem stress and are relatively inexpensive to collect (Barbour et al., 1999).

In spring of 2014, Kawartha Conservation conducted a bioassessment using benthic macroinvertebrates to gain insight into the status of the current condition of the aquatic ecosystem within the subwatersheds of Pigeon Lake. Well-defined, wadeable steams within subwatersheds that directly drain into Pigeon Lake were targeted for assessment. Based on previous benthos surveys in neighbouring Sturgeon Lake basin, we know small 1st order streams are typically dry or ill-defined, so they were excluded from sampling. The remaining streams (i.e., 2nd to 4th order), which comprise 45% of total stream length, were targeted for sampling. Fifty sites were randomly chosen on the targeted streams using GRTS selection methodology outlined in USEPA (2011). One-third (16 sites) were randomly chosen and actually sampled. Most sites not sampled were due to it being difficult to connect with landowners to obtain permission. The majority of sampled sites are in the Pigeon River subwatershed. No samples were taken from Nogies Creek due to the remoteness of random sample locations.

The bioassessment is based on sampling 16 random sites, following the transect kick-and-sweep methodology outlined in the 'Streams' module of the Ontario Benthos Biomonitoring Network (OBBN) protocol (Jones et al., 2005). All benthos collected were preserved in alcohol and identified under a microscope to family-level taxonomic resolution wherever possible. Table 8.8 provides a summary of the major habitat characteristics at all bioassessment sites. All sites were sampled in May with water temperatures ranging from 8.8 to 22.3°C. Stream sizes sampled were small-to-large, having wetted widths ranging from 1.0 to 5.9 m and maximum depths ranging from 100 to 760 mm. Substrates encountered were fine to coarse substrates typically dominated by sand and gravel. Most watercourses are relatively slow-flowing, having water velocities ranging from 0 to 100 mm hydraulic head.

All raw benthos taxa data are found in Appendix 5. Approximately 52 unique taxa were found within the planning area. In terms of major OBBN groupings when all sites are combined, Chironomidae, Coleoptera, Ephemeroptera, Plecoptera, Simuliidae, Amphipoda, Tricoptera, Bivalvia, Gastropoda, Tipulidae, and Ceratopogonidae collectively comprise over 95% of all taxa (Figure 8.13). In terms of benthos families, the top five taxa within the planning area are Chironomidae (32%), Elmidae (12%), Simuliidae (7%), Siphlonuridae (7%), and Nemouridae (6%), which collectively comprise approximately 64% of all taxa. In terms of common benthos found at most sites, Chironomidae were found at 100% of sites; Elmidae and Tipulidae at 81%; Simuliidae, Pisidiidae, and Hydropsychidae at 75%; Siphlonuridae at 63%; Ceratopogonidae, Tabanidae, and Heptageniidae at 56%; and, Physidae, Perlodidae, and Lepidostomatidae at 50% of sites.

Table 8.8. Site and Habitat Characteristics at Bioassessment Sites

Site ID	Sub-watershed	Date	Water Temp (°C)	Substrate (dom+subdom)	Depth (mm)	Hydraulic Head (mm)	Width (m)
PL234-07	Fleetwood Creek	2014/05/29	17.2	Sand and Cobble	650-760	0-0	5.3-5.9
PL234-09	Pigeon River	2014/05/27	17.5	Gravel and Sand	120-200	20-30	1.0-1.2
PL234-10	Pigeon River	2014/05/14	12.9	Gravel and Sand	150-450	0-25	1.8-2.2
PL234-12	Potash Creek	2014/05/23	15.8	Silt and Sand	350-550	0-0	1.9-2.6
PL234-14	Pigeon River	2014/05/15	13.6	Sand and Silt	260-450	0-10	2.2-3.0
PL234-18	Pigeon River	2014/05/27	22.3	Gravel and Sand	130-700	0-30	1.3-5.5
PL234-22	Fleetwood Creek	2014/05/08	9.2	Sand and Gravel	135-350	15-100	3.9-5.2
PL234-25	Fleetwood Creek	2014/05/26	15.6	Sand and Gravel	260-305	0-10	2.0-2.6
PL234-30	Pigeon River	2014/05/27	17.9	Sand and Silt	100-300	0-5	1.1-1.1
PL234-34	Pigeon River	2014/05/26	16.3	Sand and Cobble	100-190	0-5	2.3-2.6
PL234-37	Pigeon River	2014/05/02	9.5	Silt and Sand	200-340	0-5	3.1-3.9
PL234-39	Fleetwood Creek	2014/05/08	11.8	Sand and Silt	195-380	0-0	1.3-2.0
PL234-42	Pigeon River	2014/05/02	8.8	Gravel and Cobble	120-430	5-45	2.4-3.0
PL234-45	Pigeon River	2014/05/15	16.8	Sand and Boulder	210-310	0-20	1.0-1.7
PL234-47	Pigeon Lake Tribs.	2014/05/12	14.6	Gravel and Cobble	235-395	0-30	1.3-3.1
PL234-48	Pigeon River	2014/05/12	17.8	Gravel and Cobble	135-300	0-20	3.2-4.0

To characterize aquatic ecosystem health within the subwatersheds, benthos data are summarized for each site using the Hilsenhoff Family Biotic Index (Hilsenhoff, 1988). In this approach, taxa identified down to the family-level are assigned a value between 0 (least tolerant) to 10 (most tolerant) based on their tolerances to nutrient enrichment according to values in Conservation Ontario (2011). An index value is calculated by summarizing the number of benthos in a given taxa, multiplied by their tolerance value, and divided by the number of total organisms in the sample. This approach is similar to the methodology used by conservation authorities for Watershed Reporting (Conservation Ontario, 2011). It should be noted that this biotic index performs most accurate when applied to streams with fast flowing water (i.e., riffles) and coarse substrates (i.e., gravel, cobble). Since many of the sites exhibited slow velocities and fine substrates, biotic index determinations should be interpreted with some caution as these systems may naturally (i.e., under minimal stress) contain tolerant benthos. Currently, no know scientifically-defensible biocriteria standards exist for all types of streams in the Kawartha Lakes.

As shown in Table 8.9, compared to the Hilsenhoff Family Biotic Index, sites were classified as Very Good (13%), Good (38%), Fair (31%), and Fairly Poor (19%). In terms of Watershed Reporting grade-values, sites were classified as grade: A (13%), B (38%), C (31%), D (19%), and F (0%). Approximately 82% of sites were determined to be in a state that was Fair (C-grade) or better, whereas 19% scored worse than Fair. The sites that rated fair or better had much higher representation of mayflies, stoneflies and caddisflies within the sample. Mayflies, stoneflies, and caddisflies are considered sensitive taxa, and abundances of benthos within these orders are known to decrease in response to increasing perturbation (Barbour et al., 1999). These taxa represent 25% of all taxa counts within the Pigeon Lake tributaries, and at least one family within these taxa were found at 100% of the sites.

Table 8.9. Family Biotic Index and Watershed Report Card Results

Family Biotic Index	Watershed Report Card Grade	**PLMP Sites (#)**	**PLMP Sites (%)**
0.00-3.75 (Excellent)	A	0	0%
3.76-4.25 (Very Good)	A	2	13%
4.26-5.00 (Good)	B	6	38%
5.01-5.75 (Fair)	C	5	31%
5.75-6.50 (Fairly Poor)	D	3	19%
6.51-7.25 (Poor)	F	0	0%
7.26-10.00 (Very Poor)	F	0	0%

When comparing benthos communities found in a similar 2012 bioassessment of tributaries of Sturgeon Lake, and 2013 bioassessment of tributaries of Balsam Lake and Cameron Lake, the tributaries of Pigeon Lake appear to be in better aquatic ecological condition than Sturgeon Lake, and similar to Balsam Lake and Cameron Lake (Table 8.10).

Table 8.10. Comparison of Bioassessment Results From Pigeon Lake Tributaries to Balsam Lake and Cameron Lake, and Sturgeon Lake Tributaries.

	Pigeon Lake Tributaries (2014)	Balsam/Cameron Lake Tributaries (2013)	Sturgeon Lake Tributaries (2012)
Number of Random Sites	16	16	18
Family Biotic Index	5.06 (Fair)	5.17 (Fair)	6.06 (Fairly Poor)
Watershed Report Card Grade	C	C	D
Proportion of sites that are Fair (C-Grade) or better	82%	56%	33%
Taxa Richness	19.8 (52 in total)	15.9 (52 in total)	17.0 (63 in total)
Sensitive Taxa (%EPT)	25.1	26.9	11.4

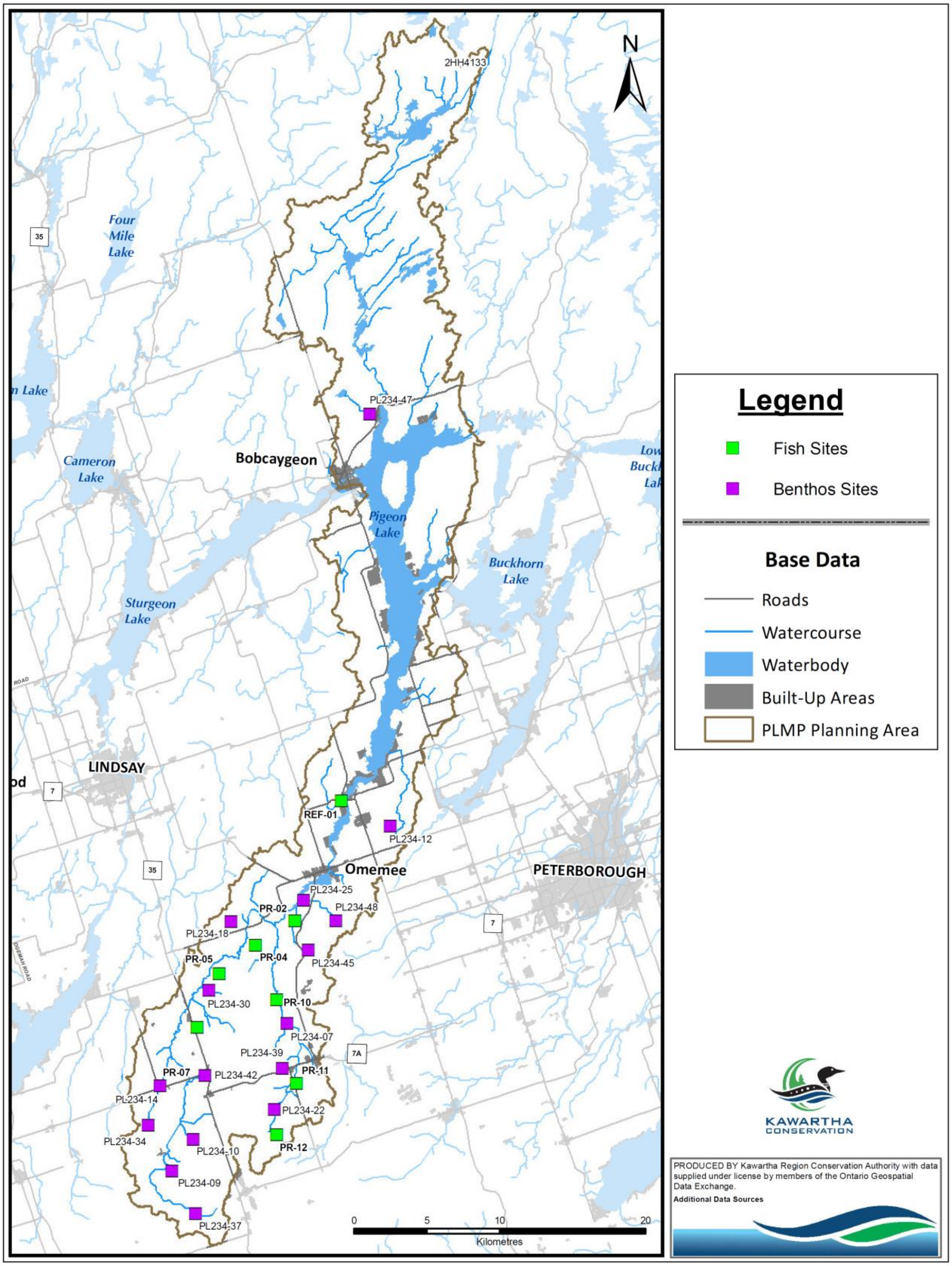

Figure 8.12. Aquatic Community Sample Sites

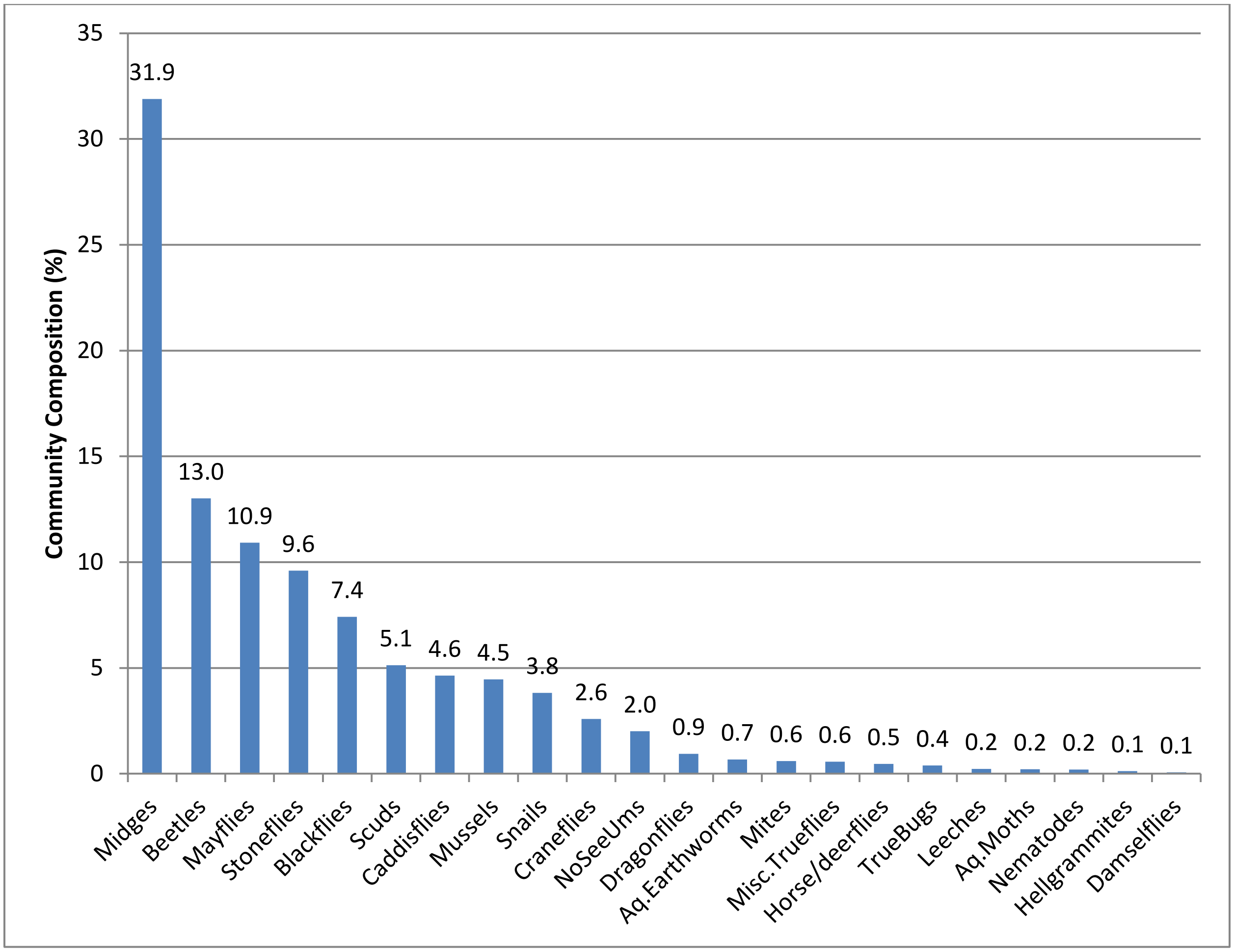

Figure 8.13. Major Benthos Taxa Found in the Tributaries

9.0 Terrestrial Ecology

This section reports on the terrestrial natural heritage system within the Pigeon Lake watershed through an analysis of existing natural cover, vegetation communities, wildlife habitat, biodiversity, and significant natural heritage features.

9.1 Summary of Observations, Key Issues, and Information Gaps

OBSERVATIONS

- ***Natural Heritage conditions are better in the Northern portion of the Pigeon Lake watershed where there is less urban development and less intensive and non-intensive agriculture.*** The area to the north of Pigeon Lake contains large tracts of forests and wetlands providing not only habitat for many species, but also helping to maintain good water quality through mitigating runoff, providing filtering and uptake of nutrients and solids, and creating connections between the lake and the natural areas to the north, particularly the unique features of the Land Between.

- ***4% (2720 Ha) of the Pigeon Lake watershed includes Areas of Natural and Scientific Interest (ANSI).*** ANSI's are identified for their significance and uniqueness on the landscape. ANSI's are often sources of biodiversity and hold species at risk, habitat that supports species diversity, and/or habitat that provides unique biological and species function. These areas have been identified for their values related to protection, scientific study or education.

- ***The Pigeon Lake watershed has an abundance of wetlands, the majority being swamp type wetlands.*** Wetlands serve a number of functions within a watershed, not the least of which is functioning to improve water quality. Swamp type wetlands often contain dense forests, which act to slow the movement of water through watersheds, and acting as groundwater recharge areas, particularly important to the headwaters of cold water streams such as Pigeon River. Marsh type wetlands help to reduce erosion around lakes and provide habitat for numerous fish, bird and mammal species. The southern portion of Pigeon Lake contains large areas of Provincially Significant Wetlands.

KEY ISSUES

- ***A number of natural heritage features exist in the Pigeon Lake watershed that may be considered locally significant; however they are not afforded any legislative protection.*** ANSI's are the only areas that are afforded protection due to their provincial significance, however there are a number of other natural heritage features that are important locally that have not yet been identified or set aside for protection.

- ***Forest cover is below guidelines in the Potash Creek watershed***. Potash Creek falls below the minimum recommended forest cover set by Environment Canada at 30%. Watersheds that fall below this threshold often demonstrate degraded water quality and fragmented terrestrial ecosystems.

- ***Interior forest is below guidelines for all but one watershed and deep interior forest is below guidelines for the entire Pigeon Lake study area.*** Interior forest is an important part of a healthy forested ecosystem, without interior forest a number of species disappear from ecosystems. Interior forest is also a measure of the health of forests overall and can indicate that state of forests within a watershed.

- ***The existing natural heritage features are fragmented and lacking in connections, particularly in the southern more developed areas in the watershed.*** The fragmentation of natural heritage features makes the movement of species more difficult and therefore ecosystems are less resilient due to limited diversity. A healthy natural heritage system with strong connections indicates a healthy and resilient watershed.

- ***27 Species at risk have been identified in the Pigeon Lake study area.*** Of the 27 species, 7 are dependent on the lake and/or its tributaries for survival, these species are: Black Tern, Blandings Turtle, Cyrano Darner, Least Bittern, Northern Map Turtle, Snapping Turtle and Western Chorus Frog

- ***With increasing farmland values and cash crop returns, there is a trend to clear more land for agriculture.*** This often means clearing brush from former agricultural lands of lower land classes that were abandoned, reducing natural buffers alongside watercourses, destruction of linkages between habitats, or even converting grown forest areas into agriculture. The pattern of increasing drainage in low lying areas and converting them to row crop farming is serving to reduce the amount of wetland found in Pigeon Lakes watersheds, especially swamp type wetlands

- ***Development Intensification adjacent to and in natural features.*** Development around the lake is increasing the amount of pressure on natural areas as portions of forests and wetlands continue to be removed to make room for houses, cottages and subdivisions. Lakeshore areas continue to be heavily developed and less desirable areas such as swamps are targeted.

- ***Climate change has the potential to continue to alter terrestrial ecosystem conditions****.* The impacts of climate change will emanate from well beyond the watershed, but they can affect physical and biotic attributes and ecological functions within the watershed. Forests, already stressed by invasive plant and insect species, will continue to degrade due to climate change pressures. Without healthy natural heritage systems, diversity will decline species will be less resilient to the changes that are upon them.

INFORMATION GAPS

- ***Limited understanding of the health and quality of terrestrial ecosystems.*** The terrestrial ecosystems have not been inventoried recently in any detailed manner to determine their health. No comprehensive and updated list of species, including species at risk exist for the Pigeon Lake watershed.

- ***Lack of information to determine the impacts of climate change on terrestrial ecosystems.*** Much like a complete inventory, no assessment of the resiliency of the terrestrial ecosystem to climate change has been completed.

9.2 Natural Cover

An area of natural cover refers 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 runoff;
- improving air quality through filtration and oxygen generation;
- improving the natural aesthetic of communities thus contributing to the wellbeing 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 runoff;
- 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 headwaters, wetlands, large forest tracts and riparian buffer areas, may affect any or all of the above functions.

The entire Pigeon Lake watershed contains 387 km^2 of natural cover, representing 57% of the total terrestrial area. This includes only areas classified as forest, wetland, and open water. There is a further 8% cover found in meadow and cultural forest. Figure 9.1 demonstrates the cover types existing within the eight watersheds that drain into Pigeon Lake. Meadows and cultural plantations are separated out from natural cover because they do not represent natural cover areas, but rather areas that are under recent human influence. Table 9.1 illustrates the percentage of each land use type within the watershed.

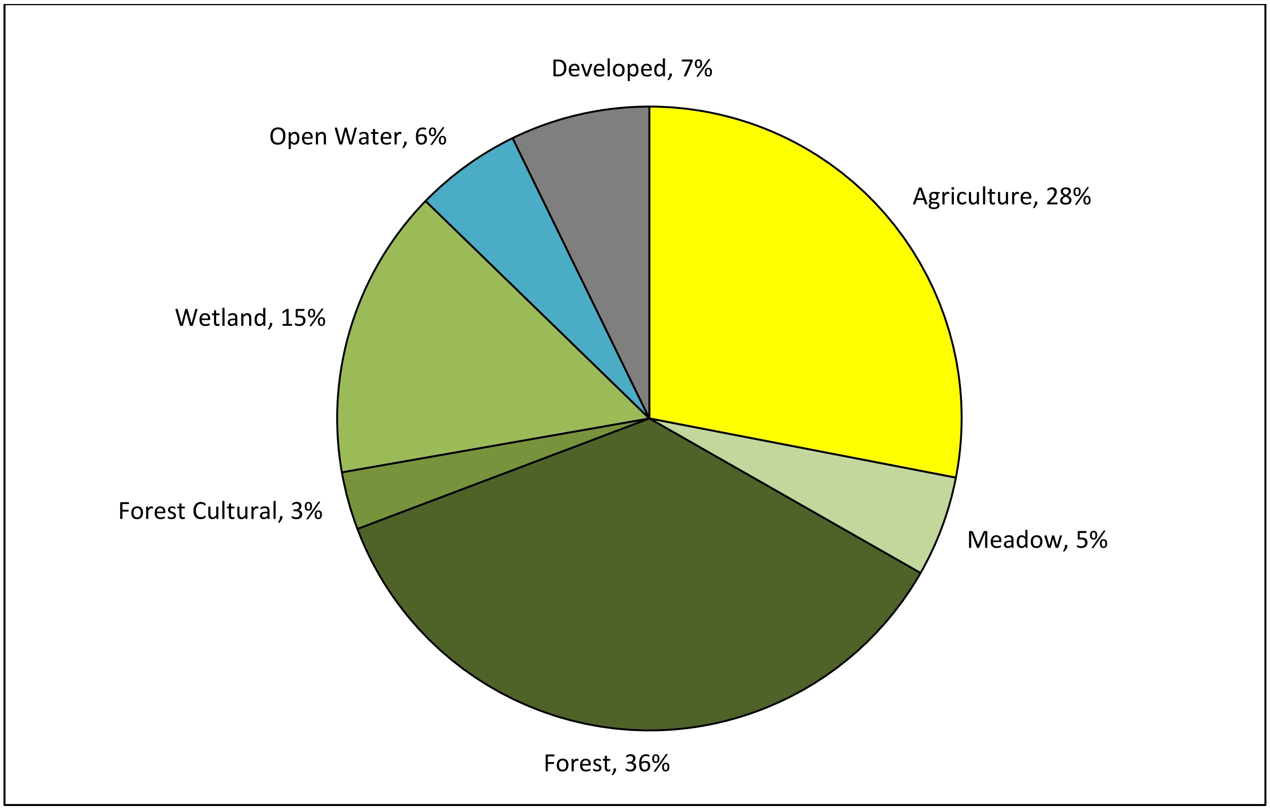

Figure 9.1. Pigeon Lake Watershed Land Cover Based on Ecological Land Classification

For management purposes, ecologists have created a hierarchy for the naming of ecosystems to reduce the complexity of managing the ecological resources on our planet. The area that the Pigeon Lake watershed falls in has been separated into management units known as eco-districts. Eco-districts, 71 of which are found in Ontario, are distinguished by their characteristic pattern of landscape features, with similar climate, soils and elevation. Eco-district 6E-8 represents the Pigeon Lake watershed. Ecodistrict 6E-8 is the drumlinized till plain that extends across the Kawartha Lakes and eastward and consists of deciduous, mixed and coniferous forests, with extensive areas of swamp and to a lesser extent, marsh. The Great Lake Conservation Blueprint would require that 30% of eco-district 6E-8 be set aside as natural cover in order meet conservation targets.

Table 9.1. Area and Percentage of Cover Types in the Pigeon Lake Watershed

Land Use	Watershed Area km2	Watershed Area(%)
Watershed (terrestrial portion)	679	100
Forest	364	39
Forested Wetland	60.8	8.9
Non-Forested Wetland	41.4	6
Meadow	35.4	5.2
Total Cover (including plantations, meadows and thickets)	402.1	59.2

Forests

Forests covered more than 90% of Southern Ontario prior to European settlement *(*Larson et al, 1999*)* and currently account for 46%of the terrestrial portion of the Pigeon Lake watershed (a combination of upland forests (39%) and forested/treed wetlands (9%)). 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 forests that are found in the Pigeon Lake watershed are most likely either cleared areas that were abandoned and regenerated over time, or the remnants of forests that were cleared during European settlement. Today most of the forests and woodlands found in this area are relatively young and quite different from older forests that survived the clearing of the landscape and are now quite rare in Ontario. Today's forests are found in areas that are unsuitable for agriculture or development, such as swamps and river valleys that are prone to flooding, and are therefore often quite fragmented or on the Canadian Shield, where granite bedrock is unsuitable for cropland. This is reflected in the Pigeon Lake watershed by the fact that the dominant natural area type is forest, specifically coniferous forest and that coniferous, mixed and deciduous swamps account for 9% of the Pigeon Lake landscape and almost one quarter of the forested areas in the watershed.

The entire Pigeon Lake watershed is currently 16% higher than the target of 30% forest cover for Areas of Concern watersheds within the great lakes basin (Environment Canada, 2004), and Pigeon Lake is 11% higher than the Conservation Ontario target (Conservation Ontario, 2011) of 35% forest cover for watersheds in Ontario. Only the Potash Creek watershed falls below the 30% guideline, 3 others fall below the Conservation Ontario guideline (Figure 9.2).

Comparing the amount of forest cover with target levels suggests that some restoration efforts to increase forest cover would be beneficial for overall watershed health. The areas of the watershed available for forest restoration include all those areas not already under natural cover. This includes lands currently being used for agriculture, inactive landfill, manicured open space, urban areas, aggregate extraction areas, and rural development (Chapter 3: Land Use). This determination was made based on an assessment of the amounts of each vegetation community type and land use type existing in the watershed.

Areas that are inappropriate for forest restoration include roads, active landfill sites and active aggregate extraction areas. If forest restoration was completed in urban areas and rural development areas it would be possible only in small patches and would not increase percent forest cover enough to meet target levels. Additionally, restoration efforts will have the highest benefit if they are focused on areas where habitat connectivity can be simultaneously improved.

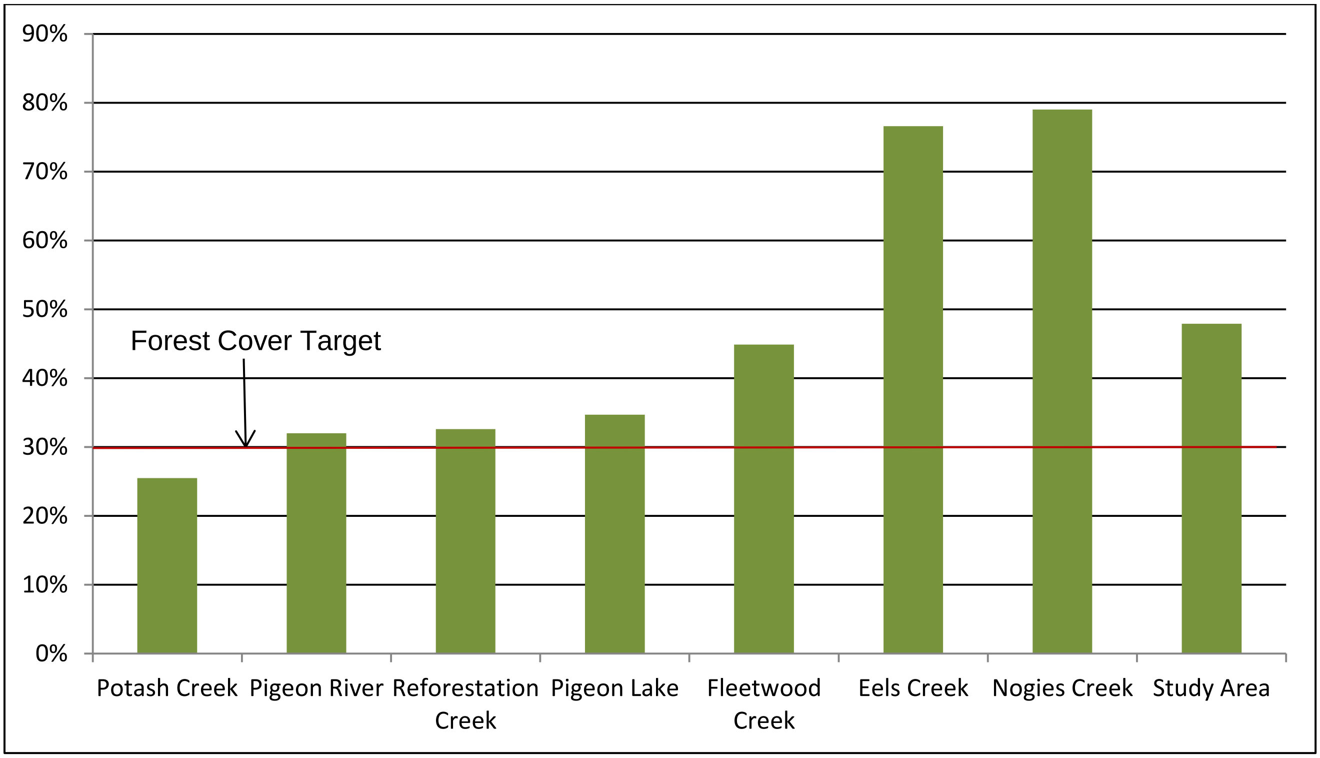

Figure 9.2. Forest Cover in the Pigeon Lake Watershed

9.3 Ecological Land Classification

Ecological Land Classification (ELC) is a method to further classify natural cover types into vegetation community types within the Pigeon Lake watershed. Vegetation communities for the watersheds were classified and mapped in 2011-2013 based on the ELC System for Southern Ontario (Lee et al., 1998). All areas of the watershed were classified through interpretation of 2008 aerial photography. In total, 14 unique types of cultural areas and 18 unique types of natural areas, based on the community series level of detail, were identified for the Pigeon Lake watershed. Cultural areas refer to communities that have resulted from, or are maintained by human-based influences. Cultural areas are often disturbed and, where plant species are present, a high proportion are of non-native origin and often invasive. Natural areas refer to natural cover that has not been subject to recent severe human-based disturbance, and therefore offer higher quality habitat and are a valuable watershed resource. Vegetation community types are described in Attachment 7, and mapped in Figure 9.3.

The ELC assessment shows that the Pigeon Lake watershed contains 43% cultural community types and 57% natural community types. Coniferous forest in the Pigeon Lake watershed, at 14.2%, encompasses the greatest area of the natural cover community types, with mixed forest and deciduous forest being the next two most dominant community types. Nine wetland types have been identified within both the Pigeon Lake and account for 15% of the total study area. The watersheds contain mostly coniferous swamp, mixed swamp and thicket swamp and the rest is made up of equal amounts of deciduous swamp, meadow marsh and shallow marsh, only minimal areas of aquatic wetland communities are found within the watershed outside of the lake area, and very little bog and fen communities. The areas classified as marsh types do not include the areas in/on Pigeon Lake, as the ELC classification was only applied to terrestrial communities.

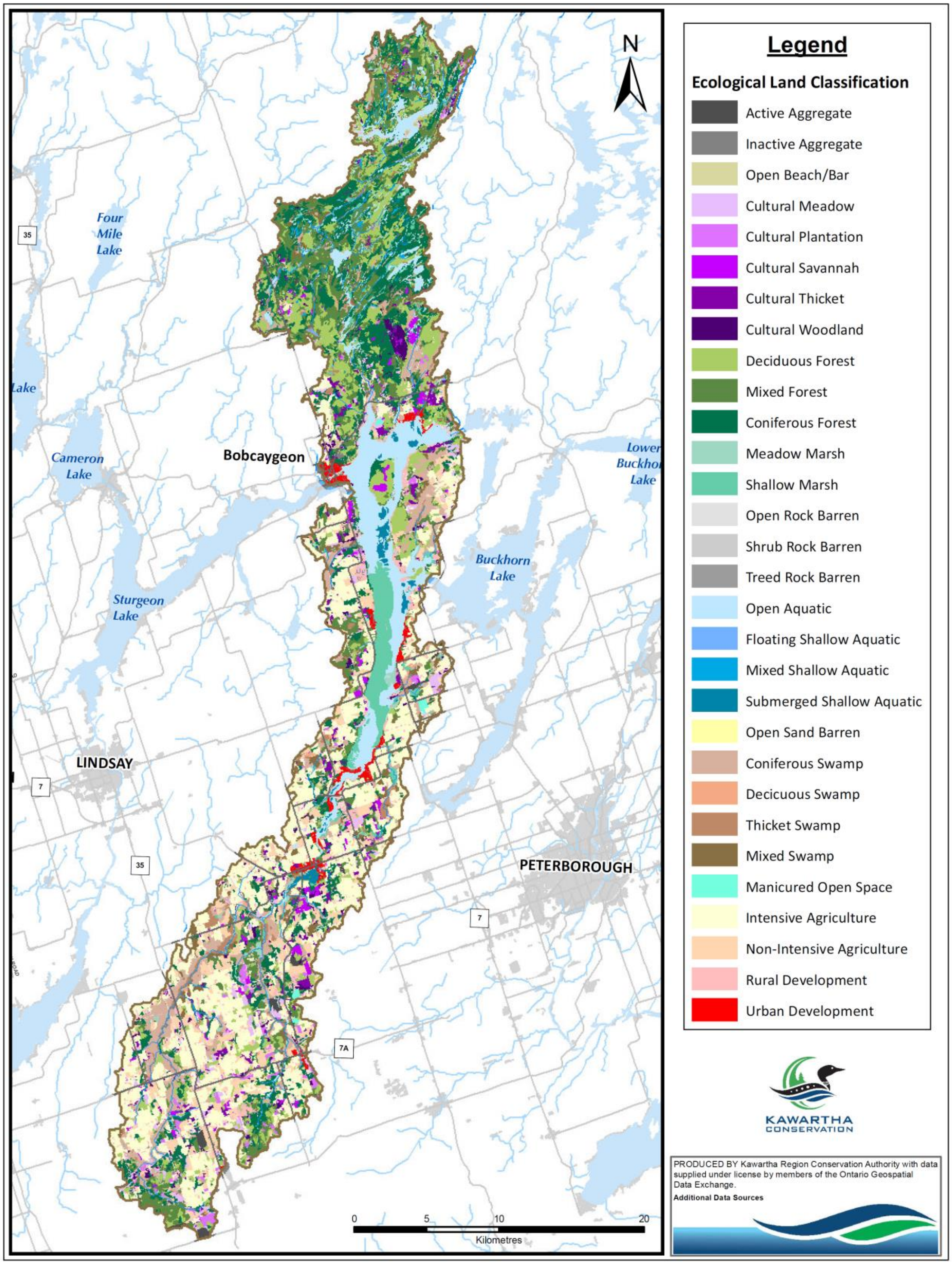

Figure 9.3. Ecological Land Classification of the Pigeon Lake Watershed

9.4 Terrestrial Biodiversity

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

The Great Lakes Blueprint for Biodiversity has identified 29 species at risk as conservation targets within ecodistricts 6E-8. (Phair et al., 2005)

It is important to consider the species identified at an ecodistrict level as well as a watershed level since terrestrial species are not bounded by watersheds, and therefore they may be dependent on specific features found either inside or outside of the Pigeon Lake watershed. Furthermore, when developing a terrestrial natural heritage system, it makes sense to follow an established blueprint for biodiversity rather than creating one at the Pigeon Lake watershed level.

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 woodlands greater than 100 meters from any edge – a field, road or hydro corridor. To put this into perspective, a square 4 hectare (10 acre) woodlot measures 200 meters by 200 meters, 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 9.2 lists the general response of species to varying sizes of forest patches.

Table 9.2. Anticipated Response by Forest Birds to the Size of the 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.

* Environment Canada (2004)

Like many natural heritage features, guidelines for the minimum amount of forest interior have been developed. Environment Canada recommends that the proportion of the watershed that is interior forest cover, 100 meters or further from the forest edge, should be greater than 10%. The proportion of the watershed that is forest cover 200 meters or further from the forest edge should be greater than 5%. Pigeon Lake watershed has 5.3 % interior (>100m) and 0.8 % deep interior (>200m). Therefore the Pigeon Lake watershed is below the targets for both interior and deep interior forest cover. Figure 9.4 shows the distribution of interior forest areas within the watershed.

9.5 Species and Habitats at Risk

Endangered, rare and threatened species and their habitat

Significant portions of endangered, rare and threatened species and their habitat exist within several areas of the watershed. A full list of species, occurrences and their habitats is available on the OMNRF Natural Heritage Information Centre web site.

SPECIES	SRANK	COSEWIC	SARO
American Ginseng	S2	END	END
Barn Swallow	S4B	THR	THR
Black Tern	S3B	NAR	SC
Blandings Turtle	S3	THR	THR
Bobolink	S4B	THR	THR
Braun's Holly Fern	S3		
Butternut	S3?	END	END
Chimney Swift	S4B, S4N	THR	THR
Common Five Lined Skink	S3	SC	SC
Cyrano Darner	S3		
Eastern Hognose Snake	S3	THR	THR
Eastern Meadowlark	S4B	THR	THR
Gold Moss	SNA		
Henslow's Sparrow	SHB	END	END
Least Bittern	S4B	THR	THR
Long-Stalked Panicgrass	S2		
Milksnake	S3	SC	SC
Mottled Dusky Wind	S2	END	
Northern Map Turtle	S3	SC	SC
Northern Myotis	S3	?	END
Red Headed Woodpecker	S4B	THR	SC
Snapping Turtle	S3	SC	SC
Stiff Gentian	S2		
Tapered Vertigo	S2S3		
Tri Coloured Bat	S3?		
Western Chorus Frog	S3	THR	NAR
Whip-Poor-Will	S4B	THR	THR

THR – Threatened, END – Endangered, NAR – Not at Risk, SC – Special Concern

SX – Presumed Extirpated, SH – Possibly Extirpated, S1 – Critically Imperilled, S2 – Imperiled, S3 – Vulnerable, S4 – Apparently Secure, S5 – Secure (B – Breeding, N – Nonbreeding, M – Migrant, ? – Inexact/Uncertain)

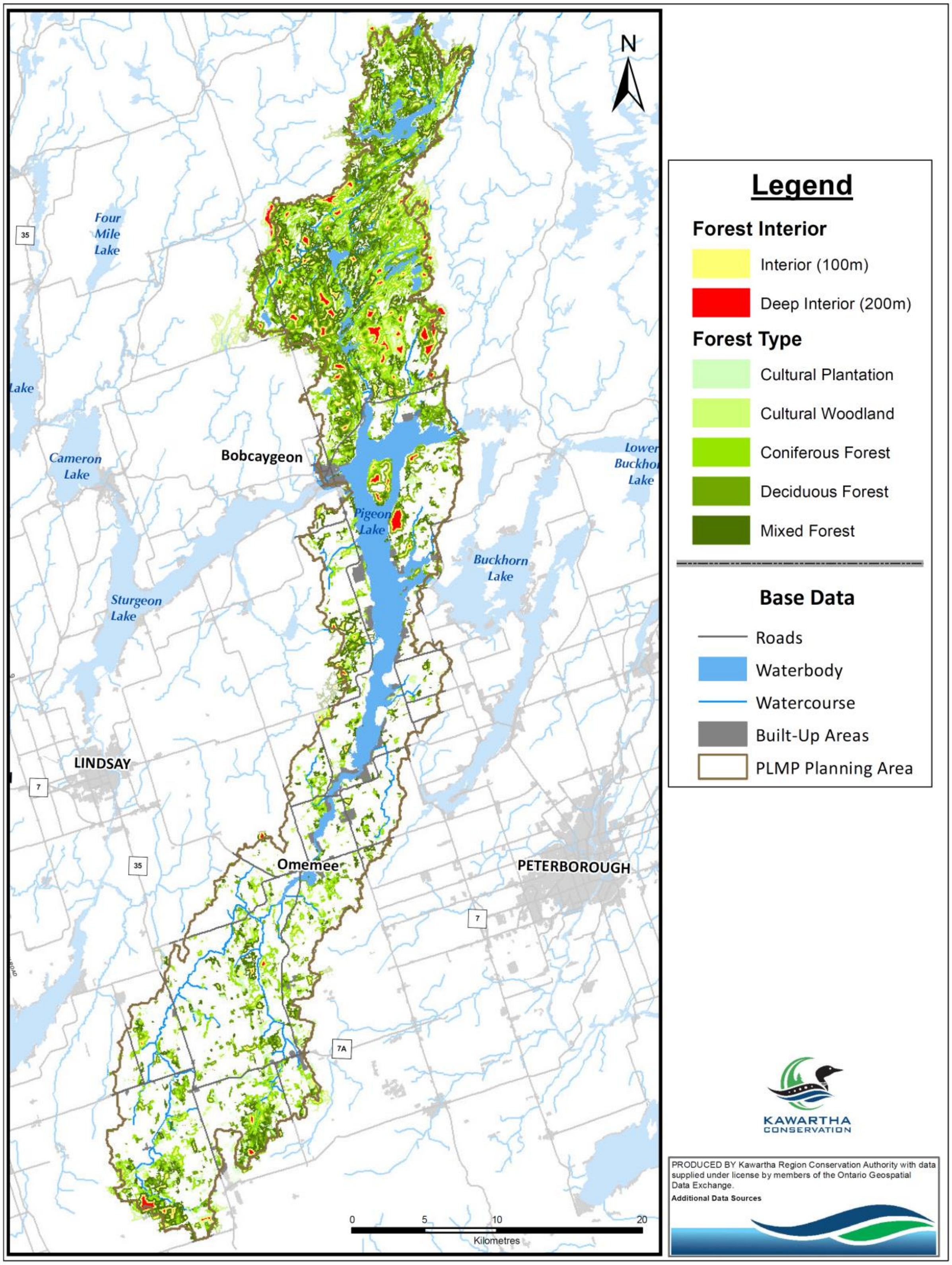

Figure 9.4. Areas of Interior Forest in the Pigeon Lake Watershed

9.6 Significant Natural Heritage Features

Identifying significant natural heritage features provides an understanding of the unique conservation values associated with the watershed. This understanding allows natural heritage management efforts within the watershed 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.

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 are designated based on ecological significance, and Earth Science ANSIs are designated based on geological significance. There are 8 ANSI sites within the Pigeon Lake watershed. They encompass 27.2 km^2 or 4% of the Pigeon Lake watershed terrestrial area (Figure 9.5). Table 9.3 describes each candidate ANSI site.

There are a number of locally significant areas of natural and scientific interest located in the Pigeon Lake watershed that have not been classified or identified by the province or Kawartha Conservation as regionally or provincially significant. These locally significant areas are an opportunity for further study, characterization, and potentially, inclusion into a natural heritage system.

Table 9.3. ANSI Sites in the Pigeon Lake Watershed

Site Name	Type	Area (ha)
Omemee Esker South	ANSI – Earth Science	365.51
Big Island (Boyd Island)	ANSI – Life Science	653.61
Pigeon Lake Marsh	ANSI – Life Science	467.61
Emily River Swamp	ANSI – Life Science	156.04
Oak Orchard and Buckhorn Lake Islands	ANSI – Life Science	16.83
Fleetwood Kames	Candidate ANSI – Earth Science	505.83
Silver Lake Road Cut	Candidate ANSI – Earth Science	0.0002
Fleetwood Creek Headwaters	Candidate ANSI – Life Science	555.4

Significant Wildlife Habitat

The identification of significant wildlife habitat (SWH) areas for the watershed was guided by the Significant Wildlife Habitat Technical Guide (OMNR, 2000), and mapping provided by the MNR.

SWH is defined 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.

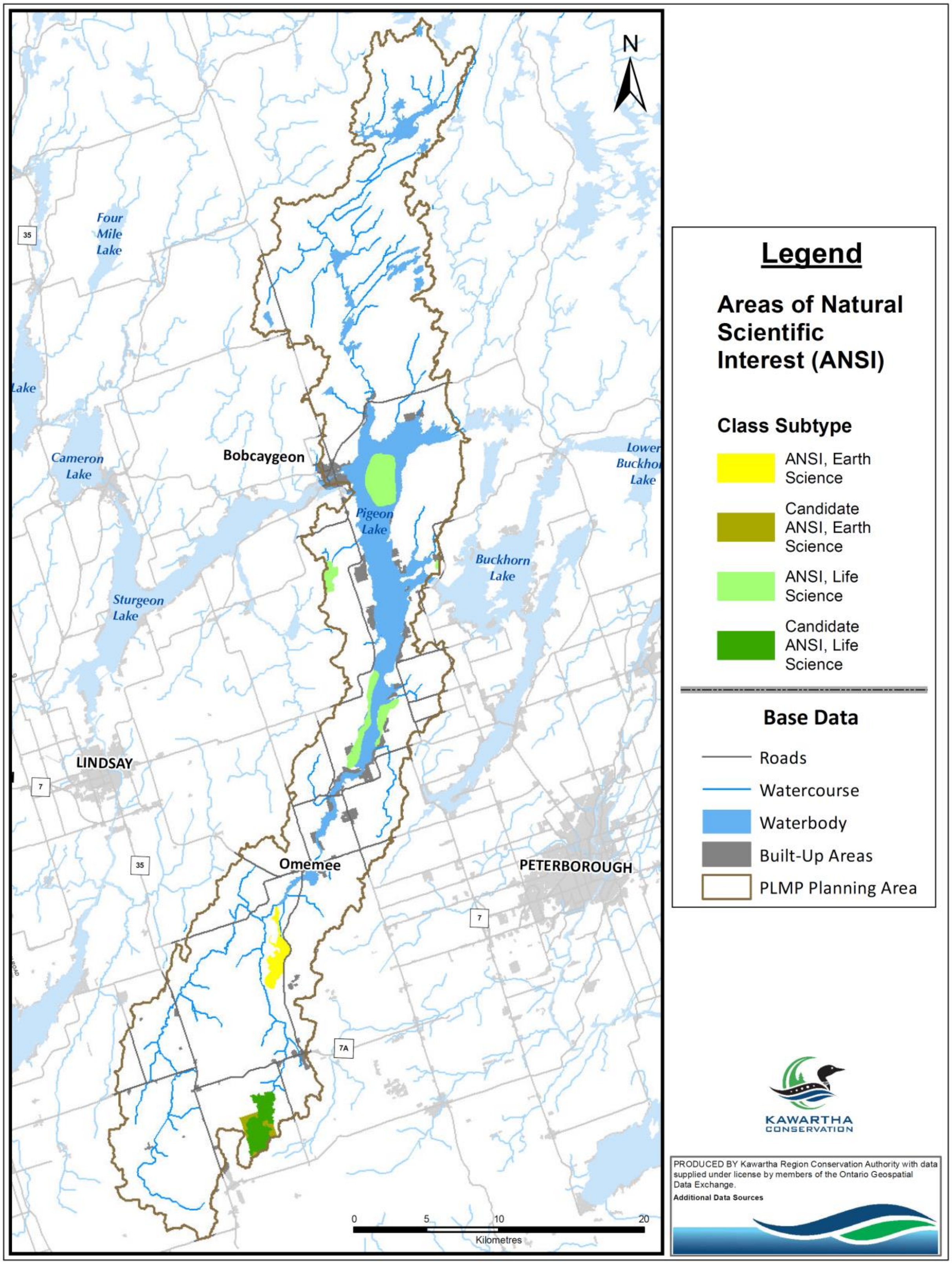

Figure 9.5. Areas of Natural Scientific Interest in the Pigeon Lake Watershed

Seasonal Concentration Areas

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

Animal Movement Corridors

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

The areas of the Pigeon Lake watershed that are natural heritage features such as wetlands and forests, are composed of both Core (large, unbroken areas that support a greater number of species and diversity) and linkages in the form of corridors. These areas of natural cover are clustered primarily along the shoreline of Pigeon Lake and within the natural areas along the surrounding tributaries. As the natural areas within the Pigeon Lake watershed tend to be quite fragmented, improving corridors and linkages should be a planning priority.

Significant Woodlands

Woodlands are considered significant because of the features and functions that they provide. Significant woodlands may include areas that have supported a treed community for more than 100 years, contain significant species, contain or support other significant natural heritage features (such as significant wildlife habitat), provide supporting habitat for another KNHF, or act as an ecological linkage between KNHFs. Significant woodlands within the watershed are illustrated in Figure 9.7.

Wetlands

Wetlands are key natural heritage and hydro logically sensitive features that occur on the landscape as single contiguous entities, or as complexes made up of a grouping of several small wetlands. All wetlands have high ecological value, and are significant to the management of the watershed; however, the classification of provincially significant wetlands assists with prioritizing wetlands for conservation and protection under the Ontario Provincial Policy Statement. Figure 9.6 illustrates the location of wetlands within the watershed. Figure 9.3 also illustrates wetland classification by indicating the vegetation community series.

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

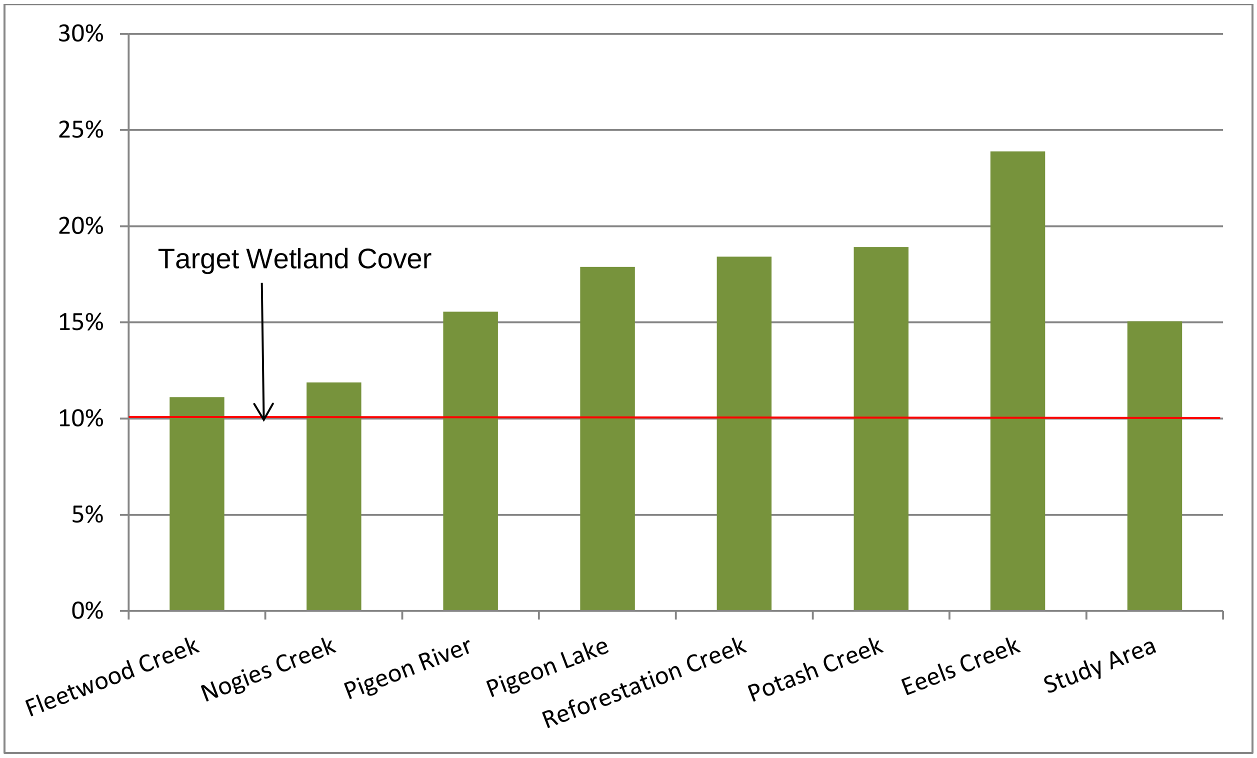

Figure 9.6. Wetland Cover in the Pigeon Lake Watershed

The Pigeon Lake watershed contains approximately 102 km^2 of wetland representing 15% of the terrestrial area; this exceeds the 10% minimum recommended percentage of wetland cover. Of those wetlands, approximately 54km^2 (8% of the study area) have been designated as provincially significant. All evaluated wetlands including provincially significant wetlands (PSWs) are illustrated in Figure 9.7.

Wetlands have also been classified through air photo interpretation to a community series level using the ELC System for southern Ontario, first approximation (Lee et al., 1998). The wetland types identified are further described in Appendix 7.

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 water filters, having the capacity to remove harmful impurities, bacteria and excess nutrients. In fact wetlands are such effective filters that constructed wetlands have been used to treat urban storm water runoff in Europe (and now in Ontario) for several decades. A study conducted on 57 wetlands from around the world concluded that 80% of wetlands studied reduced nitrogen loadings and 84% of wetlands studied reduced phosphorus loadings with the water flowing through them (Fisher and Acreman, 2004).
- Wetland plants are effective for stabilizing shoreline areas, trapping sediments and lessening the effects of erosion.

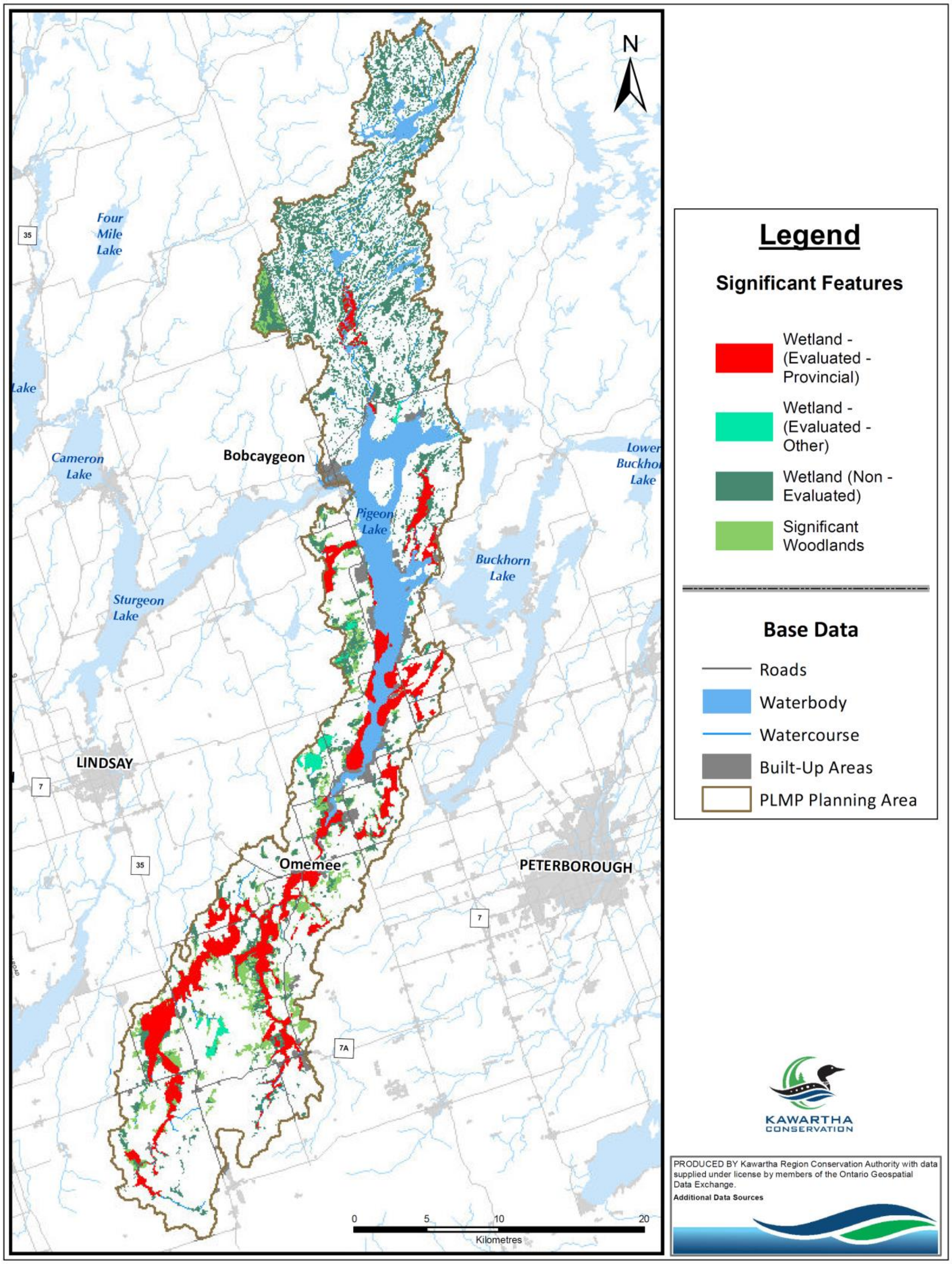

Figure 9.7. Significant Natural Features in the Pigeon Lake Watershed

- Wetlands store water, reduce flood events, and help to replenish groundwater. After storms or spring snow melt, water is gradually released into streams and rivers, and can provide a critical function by maintaining stream flow during periods of drought.

Ecological Goods and Services

Natural areas such as wetlands and forests are a critical part of any terrestrial ecosystem. However, the value of natural areas goes far beyond the role they play in the local ecosystems, and recently it has become more common to identify the benefits that are produced by the ecological functions, and translate those benefits into the monetary value of the ecological goods and services that they produce. Examples of ecological goods and services are clean air, fresh water, maintaining biodiversity, renewal of soil and vegetation, carbon storage, pollination and natural biological controls.

The type of natural area may influence its ecological goods and services value, but its location on the landscape is also a major factor. For example, wetlands found in non-urban, non-coastal areas are valued at $15,170/ha, however an urban wetland is valued at $161,420/ha (Troy and Bagstad, 2009).The values placed on various land cover types was estimated by looking at the benefits that people obtain directly or indirectly from ecological systems. Some examples are food production, climate stabilization and flood control, aesthetic views, and recreational opportunities to name a few. A joint study by Ducks Unlimited and the University of Guelph determined that the riparian wetlands in the Black River subwatershed (Lake Simcoe CA) provide phosphorous removal that equates to $292,661 in water treatment services (Pattison et al., 2011).

9.7 Kawarthas, Naturally Connected Natural Heritage System

The Kawarthas, Naturally Connected project is a collaborative engagement process in which community members, practitioners, and other stakeholders in the Kawartha Lakes region developed a natural heritage system (NHS) using the best available data and tools (Figure 9.8).

Kawarthas, Naturally Connected is a multi-partner initiative established in 2011 by community members, practitioners, and other stakeholders in the City of Kawartha Lakes, Peterborough County, and the City of Peterborough, to ensure the protection of the cultural, social, ecological and economic attributes of the area.

Natural Heritage Systems (NHS) are networks made of natural features and areas such as wetlands, forests, river corridors, lakes and meadows. They can also include areas that have the potential to be restored. These natural areas provide “ecosystem services” that support life and the health of people, plants and wildlife. Some of the services provided by our natural systems include clean air and clean water, pollination and food production, habitat for fish and wildlife species, resiliency to environmental stressors (climate change, invasive species, flooding, soil erosion), production of medicines, biofuels and other products and recreational opportunities.

Kawarthas, Naturally Connected provides support for Lake Management Plan implementation through identification and prioritization of areas for stewardship activities. The Natural Heritage System has included natural features that are the highest priority for protection and restoration in order to achieve or sustain a healthy ecosystem that supports sustainable use of the land. Currently the Kawarthas, Naturally Connected system consists of a map of the system. There is work being done towards establishing the role that the system will have in municipal planning, additionally the system can be applied to stewardship prioritization and land acquisition for long term protection of natural features.

For more information or how to become involved in developing the Naturally Connected system you can visit http://www.kawarthasnaturally.ca/

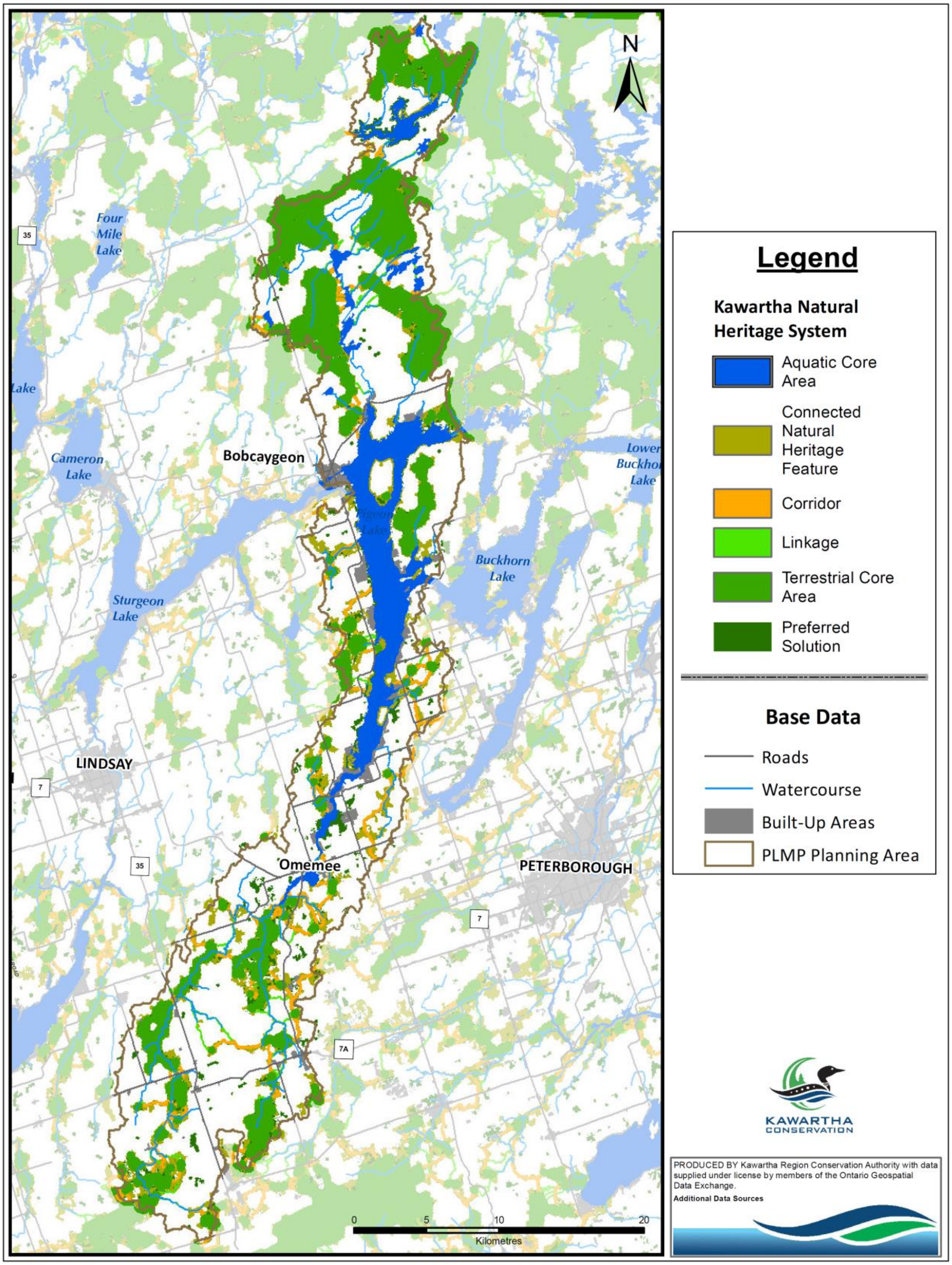

Figure 9.8. Kawarthas Naturally Connected Natural Heritage System in the Pigeon Lake Watershed

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Glossary

Agricultural Area:	A portion of the watershed where the predominant land use is agriculture or agriculture related
Agricultural activities:	Refers to any actions related to farm operations. This includes but is not limited to: growing crops, raising livestock, spreading manure, irrigation and clearing fields
Anthropogenic:	Effects, processes or materials that are derived from or as a result of human activities
Aquatic system:	An ecosystem located within a water body (Also see: Ecosystem)
Aquatic vegetation:	Refers to plants and algae that grow within an aquatic environment
Aquifer:	Layer of permeable rocks or loose materials (gravel, sand) that is saturated with water and through which groundwater moves and can be extracted using water well
Baseflow:	The portion of stream flow that is entirely attributed to groundwater inputs
Benthics:	Organisms that live in the benthic zone at the bottom of a water body
Best management practice (BMP):	A term used to describe the preferred method of management that has proven to reliably lead to a desired result. Usually associated with stormwater management or agricultural practices
Bioaccumulation:	The build-up of substances such as pesticides or heavy metals within an organism. This occurs when the organism obtains a substance at a greater rate than it can dissipate it.
Biodiversity:	The variability among living organisms and the ecological complexes of which they are part. A healthy ecosystem is traditionally one with a high level of biodiversity.
Biosolids:	A term used in wastewater management referring to treated sludge from commercial and domestic sewage and wastewater treatment.
Biota:	The total collection of organisms of a geographic region.
Coldwater fish:	Fish species such as brook trout that prefer colder water temperatures (usually below 15˚C).
Conductivity:	In regards to water, conductivity measures the ability of a water sample to conduct electricity. This is dependent on the concentration of dissolved salts and other ionizing chemicals.
Dissolved oxygen (DO):	An amount of oxygen that is being dissolved in the water column.
Drumlin:	A geographic feature created through glaciation in the form of a "tear drop" shaped hill. Usually occurs in clusters or "fields".
Dry deposition:	Materials such as dust that fall out of the atmosphere onto the earth's surface.
Ecological functions:	The natural processes, products or services that living and non-living environments provide or perform within or between species, ecosystems and landscapes.
Ecosystem:	A recognizable ecological unit such as a group of plant and animal species living together in a particular area.

End-of-pipe practices: Stormwater management controls or facilities located at a storm sewer outlet. (Also see: stormwater management controls, stormwater management facilities)

Erosion: The removal of soil sediment and rock in the natural environment. This may be as a result of natural processes such as weathering or through anthropogenic processes such as deforestation and poor farm management practices.

Eutrophication: A natural or human-caused process whereby water bodies receive excess nutrients (phosphorus and nitrogen specifically) that stimulate excessive aquatic plant and/or algae growth. Nutrients can come from natural sources such as erosion of soils or stream banks, or human sources (fertilizers, urban runoff, sewage treatment plant discharges, etc.).

Eutrophic water body: A lake, stream or any other natural or man-made water body that has high levels of nutrients in its water, is highly productive and supports high growth rates of aquatic vegetation and/or algae.

Evaporation: The transfer of water from the earth's surface into the atmosphere under influence of solar radiation and heat, and wind.

Evapotranspiration: The transfer of water from vegetation into the atmosphere.

Farming activities: (See agricultural activities)

Freshet: High water levels resulting from heavy rains or snowmelt. Usually associated with a spring thaw event.

Groundwater: Water located beneath the surface, usually in aquifers or other porous spaces.

Groundwater discharge: The flow rate of groundwater through an aquifer usually expressed in cubic meters per second.

Habitat: An ecological or environmental area that is inhabited by a particular organism and that influences or is utilized by that organism.

Hardness: In regards to water, hardness measures the concentration of dissolved minerals such as calcium and magnesium. Hard water has a high mineral concentration.

Infiltration: Water entering the ground via pores in the earth's surface.

Invasive species: A non-indigenous plant or animal, e.g., Eurasian milfoil (Also see: native species)

Lot level practices: In regards to stormwater, these are changes that can be made on a lot or property to reduce the quantity or improve the quality of stormwater runoff, e.g., installation of rain barrels.

Macrophytes: Aquatic plants that grow in or near the water.

Marsh: A marsh is an area 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 ≤ 25% and cover of emergent hydrophytic macrophytes is greater than or equal to 25%.

Meadow Marsh: Areas with <2m of water over substrates. Often seasonally flooded with soils drying out by mid-summer. Tree and shrub cover is ≤ 25% and area is dominated by emergent hydrophytic macrophytes. Represents the wetland-terrestrial interface.

Mesotrophic water body:	A lake, stream or any other natural or man-made water body that has moderate levels of nutrients in its water and consequently moderate plant growth.
Heavy metals:	In regards to water quality, this refers to metals located within the water column as a result of natural or anthropogenic processes. Heavy metals are usually toxic for aquatic organisms and humans, e.g., lead, cadmium, thallium and mercury.
Moraine:	A geographic feature consisting of a mound of earth and rock pushed up in front of an advancing glacier.
Naturalization:	(See restoration)
Native species:	A species that is indigenous to an ecosystem in that it occurs there naturally without any human intervention.
Nutrients:	In terms of water quality, this refers to the chemicals that aquatic vegetation requires for vital functions. Nutrients include phosphorus, nitrogen, potassium and some other chemical elements.
Oligotrophic water body:	A lake, stream or any other natural or man-made water body that has very low levels of nutrients, such as phosphorus and nitrogen, in its water and, as a result, low productivity with few aquatic plants.
Precipitation:	The transfer of water from the atmosphere to the earth's surface in the form of rain, snow, hail, dew, etc.
Provincially significant wetland (PSW):	Based on the guidelines for wetland management (MNR, 1984), these are wetlands classed as 1 through 3 in the wetlands policy (Section 3 of the Planning Act).
Recharge:	In regards to groundwater, recharge refers to water being added to a groundwater system such as an aquifer.
Restoration:	Returning an altered landscape back to its original form through physical restructuring and the reintroduction of native species. For example, shoreline restoration or naturalization refers to the removal of non-natural features such as lawns and break walls and the addition of native plant species.
Riparian zone/area:	The interface between land and a stream or lake.
Secchi disk:	White and black disk 20 centimeters in diameter used to measure water transparency in lakes. The disc is lowered into the water on the line. The depth at which the pattern on the disk is no longer visible is taken as a measure of the transparency of the water. This measure is known as the Secchi depth and is related to water turbidity in the lake.
Sediments:	Any particulate matter that can be transported by flowing water, and eventually deposited on the bottom of a water body.
Sewershed:	The total area of land that drains to a sewer system.
Stormwater:	A term used to describe water that originates during a precipitation event. Usually used to define water that flows through storm sewer systems in urban areas.
Stormwater management control:	A device or system used to treat stormwater quality or quantity. Examples are oil grit separators, infiltration trenches, etc.
Stormwater management facility:	A constructed wet pond, dry pond or wetland used to detain stormwater in order to treat for quality or quantity. Water quality treatments primarily rely on the settling of sediments.

Subwatershed:	A subsection of a watershed. (Also see: watershed)
Surface water:	Precipitation that does not soak into the ground or return to the atmosphere but instead flows through streams, rivers, lakes and wetlands.
Suspended sediments:	Sediments that are still situated within a water column. (Also see: Sediments)
Sustainable development:	A pattern of resource use that aims to meet human needs while preserving the environment so that these needs can be met not only in the present, but also for future generations.5
Swamp:	A treed wetland consisting of greater than 25% living tree cover or 70% dead tree cover
Swamp Coniferous:	A swamp where the tree cover is made up of > 75coniferous trees
Swamp Deciduous:	A swamp where the tree cover is made up of > 75% deciduous trees
Swamp Mixed:	A swamp where the tree cover is >25% coniferous trees and >25% deciduous trees
Swamp Thicket:	A swamp where tree cover is ≤ 25% and hydrophytic shrub cover is >25%.
Total phosphorus (TP):	A measure of both soluble and insoluble phosphorus forms within a water column. The insoluble component is primarily decaying plant and animal matter or soil particles. Soluble phosphorus (e.g., orthophosphates) is dissolved in water column in molecular form. It is readily available to aquatic plants and algae.
Transpiration:	Evaporation from aerial parts of a plant such as the leaves. (Also see: Evaporation, Evapotranspiration)
Urban area:	An area with an increased density of human-created structures and population when compared to surrounding areas. In Canada, an urban area is defined as having more than 400 people per square kilometer and has more than 1,000 people in total.
Warm water fish:	Fish species that prefer warmer water temperatures such as muskellunge and smallmouth bass.
Water budget:	A summary of the quantity of water in the atmosphere, ground and surface water systems within a watershed.
Water quality:	An integrated index of chemical, physical and microbiological characteristics of natural water that determines suitability of water for the aquatic life and various human uses.
Watershed:	The total area of land that drains to a river or other large body of water.
Wet deposition:	Materials deposited on the surface by precipitation.
Wetland:	Lands that are seasonally or permanently covered by shallow water as well as lands where the water table is close to or at the surface. The four major types of wetlands are swamps, marshes, bogs and fens.
Woodland:	Treed areas that provide environmental and economic benefits such as erosion prevention, water retention, provision of habitat, recreation and the sustainable harvest of woodland products.

Appendix 1

2004 Visitor Statistics for CKL

Tourism Parameter	Percentage
Same day vs. Overnight Visitors	
Same day Visitors	44%
Overnight Visitors	56%
Origin of Visitors	
Ontario	93%
Other Province	4.3%
United States	2%
Other	1%
Visiting Purpose	
Pleasure	69%
Visiting Friends and Relatives	27%
Business	<0.1%
Visiting Season	
January to March	29%
April to June	23%
July to September	27%
October to December	25%
Overnight Visitor Accommodations	
Roofed Commercial Buildings	14%
Campgrounds/Trailer Parks	28%
Private Homes/Cottages	55%

Source: (The Tourism Company and CKL, 2008)

Appendix 2

Surface Water Quality Standards and Guidelines

Parameter	Objective/Guideline	Authority
E.coli	100 cfu/100 mL	Provincial Water Quality Objectives
Nitrate	2.93 mg/L	Canadian Water Quality Guidelines for the Protection of Aquatic Life
Total Nitrogen	1.0 mg/L	Alberta Surface Water Quality Guidelines
Total Phosphorus	0.030 mg/L	Provincial Water Quality Objectives (Streams)
Total Phosphorus	0.020 mg/L	Provincial Water Quality Objectives (Lakes)
Total Phosphorus	0.010 mg/L	Provincial Water Quality Objectives (Lakes with natural TP concentration below 0.010 mg/L)
Total Suspended Solids	Background + 25 mg/L	Canadian Water Quality Guidelines for the Protection of Aquatic Life

Appendix 3

List of Documented Fish Species Within the PLMP Planning Area, by Subwatershed

Fish Species	Pigeon River	Fleetwood Creek	Potash Creek	Reforestation Creek	Bears Creek	Nogies Creek	Eels Creek	Pigeon Lake Tribs
Banded Killifish								
Blackchin Shiner	1					1		
Blacknose Dace	1	1						
Blacknose Shiner	1							
Bluegill	1							
Bluntnose Minnow	1	1				1		
Brassy Minnow		1				1		
Brook Stickleback	1	1	1	1	1			
Brook Trout	1	1	1					
Brown Bullhead	1		1					
Burbot						1		
Central Mudminnow	1	1	1	1		1		
Common Carp						1		
Common Shiner	1	1				1		
Creek Chub	1	1	1	1		1		
Fallfish						1		
Fathead Minnow	1	1	1	1		1		
Golden Shiner						1		
Iowa Darter		1		1		1		
Lake Herring								
Largemouth Bass	1	1				1		
Logperch						1		
Longnose Dace	1	1						
Mottled Sculpin	1	1						
Muskellunge				1		1		
Northern Pike						1		
Northern Redbelly Dace	1	1	1		1			
Pearl Dace		1						
Pumpkinseed	1	1		1		1		
Rock Bass	1	1		1		1		
Slimy Sculpin		1						
Smallmouth Bass						1		
Spottail Shiner				1				
Walleye								
White Sucker	1	1	1	1	1	1		
Yellow Bullhead						1		

Yellow Perch	1		1	1		1		
UNKNOWN Notropis Sp.	1							
UNKNOWN	1							
UNKNOWN	1							
TOTAL (not including UNKNOWNS)	**20**	**19**	**9**	**11**	**3**	**22**		**0**
ROM (OMNR1970's)	x	x	x	x	x	x		
OMNR_ARA2002 (exported2006)	no data	no data	x	x	no data	x ptboMNR only		
Kawartha Conservation (2015)	x	x		x				

Appendix 4

Fishes captured at present vs. historical comparison sites

Site ID	PR-02		PR-04		PR-05		PR-06		PR-10		PR-11		PR-12		Ref-01	
	1973	2015	1973	2015	1973	2015	1973	2015	1973	2015	1973	2015	1973	2015	1976	2015
Blackchin Shiner			1	1												
Blacknose Dace								1					1			
Blacknose Shiner			1		1			1								
Bluegill		1														
Bluntnose Minnow		1		1						1	1	1				
Brassy Minnow												1				
Brook Stickleback												1			1	1
Brook Trout													1	1		
Brown Bullhead	1															
Central Mudminnow						1						1			1	
Common Shiner				1	1		1	1	1	1	1	1				
Creek Chub				1	1			1		1	1	1				
Fathead Minnow							1			1						
Iowa Darter											1				1	
Largemouth Bass		1								1		1				
Longnose Dace											1					
Mottled Sculpin									1							
Northern Redbelly Dace			1		1		1	1				1				
Pearl Dace											1					
Pumpkinseed	1	1	1								1	1				
Rock Bass	1	1		1	1						1	1				
Slimy Sculpin														1		
White Sucker						1						1				1
Yellow Perch		1													1	1
UNKNOWN			1		1											

UNKNOWN Notropis Sp.			1													
TOTAL (not incl. unknowns)	**3**	**6**	**4**	**5**	**5**	**2**	**3**	**5**	**2**	**5**	**8**	**11**	**2**	**2**	**4**	**3**

Appendix 5

Benthic macroinvertebrate raw counts (pooled for each site) and summary data for 16 bioassessment sites

Taxonomy (family-level where possible)			PL234-12	PL234-30	PL234-42	PL234-22	PL234-45	PL234-39	PL234-25	PL234-14	PL234-09	PL234-18	PL234-37	PL234-48	PL234-10	PL234-07	PL234-47	PL234-34	Abundance (sum)	ToleranceValue
Mites	Acari	Unknown Acari	0	0	1	1	0	1	0	0	6	0	12	0	0	1	4	0	**26**	**6**
Amphipods	Amphipoda	Crangonyctidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	**2**	**6**
Amphipods	Amphipoda	Gammaridae	50	0	0	0	2	0	3	0	0	0	0	0	0	120	0	0	**175**	**6**
Dragonflies	Anisoptera	Aeshnidae	0	0	0	0	1	1	0	3	1	0	0	2	1	0	0	0	**9**	**5**
Dragonflies	Anisoptera	Cordulegastridae	0	0	0	0	3	2	6	1	0	0	0	0	2	0	0	2	**16**	**3**
Dragonflies	Anisoptera	Corduliidae	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	**1**	**2**
Dragonflies	Anisoptera	Gomphidae	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	**1**	**4**
Dragonflies	Anisoptera	Libellulidae	10	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	**12**	**2**
Beetles	Coleoptera	Curculionidae	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	**2**	
Beetles	Coleoptera	Dryopidae	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	**1**	**5**
Beetles	Coleoptera	Dytiscidae	0	3	0	0	1	0	2	1	0	5	0	0	0	0	5	4	**21**	**5**
Beetles	Coleoptera	Elmidae	0	1	14	145	15	23	69	6	63	0	0	151	94	26	6	3	**616**	**5**
Beetles	Coleoptera	Haliplidae	4	0	0	0	0	1	0	0	0	2	0	0	0	0	1	0	**8**	**5**
Beetles	Coleoptera	Hydrophilidae	0	0	0	0	0	1	0	1	0	0	0	0	1	0	0	0	**3**	**5**
Beetles	Coleoptera	Limnichidae	0	0	0	3	0	0	0	0	0	0	0	0	0	1	0	0	**4**	
Beetles	Coleoptera	Noteridae	0	0	2	0	0	0	0	0	0	0	0	0	0	0	1	4	**7**	
Beetles	Coleoptera	Psephenidae	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	**1**	**4**
Beetles	Coleoptera	Unknown Coleoptera	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**	
TrueFlies	Diptera	Ceratopogonidae	6	8	0	0	0	3	1	4	0	27	18	0	2	0	0	2	**71**	**6**
TrueFlies	Diptera	Chironomidae	94	162	70	11	63	150	111	34	136	92	98	128	22	25	123	54	**1373**	**6**
TrueFlies	Diptera	Dixidae	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	**1**	**1**
TrueFlies	Diptera	Empididae	0	0	0	1	3	1	3	0	0	0	0	0	3	0	0	1	**12**	**6**
TrueFlies	Diptera	Psychodidae	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	1	**3**	**10**
TrueFlies	Diptera	Ptychopteridae	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	**1**	**9**
TrueFlies	Diptera	Sciomyzidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	**4**	

TrueFlies	Diptera	Simuliidae	0	3	126	6	41	4	0	1	27	0	75	40	3	0	16	1	**343**	**5**
TrueFlies	Diptera	Stratiomyidae	0	1	0	0	0	0	0	0	0	0	2	0	0	0	1	0	**4**	**7**
TrueFlies	Diptera	Tabanidae	1	4	0	0	2	1	1	3	0	0	0	0	2	2	0	1	**17**	**5**
TrueFlies	Diptera	Tipulidae	0	3	14	5	3	31	6	10	3	0	6	2	17	0	5	6	**111**	**4**
TrueFlies	Diptera	Unknown Diptera	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	**1**	
Mayflies	Ephemeroptera	Baetidae	0	7	7	40	1	17	0	0	0	0	0	0	0	0	0	0	**72**	**6**
Mayflies	Ephemeroptera	Caenidae	13	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	**23**	**6**
Mayflies	Ephemeroptera	Ephemerellidae	0	0	0	38	0	0	0	8	0	0	0	0	3	0	0	0	**49**	**2**
Mayflies	Ephemeroptera	Heptageniidae	0	1	4	15	11	3	10	1	0	0	0	27	2	0	0	0	**74**	**3**
Mayflies	Ephemeroptera	Leptophlebiidae	0	0	0	2	1	0	0	0	0	0	0	0	0	0	0	0	**3**	**4**
Mayflies	Ephemeroptera	Siphlonuridae	0	0	0	57	0	0	21	11	10	3	3	0	51	8	4	147	**315**	**4**
Mayflies	Ephemeroptera	Unknown Ephemeroptera	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	**2**	
Snails	Gastropoda	Hydrobiidae	1	0	1	0	0	0	0	8	0	0	0	0	2	0	5	0	**17**	**8**
Snails	Gastropoda	Lymnaeidae	4	1	0	0	1	0	0	0	0	0	3	0	0	0	0	0	**9**	**6**
Snails	Gastropoda	Physidae	23	0	1	0	0	1	3	0	0	22	14	0	1	0	0	1	**66**	**8**
Snails	Gastropoda	Planorbidae	39	1	2	0	0	0	0	3	0	3	1	0	0	0	0	1	**50**	**6**
Snails	Gastropoda	Viviparidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	**2**	**6**
Truebugs	Hemiptera	Corixidae	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	**2**	**5**
Truebugs	Hemiptera	Pleidae	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**11**	
Truebugs	Hemiptera	Veliidae	0	2	0	0	0	0	1	0	0	0	0	0	0	0	0	0	**3**	
Leeches	Hirudinea	Erpobdellidae	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	**2**	**8**
Leeches	Hirudinea	Glossiphoniidae	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**3**	**8**
Leeches	Hirudinea	Hirudinidae	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	**2**	**8**
Leeches	Hirudinea	Unknown Hirudenea	0	0	0	0	2	1	0	0	0	0	0	0	0	0	0	0	**3**	
AqMoths	Lepidoptera	Crambidae	0	0	0	0	0	0	0	3	0	1	0	2	0	0	0	1	**7**	**5**
Dobsonflies	Megaloptera	Corydalidae	0	0	0	1	0	0	2	0	0	0	0	2	0	0	0	0	**5**	**4**
Dobsonflies	Megaloptera	Sialidae	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	**3**	**4**
Nematodes	Nematoda	Unknown Nematoda	0	3	1	0	0	0	0	0	0	0	0	0	1	0	1	3	**9**	
AqEarthworms	Oligochaeta	Unknown Oligochaeta	3	0	0	1	0	0	0	0	0	2	2	2	0	0	19	0	**29**	**8**
Clams	Pelecypoda	Pisidiidae	5	37	0	0	13	8	8	11	8	24	20	5	2	0	0	39	**180**	**6**
Stoneflies	Plecoptera	Chloroperlidae	0	2	3	12	0	0	0	1	0	0	0	0	2	0	0	0	**20**	**0**
Stoneflies	Plecoptera	Nemouridae	0	4	0	27	106	48	18	23	0	0	0	0	0	0	53	0	**279**	**2**
Stoneflies	Plecoptera	Perlidae	0	0	0	0	1	0	0	0	0	0	0	5	3	0	0	0	**9**	**3**
Stoneflies	Plecoptera	Perlodidae	0	0	17	23	0	1	0	0	0	0	9	1	47	0	2	27	**127**	**2**
Caddisflies	Trichoptera	Brachycentridae	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	2	**4**	**2**
Caddisflies	Trichoptera	Glossosomatidae	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	**1**	**1**
Caddisflies	Trichoptera	Hydropsychidae	0	2	3	10	5	3	2	1	3	0	0	40	6	1	0	2	**78**	**5**

Caddisflies	Trichoptera	Lepidostomatidae	1	3	7	1	0	0	1	3	0	0	0	1	0	0	0	3	**20**	**1**
Caddisflies	Trichoptera	Limnephilidae	0	7	0	0	2	0	0	2	0	0	0	0	0	0	0	0	**11**	**4**
Caddisflies	Trichoptera	Odontoceridae	0	0	0	0	3	2	0	5	0	0	2	0	0	3	8	7	**30**	**0**
Caddisflies	Trichoptera	Philopotamidae	0	0	1	0	0	0	0	0	0	0	0	20	0	0	0	0	**21**	**4**
Caddisflies	Trichoptera	Phryganeidae	1	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	**3**	**4**
Caddisflies	Trichoptera	Polycentropodidae	0	0	0	25	0	0	0	0	5	0	0	26	0	0	0	0	**56**	**6**
Caddisflies	Trichoptera	Rhyacophilidae	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	**3**	**1**
Caddisflies	Trichoptera	Unknown Trichoptera	0	1	0	0	1	2	2	0	0	0	2	0	2	0	0	4	**14**	
Damselflies	Zygoptera	Calopterygidae	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	**2**	**6**
Damselflies	Zygoptera	Coenagrionidae	2	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	**3**	**8**
Abundance (sum)			**268**	**259**	**278**	**424**	**287**	**310**	**273**	**145**	**262**	**185**	**268**	**460**	**272**	**197**	**264**	**317**	**4469**	**-**
Richness (count)			**17**	**22**	**20**	**20**	**25**	**27**	**22**	**24**	**10**	**14**	**16**	**20**	**25**	**10**	**21**	**24**	**72**	**-**
EPT (%)			**5.6**	**10.4**	**15.5**	**59.0**	**47.7**	**24.5**	**19.8**	**38.6**	**6.9**	**2.2**	**6.0**	**26.1**	**43.0**	**11.2**	**25.4**	**60.6**	**27.2**	**-**
Taxa w/ tolerance value (%)			**96**	**98**	**99**	**99**	**98**	**99**	**99**	**100**	**100**	**100**	**99**	**100**	**99**	**99**	**97**	**96**	**-**	**-**
Hilsenhoff FBI (Value)			**6.02**	**5.72**	**4.90**	**4.19**	**3.93**	**4.98**	**5.07**	**4.40**	**5.54**	**6.14**	**5.58**	**5.14**	**4.26**	**5.68**	**4.96**	**4.39**	**-**	**-**
Hilsenhoff FBI (Class)			**FPoor**	**Fair**	**Good**	**VGood**	**VGood**	**Good**	**Fair**	**Good**	**Fair**	**FPoor**	**FPoor**	**Fair**	**Good**	**Fair**	**Good**	**Good**	**-**	**-**
Watershed Report Card (Grade)			**D**	**C**	**B**	**A**	**A**	**B**	**C**	**B**	**C**	**D**	**D**	**C**	**B**	**C**	**B**	**B**	**-**	**-**

Appendix 6

List of Aquatic Exotic Species from EDDMAPS (obtained May 2015)

Type	Common Name	Scientific Name	Kawartha Lakes subwatershed	Trent River subwatershed	Severn River subwatershed
			(2HG, 2HF, 2HH, 2HJ)	(2HK)	(2EC)
Aquatic Invertebrate	**banded mysterysnail**	**Viviparus georgianus**	x	x	x
Aquatic Invertebrate	Chinese mysterysnail	Cipangopaludina chinensis	x		
Aquatic Invertebrate	quagga mussel	Dreissena bugensis			x
Aquatic Invertebrate	**rusty crayfish**	**Orconectes rusticus**	x	x	x
Aquatic Invertebrate	spiny waterflea	Bythotrephes longimanus	x		x
Aquatic Invertebrate	**zebra mussel**	**Dreissena polymorpha**	x	x	x
Aquatic Plant	Carolina fanwort	Cabomba caroliniana		x	
Aquatic Plant	common water hyacinth	Eichhornia crassipes	x		
Aquatic Plant	creeping yellow loosestrife	Lysimachia nummularia			x
Aquatic Plant	curly-leaved pondweed	Potamogeton crispus	x		
Aquatic Plant	Eurasian water-milfoil	Myriophyllum spicatum	x		x
Aquatic Plant	**European common reed**	**Phragmites australis**	x	x	x
Aquatic Plant	**European frog-bit**	**Hydrocharis morsus-ranae**	x	x	x
Aquatic Plant	flowering-rush	Butomus umbellatus	x	x	
Aquatic Plant	**purple loosestrife**	**Lythrum salicaria**	x	x	x
Aquatic Plant	water lettuce	Pistia stratiotes			x
Aquatic Plant	water soldier	Stratiotes aloides		x	
Aquatic Plant	**yellow iris**	**Iris pseudacorus**	x	x	x
Fish	oscar	Astronotus ocellatus	x		
Fish	rainbow smelt	Osmerus mordax	x		x
Fish	red-bellied pacu	Piaractus brachypomus	x		
Fish	**round goby**	**Neogobius melanostomus**	x	x	x
Fish	white perch	Morone americana		x	
TOTAL (24)			17	12	15

Appendix 7

Community Series Description

Community Series (Code -Descriptive Name)[1]	Description of Community Series	Pigeon Lake Watershed	
		km²	%
AA - Active Aggregate	Barren, heavily disturbed open pit or quarry	4.3	0.63
AI - Inactive Aggregate	Surface cover ≥ 25% or barren, currently unused open pit or quarry	0.04	0.06
CUM – Cultural Meadow	Areas that have resulted from or are maintained by cultural or anthropogenic-based disturbances and often have a large proportion of non-native plant species. These areas are characterized by a tree and shrub cover each of less than 25%.	9.27	5.7
BBO – Open Beach/Bar	Areas of openness maintained by active shoreline processes such as ice scour, wave energy, erosion and deposition. Substrate of coarse parent mineral material, rock or bedrock. Above the seasonal high-water mark; subject to extremes in moisture and temperature. Vegetation cover varies from patchy and barren to more closed and treed, tree cover ≤ 25%, shrub cover ≤ 25%	0.006	0
CUP – Cultural Plantation	Areas that have resulted from or are maintained by cultural or anthropogenic-based disturbances and often have a large proportion of non-native plant species. These areas are characterized by tree cover > 60%.	7.62	1.12
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%.	9.97	1.47
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%.	11.35	1.67
CUW – Cultural Woodland	Areas that have resulted from or are maintained by cultural or anthropogenic-based disturbances and often have a large	9.46	1.39

[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	Pigeon Lake Watershed	
		km²	%
	proportion of non-native plant species. These areas are characterized by tree cover between 35% and 60%,		
CVI – Roads		9.5	1.41
DIS – Disturbed Areas	No natural cover, areas that have been disturbed by human influences, e.g. trails	0.51	0.08
IAG – Intensive Agriculture	Annually cultivated, crop fields, gardens, nurseries, tree farms. Variable	147.07	21.65
***MOS -** Manicured Open Space	Regularly maintained, gardens, parks, ski hills, cemeteries, open spaces. >2ha and resulting from or maintained by, cultural or anthropogenic-based disturbances	1.31	0.19
***NAG** – Non Intensive Agriculture	No cultivation, grasses, hay, pasture, grazing. Variable	43.44	6.40
***RD** – Rural Development	Variable. 0.2 ha < area < 2.0 ha containing development not associated with agriculture	24.97	3.68
***URB** – Urban Development	Variable. > 5 residential units in an area > 2 ha, generally residential	7.93	1.17
BO - Bog	Bogs are areas with ≤ 25% tree cover (trees over 2m) where substrate organic layer is > 40cm Sphagnum peat, rarely flooded, always saturated with water. The pH is moderate to highly acidic (<4.2).	0	0
BOO – Open Bog	Bog with tree cover ≤ 10%, shrub cover ≤ 25%	0	0
BOT – Treed Bog	Bog with 10% < tree cover ≤ 25%	0	0
FOC – Coniferous Forest	Areas where tree cover is greater than 60%, and the canopy is comprised of greater than 75% coniferous tree species	96.32	14.18
FOD – Deciduous Forest	Areas where tree cover is greater than 60%, and the canopy is comprised of greater than 75% deciduous tree species	75.18	11.07
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	75.85	11.17
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 ≤ 25% and area is dominated by emergent hydrophytic macrophytes. Represents the wetland-terrestrial interface.	6.91	1.02
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 ≤ 25% and cover of emergent hydrophytic macrophytes is greater than or equal to 25%.	16.93	2.49

Community Series (Code -Descriptive Name)[1]	Description of Community Series	Pigeon Lake Watershed	
		km²	%
MOS	Manicured Open Space	1.32	
OAO – Open Aquatic	Areas with water >2m deep. Plankton dominated with no macrophyte vegetation and no tree or shrub cover.	32.10	4.73
RBO – Open Rock Barren	Found where conditions are most extreme; bare rock surfaces or small patches of very shallow substrate. Tree cover ≤25%, shrub cover ≤ 25%	0.003	0
RBS – Shrub Rock Barren	Found where conditions may be less extreme; where rock is broken and cracked or where limited substrates have accumulated. Tree cover ≤ 25%, shrub cover > 25%	3.51	0.01
RBT – Treed Rock Barren	Found where bedrock is broken and cracked or where shallow substrates have accumulated. 25% < tree cover ≤ 60%	8.42	0.01
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.	0.63	0.09
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.	2.37	0.35
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.	5.30	0.78
SBS – Shrub Sand Barren	Bare sand substrates not associated with distinct topographic features (i.e. sand dune), subject to periods of prolonged drought and disturbances (e.g. fire) Tree cover ≤25%, shrub cover > 25%	0	0
SBO – Open Sand Barren	Tree cover ≤25%, shrub cover ≤ 25%	2.77	0
SWC – Coniferous Swamp	Areas with variable flooding where water depth is <2m and standing water or vernal pooling makes up >20% of the ground coverage. Tree cover is >25%, canopy height is greater than 5m, and conifer tree species make up >75% of the canopy. Hydrophytic shrubs and herbs present.	43.03	6.34
SWD – Deciduous Swamp	Areas with variable flooding where water depth is <2m and standing water or vernal pooling makes up >20% of the ground	2.59	0.38

Community Series (Code -Descriptive Name)[1]	Description of Community Series	Pigeon Lake Watershed	
		km²	%
	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.		
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.	13.98	2.06
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 ≤ 25% and hydrophytic shrub cover is >25%.	15.77	2.32
Cultural Areas		292.06	43
Natural Areas		387.12	57
Combined Areas of Cover*		439.63	64.7
Roads		9.55	3.27

* All natural areas + CUM, CUP, CUS, CUT, CUW

Discover • Protect • Restore

Kawartha Conservation
277 Kenrei Road, Lindsay ON K9V 4R1
T: 705.328.2271   F: 705.328.2286
GenInfo@KawarthaConservation.com
KawarthaConservation.com