Head Lake Watershed Characterization Report

2018

KAWARTHA CONSERVATION

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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 would like to thank everyone who provided comments, suggestions and any kind of input during the four-year period of research, monitoring and preparation of the report.

We are particularly thankful for the information, input, and advice received from the following organizations that comprise the Science and Technical Committee.

Centre for Alternative Wastewater Treatment

Fleming College

Haliburton Kawartha Pine Ridge District Health Unit

Kawartha Lakes Fisheries Assessment Unit

Kawartha Lakes Stewards Association

Scugog Lake Stewards

Head lake Stewardship Group representing: Head Lake High Shores Association, North Shore Cottagers Association, Sunset Beach Cottages Association, Hilton's Point Cottagers' Association, and residents of Rush Lake

Ontario Ministry of Environment and Climate Change

Ontario Ministry of Agriculture, Food, and Rural Affairs

Trent University

Lakehead University

University of Ontario Institute of Technology

Ontario Federation of Anglers and Hunters

Haliburton, Kawartha, and Pine Ridge District Health Unit

Funding for this project was provided by the City of Kawartha Lakes

Acronyms

CKL: City of Kawartha Lakes

CWQG: Canadian Water Quality Guideline

EC: Environment Canada

ELC: Ecological Land Classification

HL: Head Lake

HLSP: Head Lake Stewardship Plan

KLSA: Kawartha Lake Stewards Association

masl: Meters above sea level

OMNRF: Ontario Ministry of Natural Resources and Forestry

MOECC: 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 Head Lake Watershed Characterization Report is to provide a technical, comprehensive report on the current state of Head Lake and its subwatersheds that supports the development of a Head Lake Stewardship Plan. Emphasis has been placed on characterizing the immediate drainage area around Head 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, 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

The Head Lake watershed occupies a small area (121.9km^2) located to the north west of Kawartha Conservation's jurisdiction within the municipality of the City of Kawartha Lakes. Head Lake is a relatively small lake with a surface area of 9.38 km^2 located at the headwater portion of the Head River. Further downstream the Head River converges with the Black River that, in turns, flows into the Severn River and, consequently, into Georgian Bay.

Three sub-watersheds have been delineated within the Head Lake Planning Area: Fishog River; Head Lake Central and the Rush Lake sub watersheds. The Fishog River sub-watershed extends north from the mouth of the Fishog River; the Head Lake Central sub-watershed includes lands that immediately surround the lake; and the Rush Lake sub-watershed covers the southern portion of the study area.

Socio-economics

The Head Lake Watershed has an estimated year round population of approximately 200. 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. There are many private businesses in the vicinity of Head 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. These businesses benefit from the recreation opportunities the lakes provide, and help re-circulate money into the local economy.

Land Use

Almost the entire land area north of Head Lake within the Queen Elizabeth II Wildlands and consists of shallow lakes, wetlands, and forests. There are no large communities located near Head Lake, though numerous cottages, homes and two trailer parks are located by the lakeshore. As of 1994, the total building count around Head Lake was 389. With a shoreline distance of 19.3 km, the building density around the lake is a moderate

20.2 buildings/km. The majority of the land area within the Head Lake Planning Area south, east, and west of Head Lake is forested, with a few smaller, isolated wetlands, most notably surrounding a small tributary that flow into Head Lake from Duck Lake and Rush Lake to the south. The contrast between near-shore land use and land use further inland is striking at Head Lake. Within 100 meters from the shoreline 58.6% of the land is used for rural development and roads, with forests and wetlands covering the majority of the remaining land at 23.6% and 10.5% respectively. However, when the land use 1000 meters from the shore of Head Lake is evaluated, only 11.8% of the land is used for roads and rural development, with forests covering over half the area (55%), and wetlands (12.4%) and meadows (11.1%) combining to cover almost a quarter of the land.

The Head Lake watershed lies within a geological transition area between the Canadian Shield (a region characterized by relatively hard, Precambrian bedrock with bare or shallow soils), and the St. Lawrence Lowlands (a region characterized by relatively soft, sedimentary bedrock with shallow to deep soils).

Climate

The climate conditions of the Head 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. 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

Head Lake is a regulated water body. A dam that affects water level of the lake is located approximately ~5.5 km downstream of the lake, on the Head River. It is a concrete structure with two stop-log operated sluiceways and an adjoining weir. The dam was constructed in mid-1960th with the primary purpose of raising water levels to facilitate construction of the cottages at the north end of the lake. Secondary considerations for the dam were improvement of navigation and recreation use of the lake. Operation of the dam includes removing two sets of stop-logs before the winter preparing for the spring freshet. During summer, the stop-logs are returned to the dam to hold the elevated water levels in Head Lake.

Head Lake, on average, receives 59.88 million m^3 of water inflow every year. Majority of the inflow, 42.55 mln of cubic metres or 71% comes from the Fishog River. Precipitation encounters for ~15% of total water inflow, while 12.7% of water comes from the Rush Creek at the southern portion of the study area. Inflow from the central portion of the watershed, where very few watercourses exists, is almost negligible, less than 1% of total on average.

Water Quality

Head Lake can be characterized as a mesotrophic (moderate productivity) water body with excellent water quality. Water quality concerns in the Head Lake watershed are negligible. All parameters studied have concentrations far below the corresponding PWQOs or CWQGs and do not currently present any threat to aquatic life or human health. 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.

There were zero exceedences of the PWQO for phosphorus during the three year study period. Further analysis will determine the significance of winter TP loading as a result of the number of frost free days and available loading from the snow melt and soil-snow interface as a result of thawing.
The Haliburton, Kawartha, Pine Ridge District Health Unit beach posting data (due to elevated *E. coli* concentrations) shows that the public beach on Head Lake has been posted at least once per season during the monitoring years of 2011-2017.

Aquatic Ecosystems

There are no bathymetry data for Rush Lake upon release of this report. The greatest depths in Head Lake are within the south-east part of the lake, in-and-around Armstrong Island, and immediately north of Hilton's Point (Figure 6.1). The majority of the lake (approx. 66% of its surface area) is at or less then 3m deep. Most of the shoreline has relatively gradually sloping nearshore areas, except for the southeast shore along Sunset Beach Rd. and the southwest shore along Monck Rd. which have relatively narrow and steep nearshore areas. There is limited data available regarding substrates on the lakebed, and aquatic plants.

Approximately 13 fish species have been documented within Head Lake, most of which are large-bodied fishes recorded through 2 sampling events within the last 10 years. There are no fish community data for Rush Lake. According to the most recent available data (2015), the large-bodied fish community in Head Lake consists of warm- and cool-water species dominated by walleye, yellow perch, white sucker, pumpkinseed, rock bass, and muskellunge. Several fishes are important in supporting a small, but apparently viable recreational fishery particularly walleye, smallmouth bass, and muskellunge. Walleye populations are considered one of the most significant of all similar-sized lakes within the management zone (Zone 17). No known fish species listed as Special Concern, Threatened or Endangered have been documented.

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, very limited benthic community data within the subwatersheds due in large part to the remoteness of aquatic habitat within those areas.

Terrestrial Ecology

The area surrounding Head Lake contains large tracts of forests and some areas of 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. The entire Head Lake watershed contains 108 km^2 of natural cover, representing 88% of the total watershed area. This includes only areas classified as forest, wetland, rock barren and open water. There is a further 7% cover found in meadows, thickets, woodlots and plantations.

Cultural 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. A number of natural heritage features exist in the Head Lake watershed that may be considered locally significant; however they are not afforded any legislative protection. ANSI's, Provincially Significant Wetlands and Provincially Significant Woodlands, all of which can be found in the Head Lake watershed, are afforded protection due to their provincial significance. There are a number of other natural heritage features that are important locally that have not yet been identified or set aside for protection.

Head Lake is fortunate to have the Queen Elizabeth II Wildlands Provincial Park directly to the North. This is reflected in the Head Lake watershed by the fact that the dominant natural area type is forest and that coniferous, mixed and deciduous forests account for over 55% of the Head Lake landscape.

The entire Head Lake watershed is currently 25% higher than the target of 30% forest cover for Areas of Concern watersheds within the great lakes basin (Environment Canada, 2004), and Head Lake is 20% higher than the Conservation Ontario target (Conservation Ontario, 2011) of 35% forest cover for watersheds in Ontario. No sub-watershed in the Head Lake study area falls below 51% forest cover.

Five Species at Risk have been identified in the Head Lake study area and include the Blandings Turtle (*Emydoidea blandingii*), Eastern Meadowlark (*Sturnella magna*), Eastern Whip-poor-will (*Caprimulgus vociferous*), Loggerhead Shrike (*Lanius ludovicianus*), Snapping Turtle (*Chelydra serpentina*) and Butternut Tree (*Juglans cinerea*). Of the five species, two are dependent on the lake and/or its tributaries for survival; the Blanding's and Snapping Turtles. Also of note are is the population of Common Terns (*Sterna hirundo*) that nest on the Islands in Head Lake and the return of the Bald Eagle(*Haliaeetus leucocephalus*) to the area.

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1.0 Introduction

Summary of Observations/Key Issues/Information Gaps

Observations

- The Head Lake watershed occupies a small area (121.9km^2) located to the north west of Kawartha Conservation's jurisdiction within the municipality of the City of Kawartha Lakes. Head Lake is a relatively small lake with a surface area of 9.38 km^2 located at the headwater portion of the Head River. Further downstream the Head River converges with the Black River that, in turns, flows into the Severn River and, consequently, into Georgian Bay.

Key Issues

- ***The majority of the development around Head Lake is situated along the shoreline.*** This may pose risks to water quality from septic outputs, and residential pollutants such as gasoline spills, stormwater runoff, sediment loading from poor construction practices, excessive tree removal and the hardening of shorelines etc.

Information Gaps

- *There is a lack of data on Rush Lake*
- *There is a lack of data on seasonal versus year round population*.

Project History

The Head Lake and Rush Lake watersheds are located to the north west of Kawartha Conservation's jurisdiction within the municipality of the City of Kawartha Lakes. Similar to other local lakes, for the most of the 20th century, the lake serves 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. To create the framework for the future management of Head Lake, including best management practice recommendations, the City of Kawartha Lakes (CKL) initiated the development of the Head Lake Stewardship Plan (HLSP) as a continuation of the Kawartha watershed-wide lake management initiative. The first phase of watershed-wide Lake Management Planning in the City of Kawartha Lakes was initiated in 2010. During 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 (BCLMP) was started and completed in 2015. The Pigeon Lake Management Plan (PLMP) followed and was initiated in 2012 and has been completed, but final approval is currently stalled until First Nations Consultations have been completed. The Four Mile Lake plan was completed in 2016 and is in the finalizing steps of being approved by the Board of Directors and then the City of Kawartha Lakes Council.

The Watershed Characterization Report is an overview of the current state of the aquatic and terrestrial ecosystems within the Head and Rush Lakes core planning area. The core planning area includes all of the subwatersheds that drain directly into Head and Rush Lakes. 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 receiving tributaries. It provides the findings from our scientific research and environmental monitoring for the three-year period from June 2014 to June 2017. Additionally, it includes information and data from previous studies dating back to the 1980s and early 2000s.

The information gathered will help to further understand the issues and stressors impacting the lakes, provide an overview of watershed health, to ultimately inform the Head and Rush Lakes Stewardship Plans in terms of developing effective recommendations for protecting and enhancing lake health.

Study Area

The Head Lake watershed (including Rush Lake) occupies a small area (130.91km^2) located to the north east of Kawartha Conservation's jurisdiction mostly within the municipality of the City of Kawartha Lakes, but includes a small portion in Minden Hills. The majority of the land area within the Head Lake Planning Area south, east, and west of Head Lake is forested, with a few smaller, isolated wetlands, most notably surrounding a small tributary that flow into Head Lake from Duck Lake and Rush Lake to the south. The study area for the Head and Rush Lakes Management Plan is defined as three sub-watersheds which have been delineated as: the Fishog River sub-watershed extends north from the mouth of the Fishog River; the Head Lake Central sub-watershed includes lands that immediately surround the lake; and the Rush Lake sub-study area.

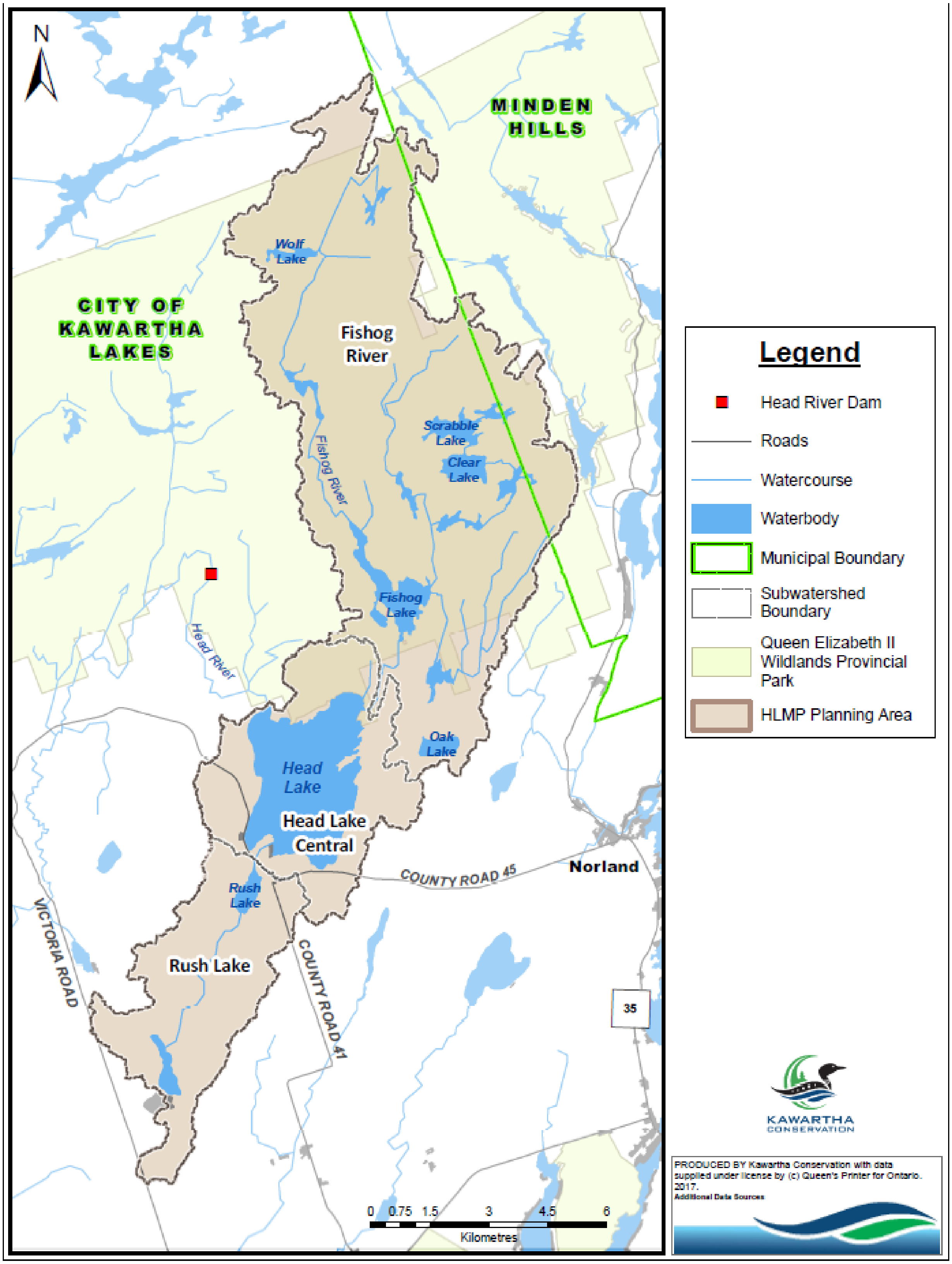


Figure 1.1. The Head and Rush Lakes study area.

1.4 History

Prior to European settlement, the Head Lake area was settled by First Nations. In the area, Indigenous Peoples were the first peoples to occupy the Head Lake region. In the past, three different First Nation communities were present in the region: the Huron, the Iroquois and the Mississaugas (Kirkconnel, 1921). The Huron people were believed to first occupy the Head Lake region through much of the 1400s and 1500s and participated in agriculture (LeCraw, 1967). Archeological evidence has found early tools and weapons in this region and four early Huron communities (prior to the settlement of the Mississauga first nations in the 1700s) were identified in the former townships of Laxton (to the south of Head Lake) and Digby (to the north of Head Lake). These communities were located (Kirkconnel, 1921):

1. On the southern shore of Beech Lake, 3-4 km east of Head Lake (in Laxton)
2. Adjacent to Oak Lake, 1-2 km east of Head Lake (in Laxton)
3. 250 m east of Head Lake, on a portage route from the Gull River (in Laxton)
4. 3 km North of Head Lake on the Head River (in Digby)

In the late 1500s and 1600s the Iroquois First Nation entered the region from what is now New York State and war ensued between the Iroquois and Hurons (LeCraw, 1967). Jesuit priests were present in this area in the late 1500s and reported two Huron groups located near Head Lake named the Rock and the Deer people (LeCraw, 1967). With the attack from the Iroquois, the Rock and Deer people fled the region in approximately 1590 and 1610 respectively to join up with the Lake Simcoe tribe in defense against the Iroquois (LeCraw, 1967). The Iroquois wiped out the Huron first nations between 1649 and 1650 and retreated southeast, leaving the Head Lake Region absent of First Nations settlements for over 100 years (LeCraw, 1967).

In the early 1700s the Mississauga First Nation living near Sault St. Marie sent people south to fight the Iroquois but, had little success against the Iroquios at this point (LeCraw, 1967). In 1740 the Algonquin council of war was formed and larger scale attacks on the Iroquois ensued with significant battles just outside what is now Coboconk (southeast of Head Lake) and at Indian Point (north of Balsam Lake) (LeCraw, 1967). The Mississauga First Nation proved victorious and settled in the Head Lake region.

Samuel de Champlain was the first European to explore the Kawarthas in 1615, though European settlement in the area did not occur for some time afterward (Kirkconnel, 1921). Shortly after the British took over control of Canada in 1790, the former area of Victoria County was sold to the British from the Mississauga First Nation in 1818 at Port Hope (LeCraw, 1967). Also during this time the British government sent out survey parties throughout southern/central Ontario with the intention of findings a safe passage from Ottawa to Georgian Bay that was south of the French River (LeCraw, 1967). The intense surveying was spurred by numerous threats from the United States at this time including the American Revolution, the War of 1812, and the Oregon Boundary Dispute (LeCraw, 1967). In 1819 Lt. J. P. Catty and a party of surveyors left Lake Simcoe and found Balsam Lake, where they travelled north along the Gull River to find Shadow Lake, just east of Head Lake (LeCraw, 1967). Coboconk, south of Shadow Lake was settled in 1852 and extensive logging took place in both the Head and Shadow Lake regions at this time (LeCraw, 1967). The first home was built on Head Lake in

1861 by the Riley family, followed by numerous other families of British, Irish, and Scottish descent (LeCraw, 1967). Shortly afterwards a lodge and Union Church were built on Head Lake in 1867 and 1888 respectively (LeCraw, 1967). Today, little logging still occurs in the area and Head Lake is now used primarily for recreation and cottages.

Head Lake is currently located entirely within the City of Kawartha Lakes, formed in 2001, but formerly Head Lake transversed the boundaries between the townships of Digby (to the north) and Laxton (to the south) as a part of Victoria County. As the township of Digby and Longford (north of Digby) had so few residents (the population in Digby is less than 100), they united with the township of Laxton for municipal and consensual purposes (Kirkconnel, 1921).

2.0 Land Use

Summary of Observations, Key Issues, and Information Gaps

Observations

- ***Almost the entire land area north of Head Lake within the Queen Elizabeth II Wildlands and consists of shallow lakes, wetlands, and forests. There are no large communities located near Head Lake, though numerous cottages, homes and two trailer parks are located by the lakeshore.***

Key Issues

- ***Bedrock aquifers dominate groundwater storage and transport, are highly vulnerable to contamination due to thin overburden depths and widespread bedrock fracturing.*** Contaminates entering bedrock aquifers around Head Lake may be quickly transported to the lake through the fracture network.
- **Head Lake is located within the Land Between which contains unique ecosystems characteristics of overlapping flora and fauna populations, as well as containing species unique to the Land Between.** It is therefore important to preserve natural land in this region.
- **Steep slopes on the east side of the lake may be easily eroded or destabilized if the land is cleared for logging or construction.**
- **While the primary water inputs into Head Lake come from the Canadian Shield, the majority of the lake is underlain by limestone giving it a higher buffering capacity than lakes entirely within the Canadian Shield**

Information Gaps

- ***There is a need to determine the magnitude of groundwater inputs into the lake***
- ***There is little information on bedrock conductivity around the lake.*** This is of importance for contaminate transport rates.

2.1 Land Use

Head Lake is located approximately 11 km NNE from Balsam Lake, and the northern shore of Head Lake borders the Queen Elizabeth II Wildlands **(Figure 2.1).** Almost the entire land area north of Head Lake is within the Queen Elizabeth II Wildlands and consists of shallow lakes, wetlands, and forests **(Figure 2.2).** There are no large communities located near Head Lake, though numerous cottages and homes are located by the lakeshore. As of 1994, the total building count around Head Lake was 389. With a shoreline distance of 19.3 km, the building density around the lake is a moderate 20.2 buildings/km. The majority of the land area within the Head Lake

Planning Area south, east, and west of Head Lake is forested, with a few smaller, isolated wetlands, most notably surrounding a small tributary that flow into Head Lake from Duck Lake and Rush Lake to the south **(Figures 2.1, 2.2)**. The wetland surrounding the tributary entering Head Lake from Duck Lake and Rush Lake to the south has been identified as a Provincially Significant Wetland **(Figure 2.3).**

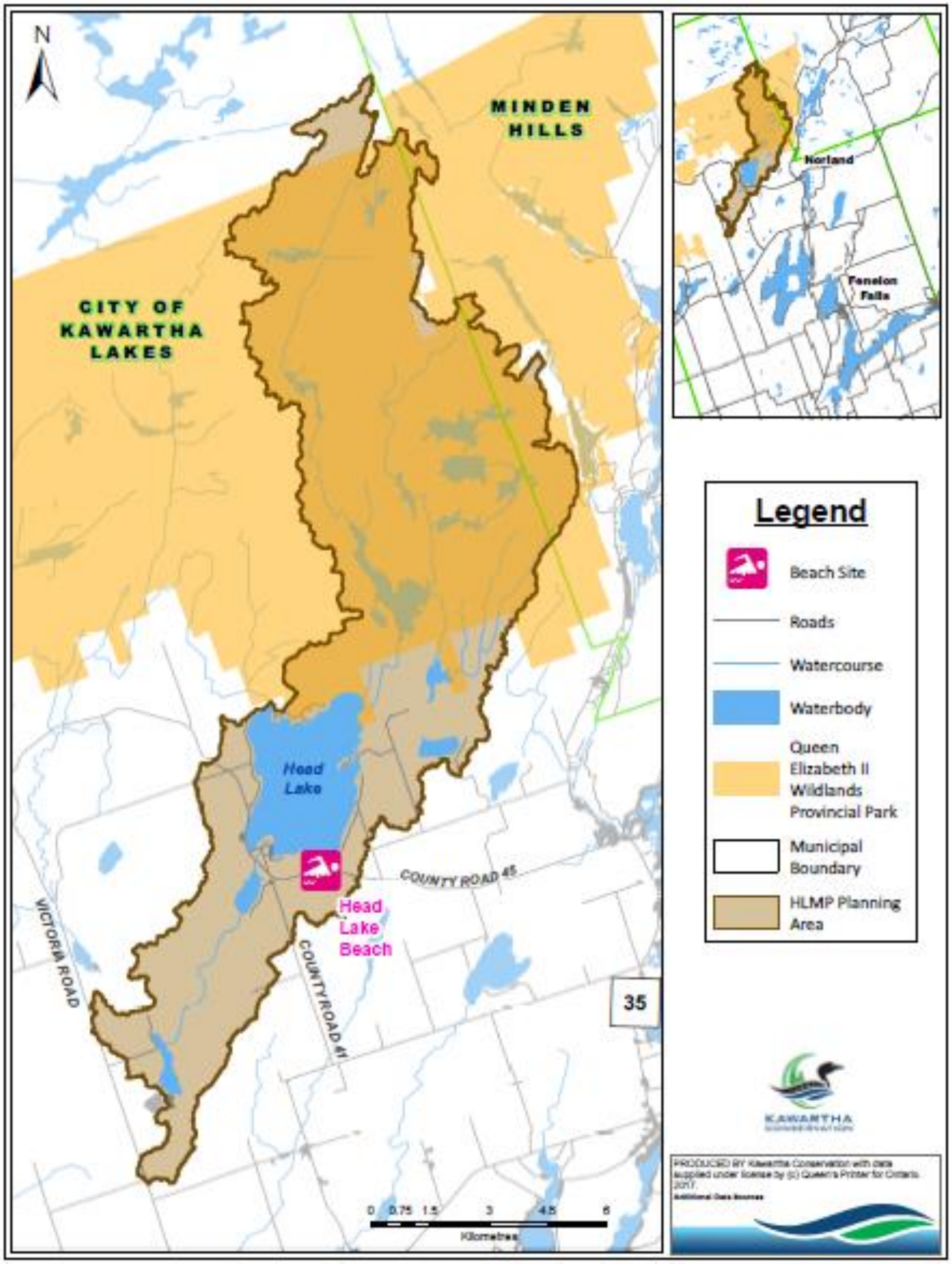


Figure 2.1. Queen Elizabeth II Wildlands Provincial Park and its vicinity to the Head Lake study area.

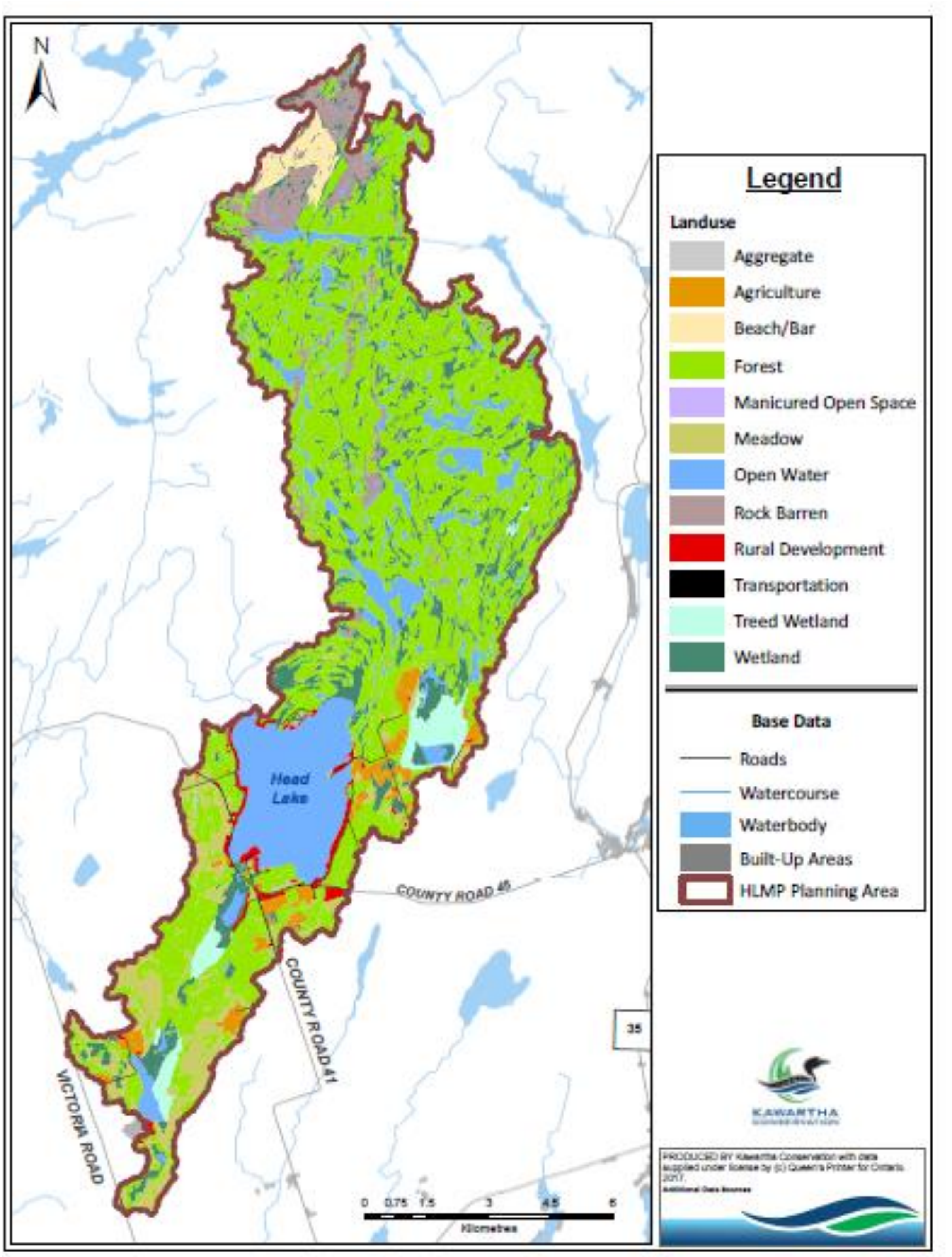


Figure 2.2. Map of land use in the Head Lake study area. Note the large tracks of natural areas.

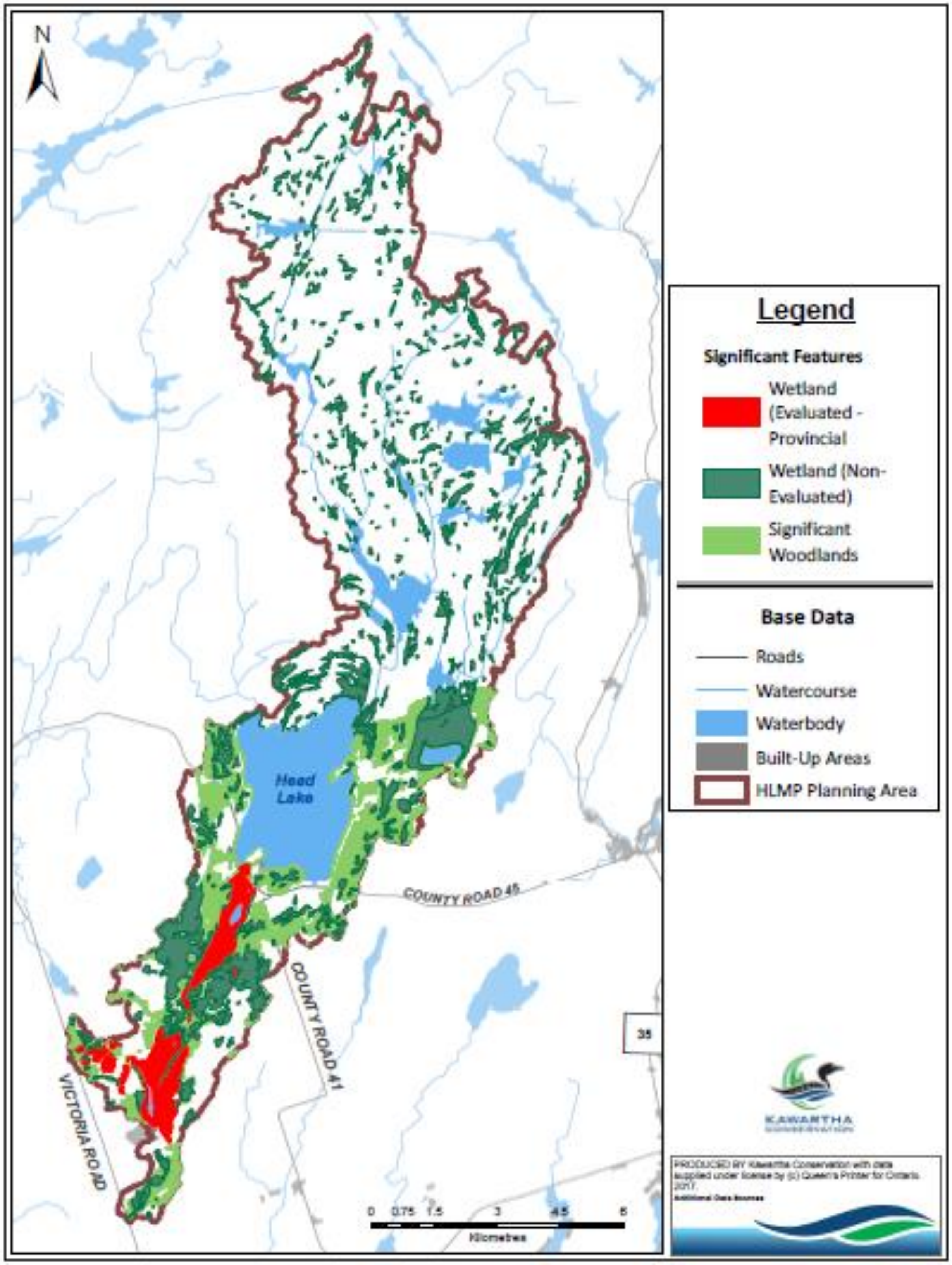


Figure 2.3. Map of wetlands (evaluated and unevaluated) within the study area of Head Lake.

The contrast between near-shore land use and land use further inland is striking at Head Lake. Within 100 meters from the shoreline 58.6% of the land is used for rural development and roads, with forests and wetlands covering the majority of the remaining land at 23.6% and 10.5% respectively **(Table 2.1)**. However, when the land use 1000 meters from the shore of Head Lake is evaluated, only 11.8% of the land is used for roads and rural development, with forests covering over half the area (55%), and wetlands (12.4%) and meadows (11.1%) combining to cover almost a quarter of the land **(Table 2.1)**. There is concern about the clear-cutting of large lake-front properties on Head Lake which could destabilize the slopes and increase sediment loading into the lake. Agriculture is minimal in the Head Lake region, though a few scattered farmers' fields are located on the eastern side of Head Lake atop the Carden Plain **(Figures 2.2, 2.4).** Within 1000m of Head Lake agriculture is comprising only 8.4% of the total land cover **(Table 2.1).**

There are three sub-watersheds that have been delineated within the Head Lake Planning Area: the Fishog River watershed, the Head Lake Central watershed, and the Rush Lake watershed **(Figure 2.5)**. Land use is generally similar between the sub-watersheds, though there are some noticeable differences **(Table 2.2).** The Head Lake Central watershed, containing Head Lake itself, clearly has the highest proportion of both open water (40%) and human development (7%). The Fishgog River watershed is predominately in both the Canadian Shield and the Queen Elizabeth II Wildlands, and contains a relatively high proportion of natural forests (62%), rock barrens (9%), and wetlands (15%). The Rush Lake watershed, south of Head Lake, contains a larger fraction of natural meadows (27%) characteristic of the Carden Plain (prairie-like landscapes within the Carden Plain are known as the 'Carden Alvar' and is an attraction for naturalists), while also contain large fractions of forest (45%), and wetlands (15%).

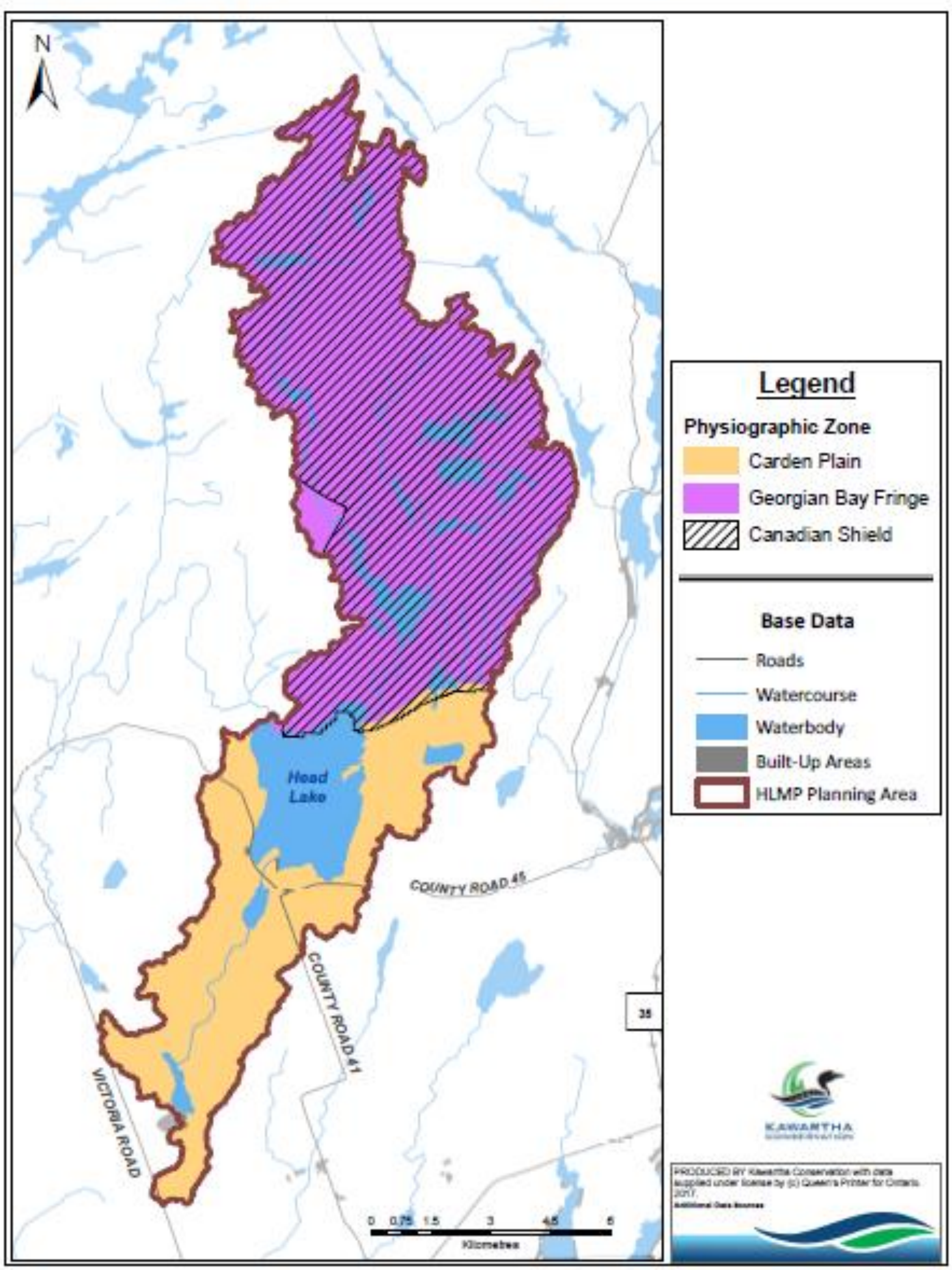


Figure 2.4. Map of the physiographic zones within the Head Lake Management planning area.

Table 2.1: Land use at 100 and 1000 meters from the shoreline of Head Lake within the Head Lake Planning area.

Land Use	100m from shoreline (%)	1000m from shoreline (%)
Rural Development	58.6	11.8
Forest	23.6	55.0
Agriculture	3.5	8.4
Wetland	10.5	12.4
Meadow	3.3	11.1
Open Water	0.4	1.4

Table 2.2: Land-use by sub-watershed in the Head Lake Planning Area. Note that 'development' includes both roads and buildings. Refer to Figure 2.6 for sub-watershed locations.

	Watershed Name		
Land use Category	**Fishgog River (%)**	**Head Lake Central (%)**	**Rush Lake (%)**
Aggregate	0.0	0.2	0.0
Agriculture	1.3	4.2	6.0
Forest	61.8	34.7	45.0
Manicured Open Space	0.0	0.2	0.0
Meadow	0.4	7.1	27.0
Open Water	10.1	39.5	4.2
Rock Barren	9.1	0.1	0.0
Rural Development	0.1	6.6	2.7
Wetland	17.2	7.6	15.1

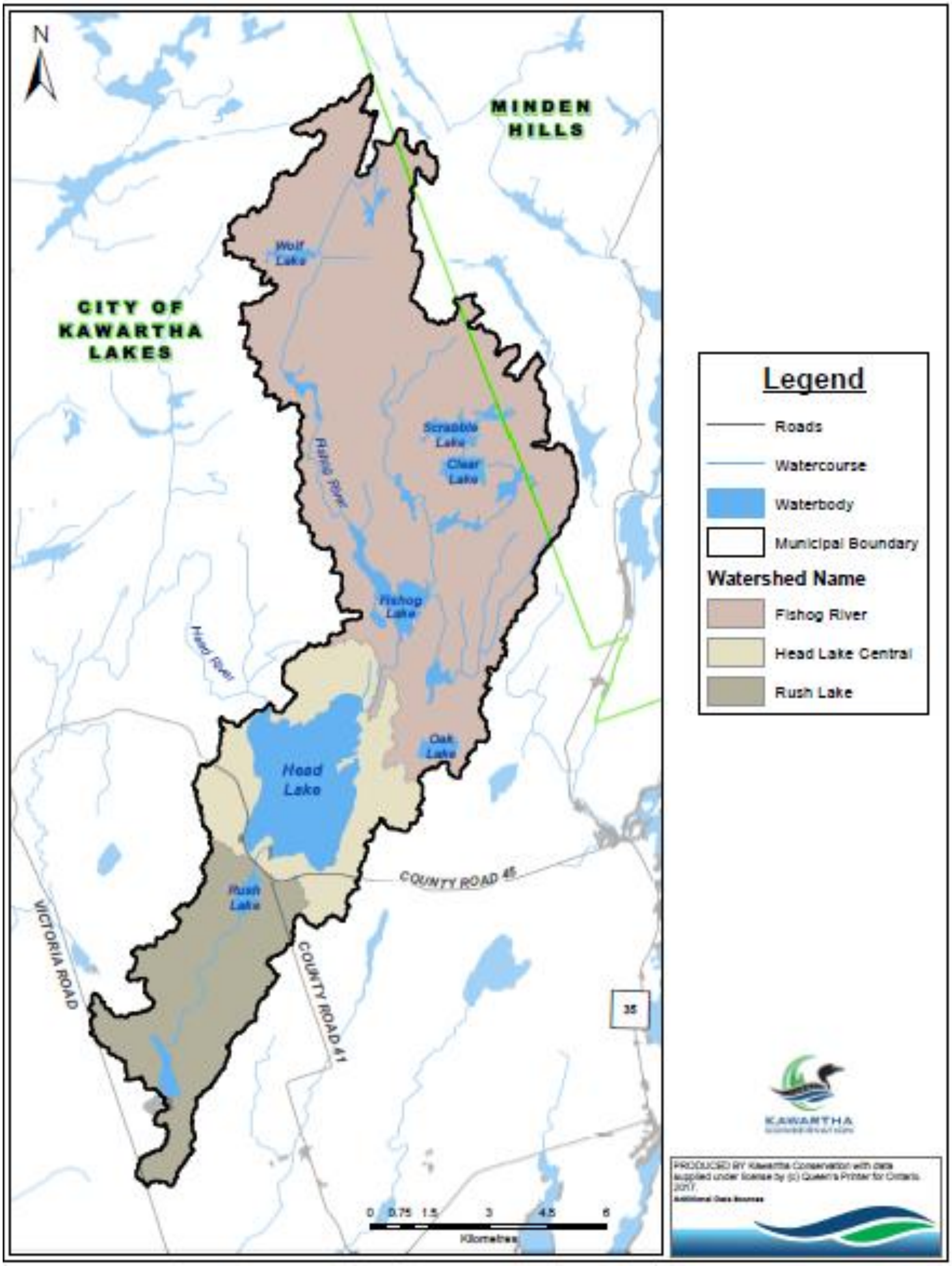


Figure 2.5. Delineation of the subwatersheds within the Head Lake study area.

2.2 The Land Between

Head Lake traverses the boundary between older Precambrian bedrock to the north and younger, Paleozoic limestones to the south, and is considered part of the 'Land Between'. The Land Between is the intersection zone between the Canadian Shield ecosystem and that of the St. Lawrence Lowlands. The Land Between is therefore considered an 'ecotone' which contains elements of both ecosystems it transverses, but that also contains elements entirely unique to the transition zone. The Land Between, which extends from the Frontenac arch, through central Ontario, and across to Georgian Bay near Parry Sound, is host to the overlapping of the southern limit of many flora and fauna typical of the Canadian Shield and the northern limit of flora and fauna characteristic of the St. Lawrence Lowlands **(Berman, 2008)**.

2.3 Geology

The northern edge of Head Lake transverses the boundary between older, Precambrian bedrock of the Canadian Shield to the north, and younger, Paleozoic, limestone bedrock to the south (underlying the Carden Plain) **(Figure 2.4**). The older Precambrian bedrock in the north is part of the Georgian Bay Fringe (GBF) physiographic zone which extends from the northern portion of the Kawartha Lakes, westward to the Muskoka region and north to Parry Sound **(Chapman and Putnam, 1984)**. The portion of the Georgian Bay Fringe north of Head Lake consists of both metavolcanic and metasedimentary rocks which are part of the Central Gneiss Belt of the Grenville Province. High deformed gneisses dominate the Central Gneiss Belt, where granitic plutons became highly metamorphosed from ancient mountain building processes **(Easton, 1992).** Near-surface bedrock is highly fractured and forms a series bedrock ridges/knobs and intervening valleys/depressions created as a result of intense tectonic and glacial activity in the region **(Chapman and Putnam, 1984).**

Soils are generally thin (<5m) within the GBF (there is no assigned soil group in this region), with deeper soil deposits forming in low-lying valleys/depressions and thinner or absent soils on bedrock ridges **(Figure 2.6).** Soils are believed to be thin in the GBF due both to the resistance of the Precambrian bedrock to weathering and to the scraping and removal of soils from this region during the Pleistocene glaciations which were deposited further south **(Chapman and Putnam, 1984**). Soils overlying the Precambrian bedrock north of Head Lake are predominately fine sandy loams or silty loams of moderate to low permeability **(Figure 2.7).** The poor infiltration rates of the soil in valleys and depressions have supported the development of numerous wetlands and the creation of large quantities of organic soils/peat **(Figure 2.2).**

The majority of Head Lake and the land to the south of the lake is underlain by Paleozoic limestones and is part of the Carden Plain physiographic zone **(Figure 2.4).** The Carden Plain has a flat topography and is generally characterized by a thin overburden of glacial tills **(Gillespie and Richards, 1957).** The limestone bedrock below the Carden Plain is part of the Simcoe Group and is Middle-Ordovician in age **(Johnson et al., 1992).** As part of the Simcoe group, the Gull River Formation underlies Head Lake, ranging between 7 to over 100 meters in depth, and thinning to the north as it approaches the Canadian Shield **(Ontario Geological Survey, 2000; Morrison Environmental, 2004)**. The Gull River Formation is fine-medium bedded, and consists of micritic to fine grained limestones and dolostones and is moderately fossiliferous (**Johnson et al., 1992; Ontario Geological Survey, 2000)**.

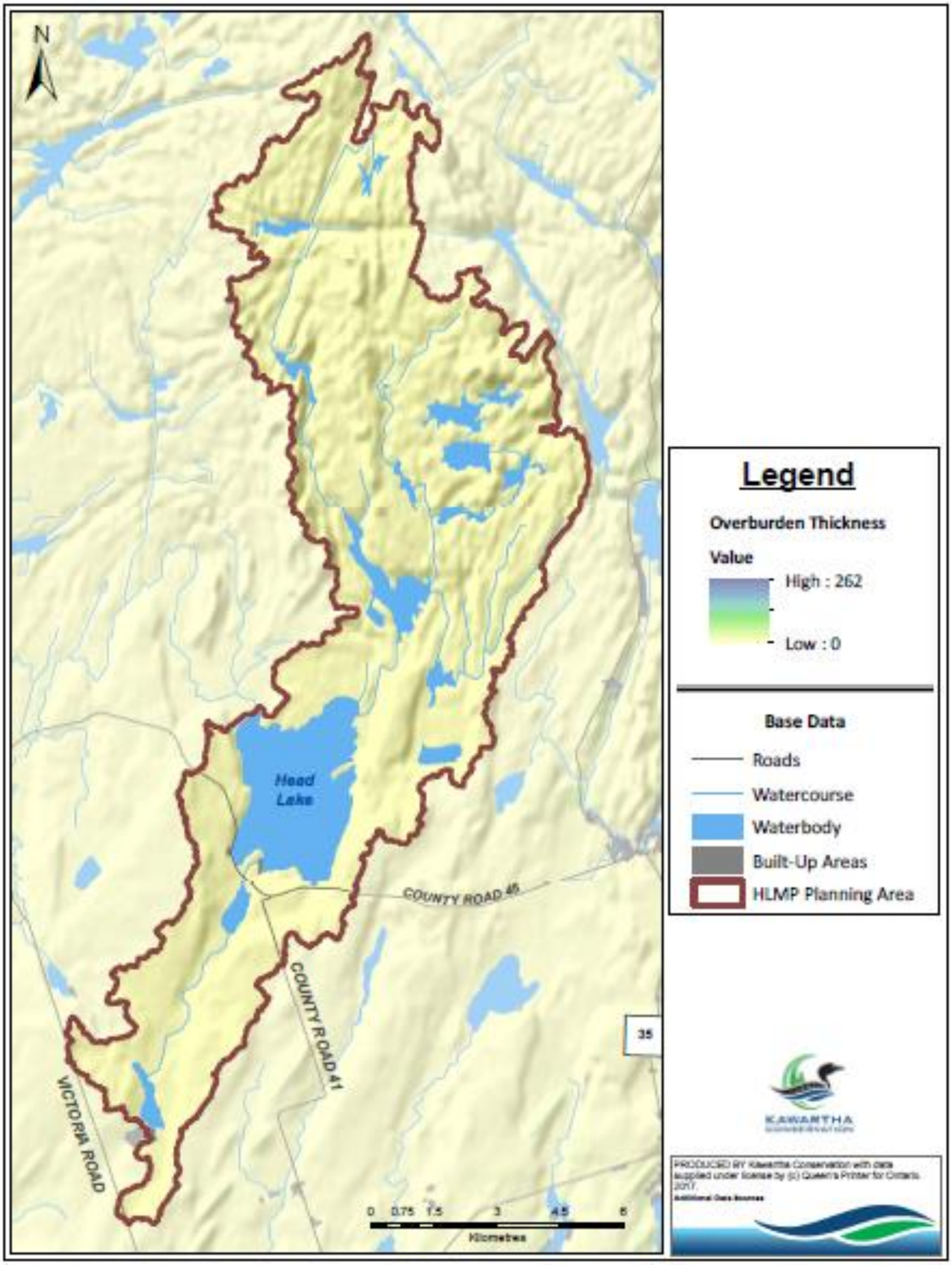


Figure 2.6. Overburden thickness values for the Head Lake study area.

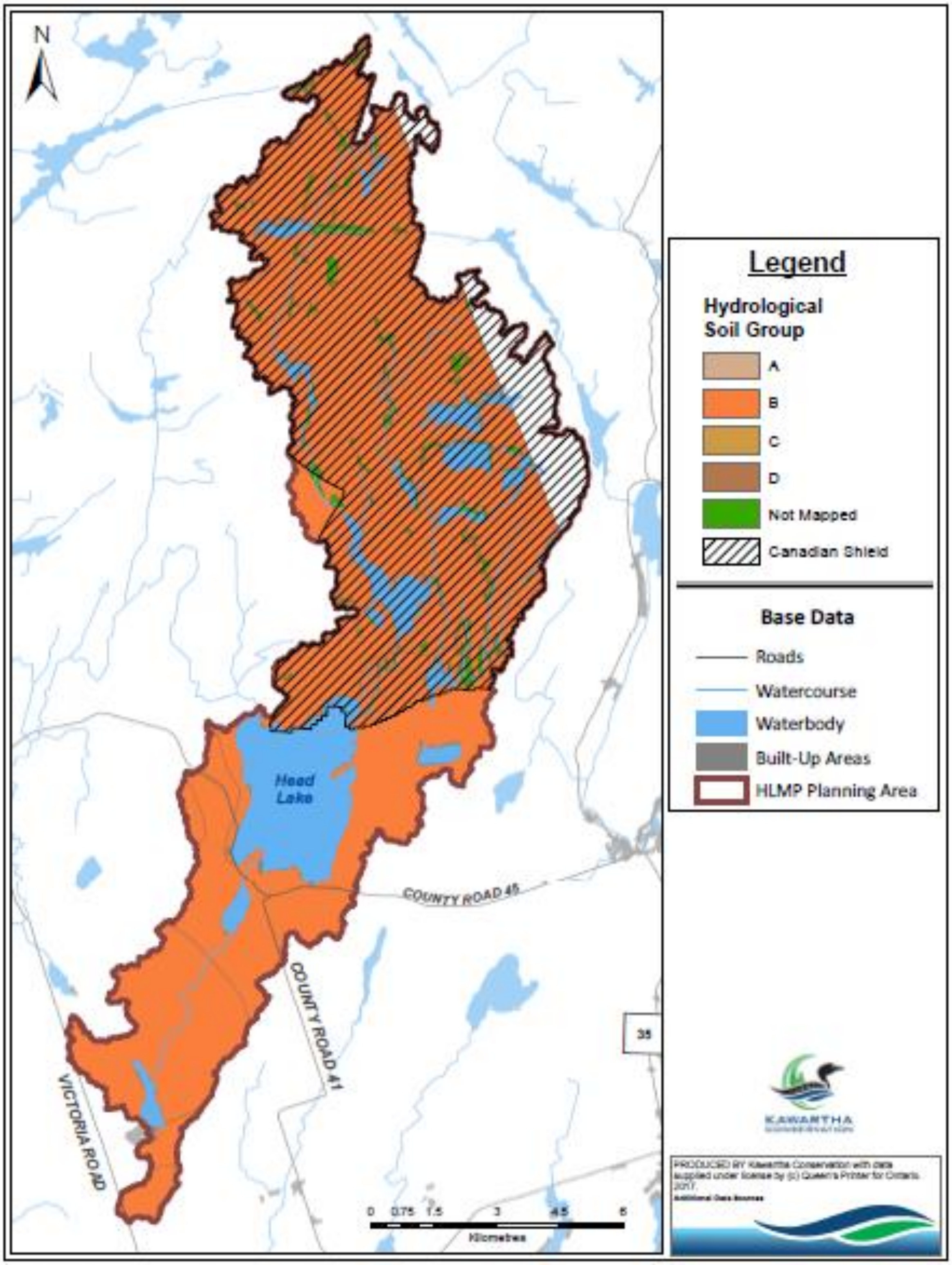


Figure 2.7. Various hydrological soil types within the Head Lake study area.

The Gull Formation is highly fractured and allows for the storage and the rapid infiltration and movement of groundwater. The southern portion of the Head Lake Planning Area is underlain by the Bobcaygeon Formation that generally consists of fine grain, heavily bioturbated limestone beds with occasional shale interbedding **(Ontario Geological Survey, 2000).**

Overburden depths in the Carden Plain near Head Lake are generally <5m thick and are a part of Dummer Loam – Shallow Phase soil series **(Figures 2.6 & 2.8)** The Dummer Loam – Shallow Phase consists of stony, calcareous, morainic deposits that comprise the western edge of the deeper Dummer Loam deposits **(Gillespie and Richards, 1957)** which extend eastward towards the Frontenac Region **(Gillespie et al., 1966).** The Dummer Loam – Shallow Phase is a coarse grained, well-drained soil with a high infiltration capacity **(Figure 2.8) (Gillespie and Richards, 1957)**. The Dummer Loam – Shallow Phase soil series is generally a poor substrate for agricultural purposes due to its shallow nature and poor water retention capacity, though a few farmers' fields have been established east of Head Lake in the Dummer Loam –Shallow Phase **(Figures 2.2 & 2.8).** The soils in the southern end of the Head Lake Planning Area (south of the Dummer Loam – Shallow Phase), are part of the Farmington Loam soil series **(Figure 2.8).** The Farmington Loam is typically less than 30 cm thick and therefore is highly susceptible to desiccation in the summer months (**Gillespie and Richards, 1957**). Like the Dummer Loam – Shallow Phase, the Farmington Loam is also poorly suited to agriculture.

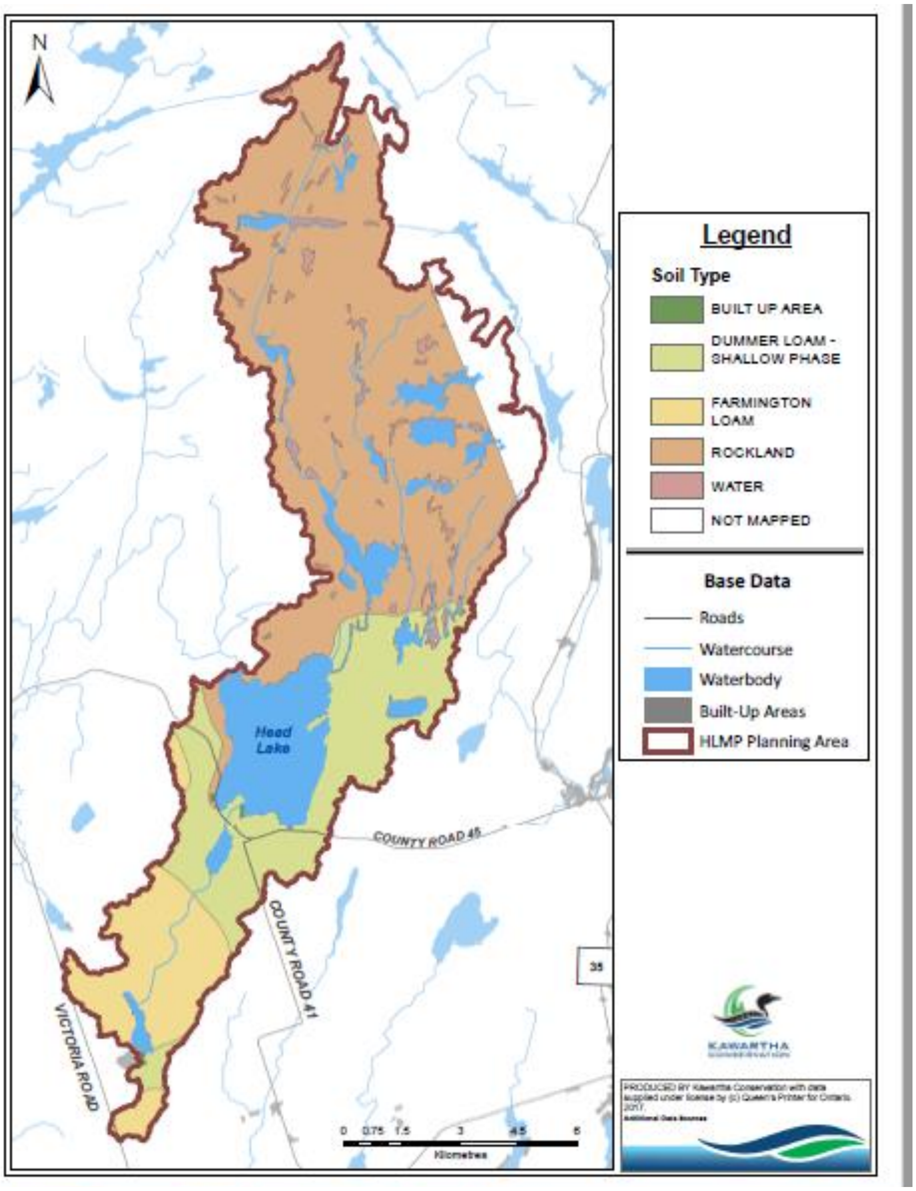


Figure 2.8. Various soils types within the Head Lake study area.

2.4 Topography

The nature of the topography surrounding Head Lake is highly dependent upon the geology of the underlying bedrock. In the GBF to the north, the topography is rugged with a series of numerous and tightly spaced ridges that are separated by intervening valleys **(Figure 2.9).** To the NE and several kilometres N of the lake these ridges are tall (with some exceeding 100m in elevation) and oriented in a NNE-SSW direction, while smaller ridges and valleys oriented in a NE-SW direction are found directly N and NW of the lake. Topography is relatively flat in the Carden Plain south of the lake, though a large ridge runs along the western shore of Head Lake and south of Head Lake past Rush Lake **(Figure 2.9).**

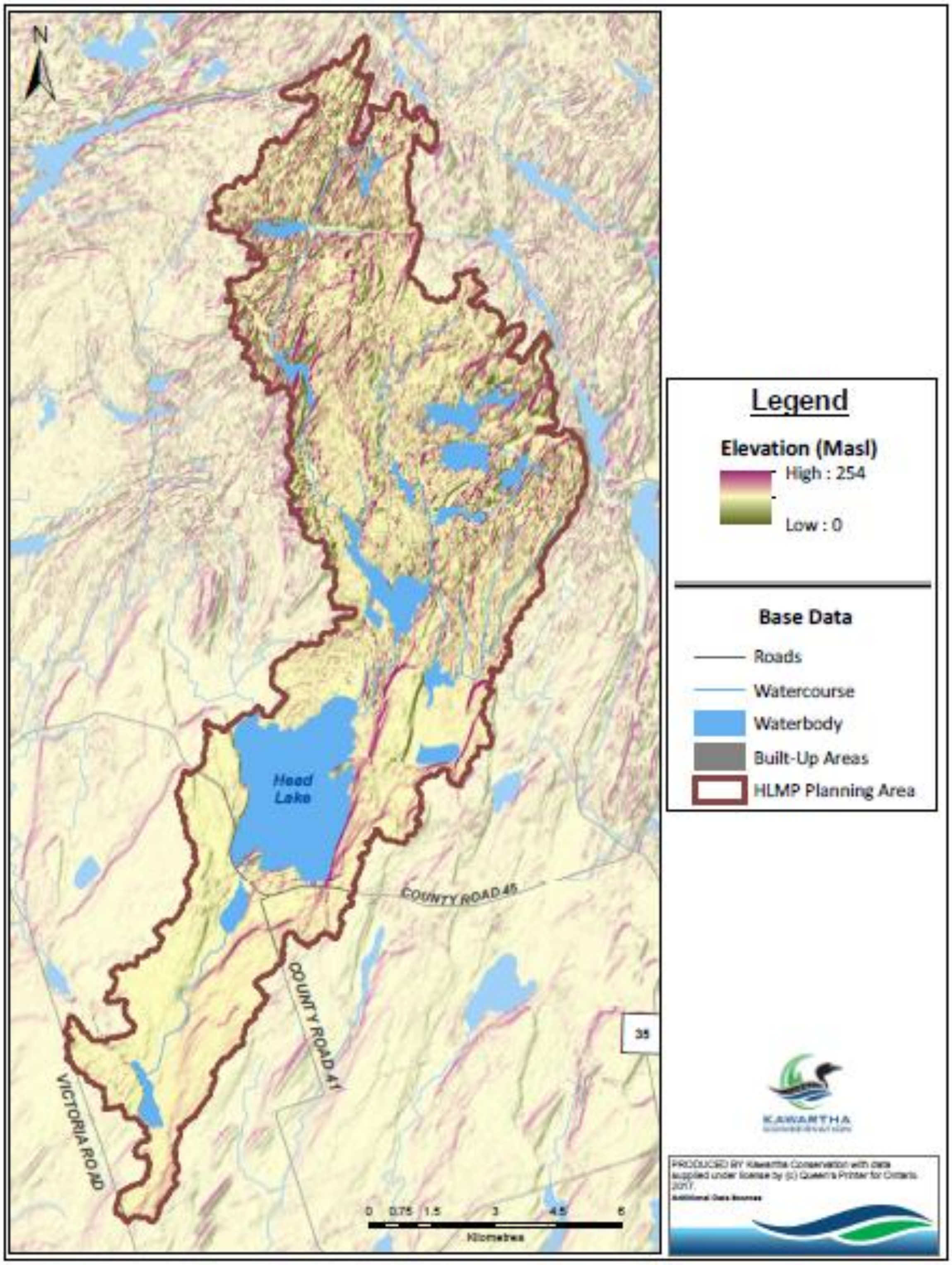


Figure 2.9. Elevations (Masl) of the Head Lake study area.

2.5 Relationship between Soil/Geology and Hydrology

North of Head Lake in the GBF, the direction and nature of flow is controlled primarily by the nature of the underlying bedrock, as it is in most portions of the Canadian Shield which have thin or absent overburden **(Spence and Woo, 2003).** The Fishog River represents the largest source of surface water into Head Lake, following by the Rush Creek. A number of smaller, ephemeral tributaries are present following periods of rainfall or snowmelt. More details on surface water flows are available in **Section 4 Water Quantity**. Due to the thin and impermeable soils and the rugged topography north of Head Lake, surface and shallow groundwater (above the Precambrian bedrock) flow likely occur rapidly into the lake.

From the Canadian Shield, groundwater flows into Head Lake and its adjacent lakes/rivers. The moderate permeability of the soils north of Head Lake **(Figure 2.7)** in combination with thin or absent overburden **(Figure 2.6)** may create local hotspots of groundwater recharge. Indeed, the classification of Head Lake as a ‘cool’ lake suggests that there may be significant groundwater discharge either directly into the lake, or into Fishog Lake/ River (Fishog Lake is considered a ‘cold’ lake implying that it may receive considerable groundwater inputs) **(Figure 2.10).** As the primary permeability of the Canadian Shield rocks is low, the permeability and storage capacity of Precambrian bedrock aquifers north of Head Lake should be dominated by secondary permeability caused by factures, joints, and faults in the Precambrian bedrock **(Freeze and Cherry, 1979; Spence and Woo, 2002; Singer, 2003).** While there are few studies in the Head Lake region that reported on the occurrence of fracturing/faulting in the Precambrian bedrock north of Head Lake, numerous bedrock fractures have been observed in the nearby lower Gull River watershed along with the occurrence of a number of natural springs **(Kawartha Conservation, 2008).** Furthermore, the specific capacity of multiple wells located in Precambrian bedrock aquifer north of Head Lake range between 11-99 m^3/day **(Morrison, 2003)**, suggesting that fractures likely contribute significantly to groundwater flow and storage in this area (un-fractured bedrock aquifers typically have a specific capacity <10 m^3/d).

Direct groundwater inputs into Head Lake may also occur from the Carden Plain to the south, east, and west of lake (**Figure 2.4**). Groundwater recharge in Carden Plain surrounding Head Lake should be sizeable, due to the thin, coarse grained overburden of the Dummer Loam – Shallow Phase (which has a high infiltration capacity), and due to the high fracture density in the Gull Formation underlying the Dummer Loam – Shallow Phase (**Singer, 2003**). Rapid recharge and shallow overburden that has a low absorptive capacity means that the bedrock aquifers in the Carden Plain are highly susceptible to contamination resulting from poor water management practices.

The transmissivity and permeability of the Paleozoic limestone to the south of Head Lake should be highly variable due to the irregular nature of fracture networks within the bedrock. In their evaluation of the hydrogeology of southern Ontario, Singer **(2003)** evaluated 6,414 wells drilled into the Simcoe Unit (of which the Gull River Formation is a part of), and found that the specific capacity ranged from 0.14 to 1503 m^3/day, with the 10^{th} and 90^{th} percentiles have a specific capacity of 0.72 and 429 m^3/day respectively (though with its high fracture density, the Gull River Formation is likely more permeable than some other formations in the Simcoe Group, including the Bobcaygeon Formation).

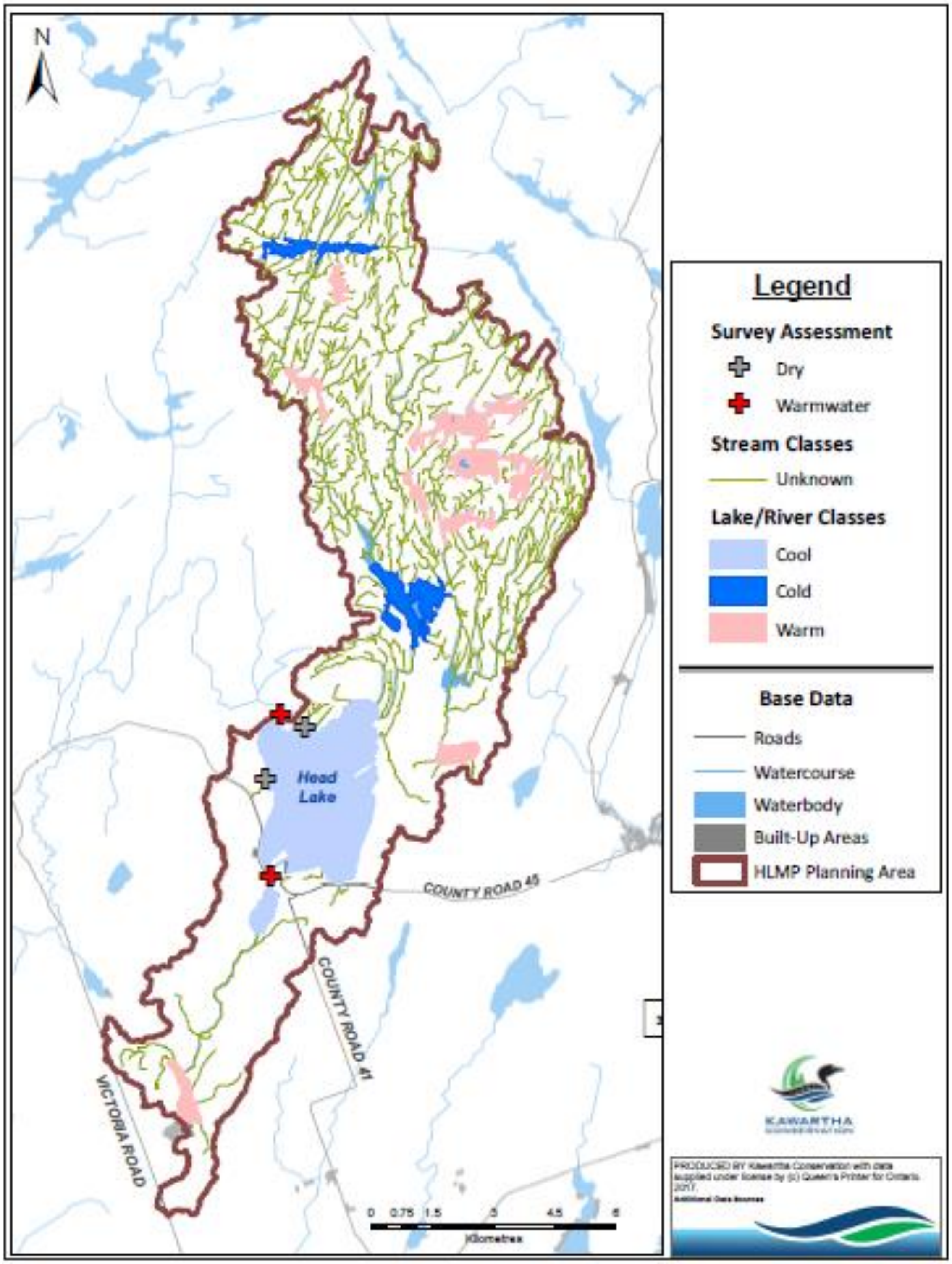


Figure 2.10. Thermal regime of water inputs into Head Lake.

Although it is difficult to estimate the magnitude of groundwater discharge into Head Lake from the Carden Plain (due to the wide range of potentially transmissivity values of the underlying Paleozoic bedrock), contaminates which have percolated into the Paleozoic bedrock may quickly enter Head Lake through the fracture network with little sorption onto the surrounding bedrock.

3.0 Climate

3.0 Summary of Observations, Key Issues, and Information Gaps

OBSERVATIONS

- **Climate within the Head 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.

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**.

3.1 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 Head 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.

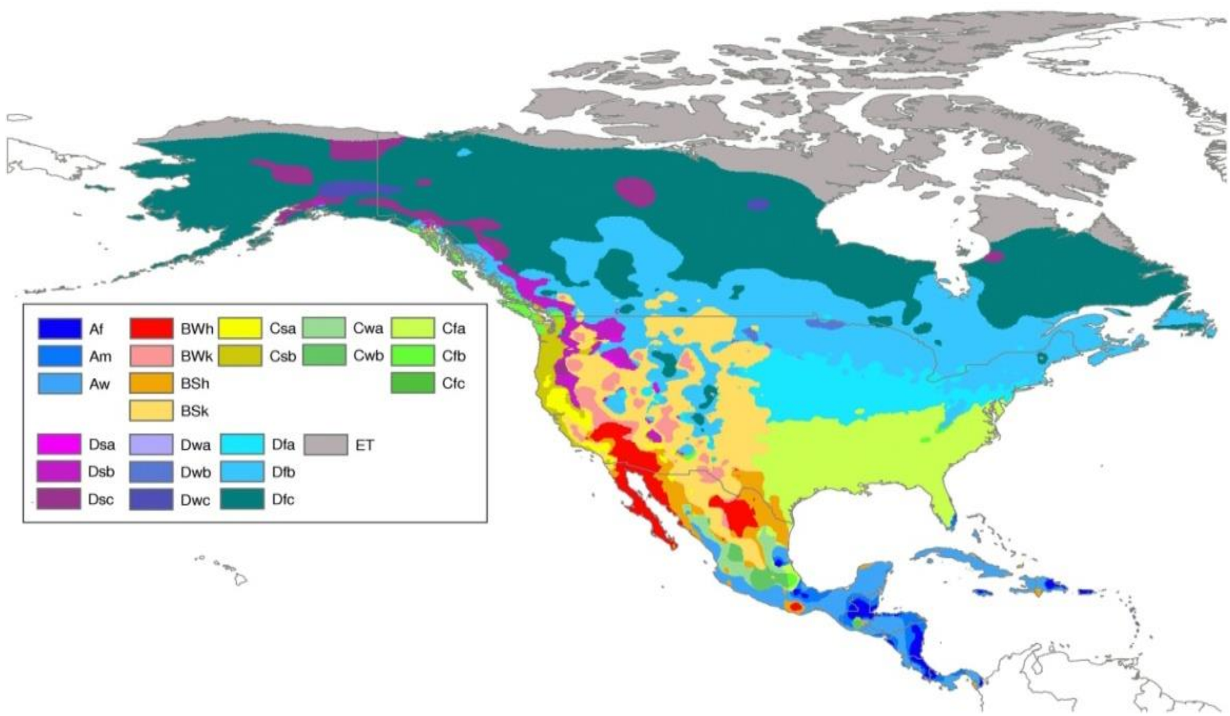


Figure 3.1. The Köppen Climate Classification System for North America
Source: http://www.eoearth.org

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 3.1).**

The climate monitoring station in Minden (Minden, Station ID 6165195) is the closest monitoring location from which data can be used to characterize climate variables of the study area. It is located outside of the study area, but no stations with the long-term records exist within the Head Lake subwatershed or its immediate vicinity. The Minden station was a component of the Environment Canada climate monitoring network, working in accordance with the United Nation's World Meteorological Organization standards and providing high quality monitoring data for over 60 years. Unfortunately, the station was decommissioned in 2011.

Average monthly temperatures and precipitation values for the Minden monitoring location are shown in **Table 3.1** and **Figure 3.2-3.4.** These data confirm the study area as belonging to the moist continental mid-latitude climate category.

Table 3.1. Average Monthly and Daily Extreme Values of Air Temperature and Precipitation for the Environment Canada Climate Monitoring Station Minden (6165195: 1981-2010).

Characteristic	Month												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Air Temperature													
Daily Average (°C)	-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)	11	13	23	30.5	34	34	**35.5**	35	33	28	23.3	17	
	2005/13	1984/23	1998/30	2002/16	2006/30	1994/16	2002/01	1887/02	2002/09	2005/05	1961/03	1982/03	
Extreme Minimum (°C)	**-41.1**	-39.4	-36.5	-24.4	-10	-3.9	-0.6	-3.3	-9.4	-13.9	-27.2	-40	
	1888/21	1962/02	1980/02	1887/01	1966/07	1972/11	1893/24	1965/30	1888/28	1887/30	1958/30	1980/25	
Precipitation													
Rainfall (mm)	30.9	25.4	38.7	67.9	97.6	90.6	82.2	78	100.2	93.8	84.3	34.4	824
Extreme Daily Rainfall (mm)	44.4	47.6	43.4	41.9	55.9	93.7	99.8	71.6	57.2	55.1	55.4	41.9	
	1998/05	1997/21	1948/19	1956/27	1894/20	1957/28	1986/25	1974/16	1965/05	1893/14	1993/27	1949/22	
Snowfall (mm)	58.8	41	32.5	10.9	0.2	0	0	0	0	3.4	25	60.3	232.1
Extreme Daily Snowfall (mm)	29.2	30.5	33	22.9	6.4	0	0	0	0	17	30	48	
	1949/02	1887/11	1943/10	1975/03	1966/03	1886/01	1886/01	1886/01	1886/01	1979/08	1987/25	2000/11	
Total Precipitation (mm)	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

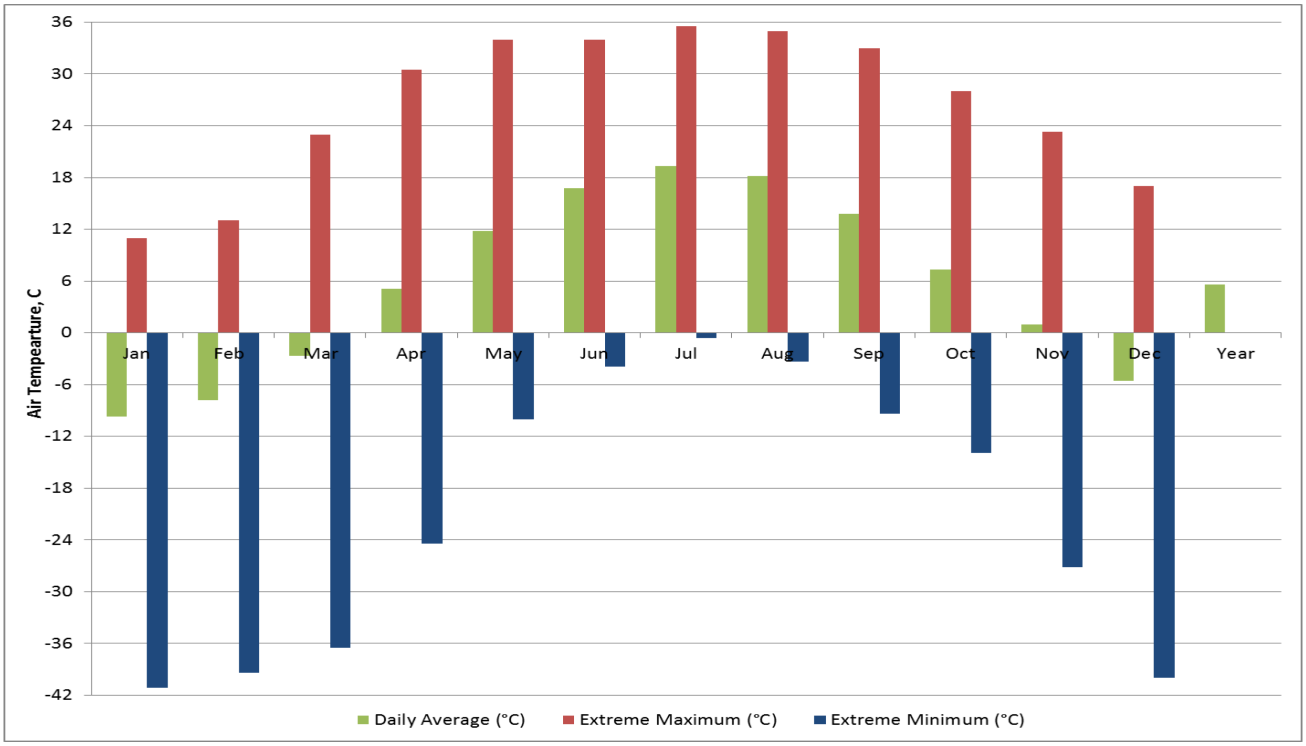


Figure 3.2. Monthly Air Temperature for the Minden Climate Monitoring Stations (6165195: 1981-2010): Daily Average, Extreme Maximum and Extreme Minimum Values.

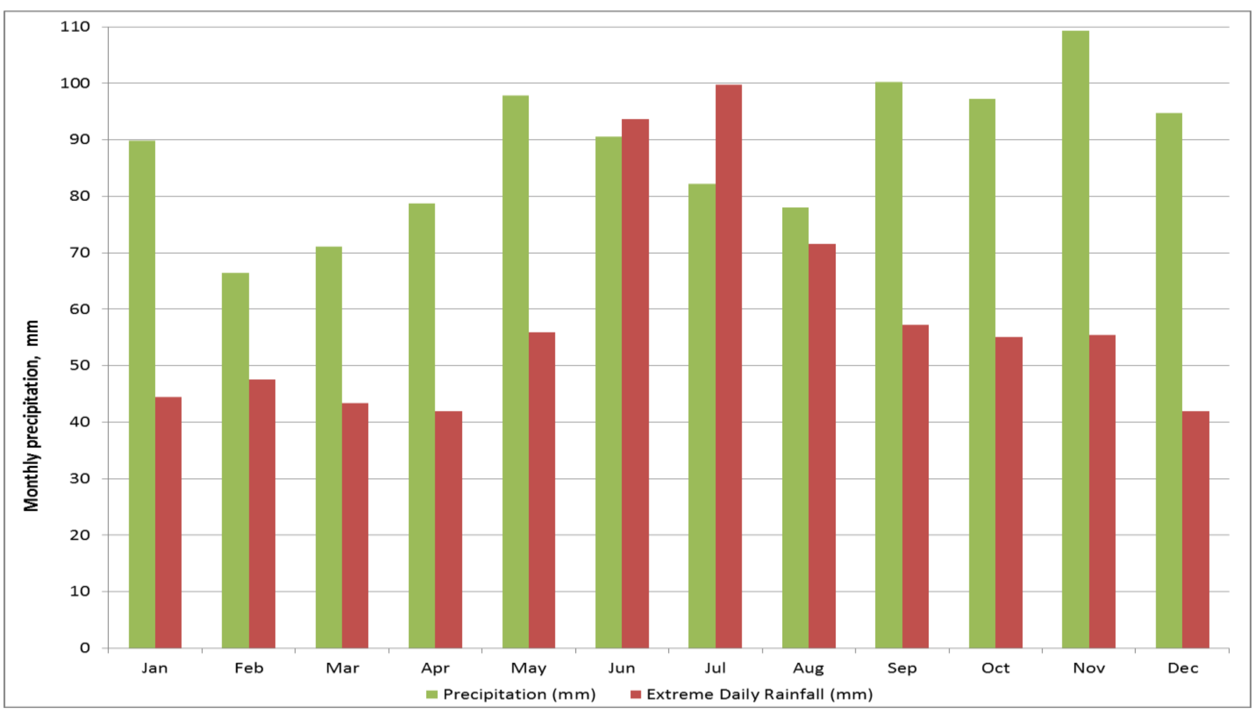


Figure 3.3. Monthly Precipitation Normals and Extreme Rainfall Values for the Minden Climate Monitoring Station (6165195: 1981-2010).

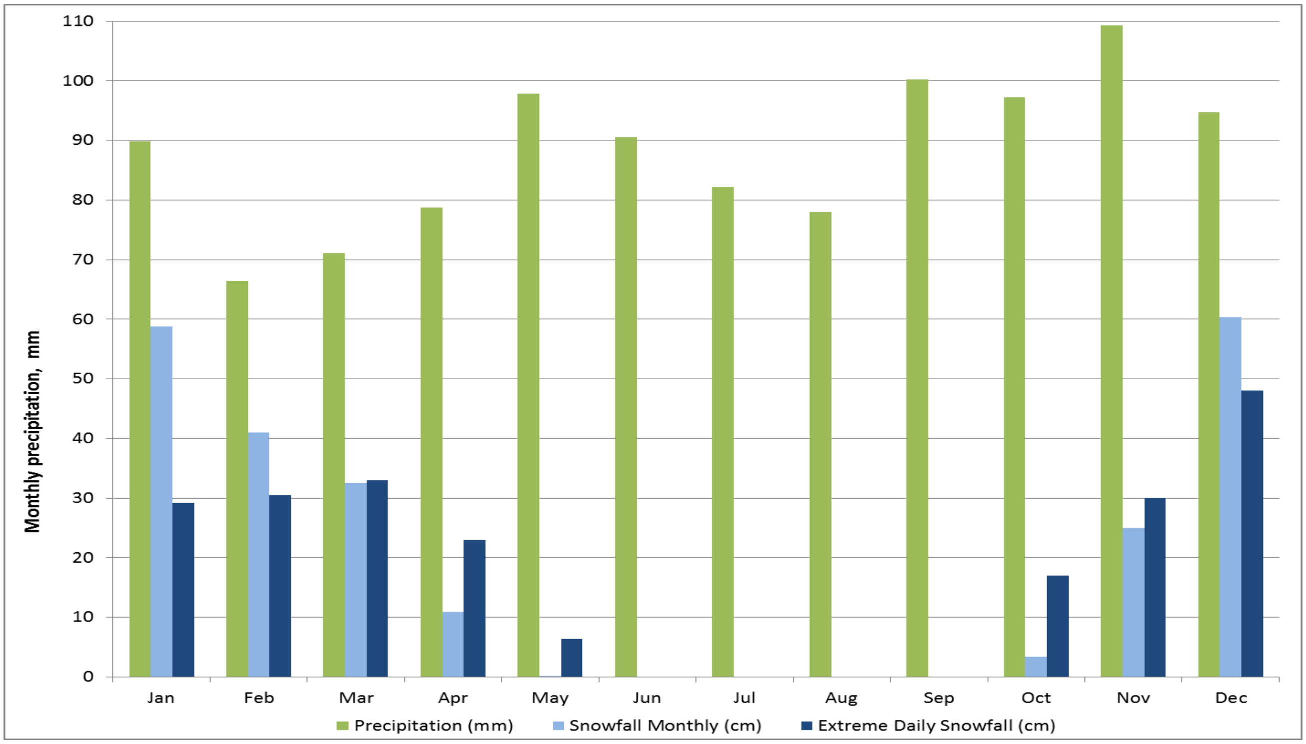


Figure 3.4. Monthly Precipitation Normals for the Environment Canada Climate Monitoring Stations: Minden (6165195: 1981-2010).

3.2 Air Temperature

The average winter monthly air temperature for the Minden climate station for the period from 1981 to 2010, ranges from -5.6°C in December to -9.7°C in January, which is the coldest month of the year **(Table 3.1).**

July is the warmest month with the average monthly temperature reaching 19.3°C. August is the second warmest month, with an average temperature of 18.2°C, while the average temperature in June is 16.8°C.

According to climate observation records, an extreme minimum temperature was observed in January 1881 at -41.1°C, while July 1, 2002 was the hottest day recorded with the temperature at 35.5°C. The average daily air temperature is 5.6°C.

3.3 Precipitation

As monitoring data demonstrates (1981-2010), 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 is observed in November and is approximately 10% of the total annual amount. The highest daily rainfall recorded in 1986 was 99.8 mm.

There is a one active precipitation monitoring location in close proximity to the Head Lake study area. Initially, the manual all-weather precipitation gauge was installed in 2013 at the Norland dam for the purposes of the Head and Shadow Lake Management Planning monitoring. It was installed and maintained by Kawartha Conservation. The monitoring location consisted of a manual accumulative gauge that collects and stores precipitation until a reading is taken.

In October 2016, a permanent automated precipitation monitoring station was established by the Trent-Severn Waterway at the same location. It consists of the all-weather weighing precipitation gauge, a data logger and transmitting equipment that ensures remote access to the gauge. Precipitation amounts for the period December 2016 - May 2017 was provided by the TSW officials. **Table 3.2** summarises monthly precipitation data recorded at the Norland dam from June 2014 to May 2017.

Table 3.2. Precipitation Amounts for the Head/Rush Lake Precipitation Monitoring Stations Presented by Hydrologic Year.

Year, hydrologic	2014-2015	2015-2016	2016-2017
June	108.1	128.1	57.1
July	65.7	88.7	92.3
August	76.6	102.2	117.7
September	91.9	77	54.7
October	120.3	89.1	73.1
November	77.2	66.6	40.3
December	60.5	95.1	110.9
January	31.4	61.7	96.3
February	19.4	58.4	80.5
March	20.4	186.4	79.4
April	83.6	56.2	103.5
May	39	57.6	179.8
Total	**794.1**	**1067.1**	**1085.6**

Recorded precipitation amounts demonstrate that the 2014-2015 hydrologic year was lower in precipitation comparing to the long-term average value. For example, precipitation observed during period of January - March 2015 was only 71.2 mm, representing only ~29% of long-term amount for this period (246 mm) recorded at Minden climate monitoring station. Furthermore, records show that hydrological year 2014-2015 was the driest during the observation period. Amount of precipitation recorded that hydrological year was only 75% of long-term average value.

3.4 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 3.4).**

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.

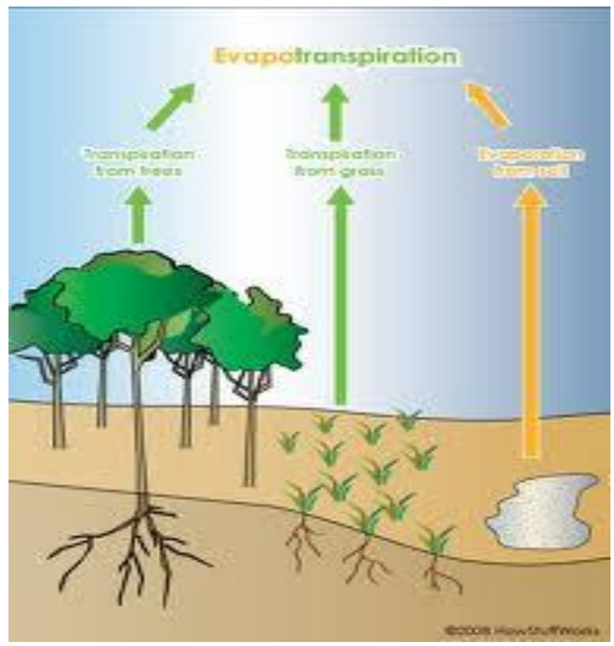


Figure 3.4. Process of Evapotranspiration
Source: http://science.howstuffworks.com

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 3.5).** According to that map, PET value for the area that encompasses the Head Lake planning area is about 560 mm (22 inches). 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 Head Lake Planning area (Fishog River watershed) is located within the Algonquin Lake-Nipissing Ecoregion, Boreal Shield Ecozone (Ecodistrict 413). The central and southern portions of the study area belong to the Manitoulin-Lake Simcoe

Mixwood Plains Ecoregion within Mixed Plains Ecozone (Ecodistricts 552). Estimated values of the potential evapotranspiration for those ecoregions are shown in **Table 3.3**.

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.

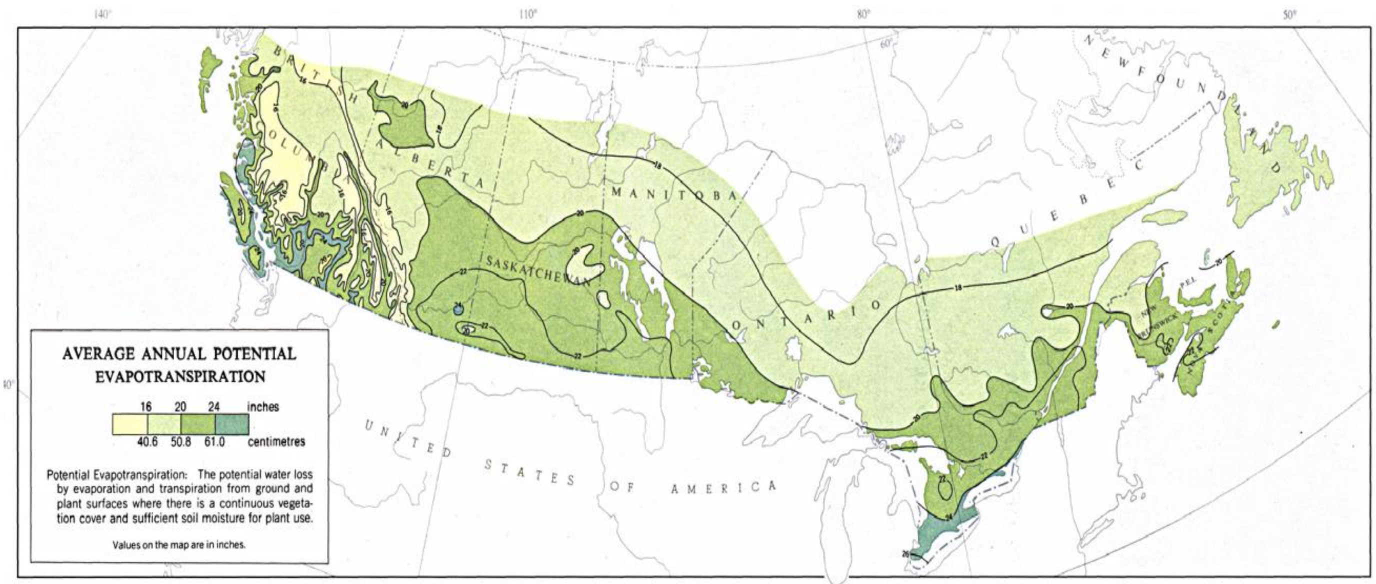


Figure 3.5. Average Annual Potential Evapotranspiration
Source: The National Atlas of Canada, 1974

Table 3.3. 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

3.5 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 experienced. 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.

Considerable amount of research on climate change has been undertaken in Ontario. Ministry of Natural Resources and forestry has produced a report where climate change projections from the Intergovernmental Panel on Climate Change's Fifth Assessment Report are summarized for the province of Ontario **(McDermid, J., Fera S., and A. Hogg. 2015**). Projected changes in climate are described under the three greenhouse gases emission scenarios. Each scenario is a 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.

- RCP 2.6 – a medium-low scenario with aggressive mitigation. Emissions peak early, and then fall due to active removal of atmospheric carbon dioxide. Requires all the main GHG emitters, including developing countries, to participate early on in climate change mitigation policy.
- RCP 4.5 – a medium stabilization scenario where emissions stabilize by 2100.
- RCP 8.5 – a very high emission scenario and a failure to curb warming by 2100. GHG emissions are up to seven times higher than preindustrial levels.

Figure 3.6 demonstrates trends in change of yearly mean air temperature in southern Ontario under different GHG emissions scenarios.

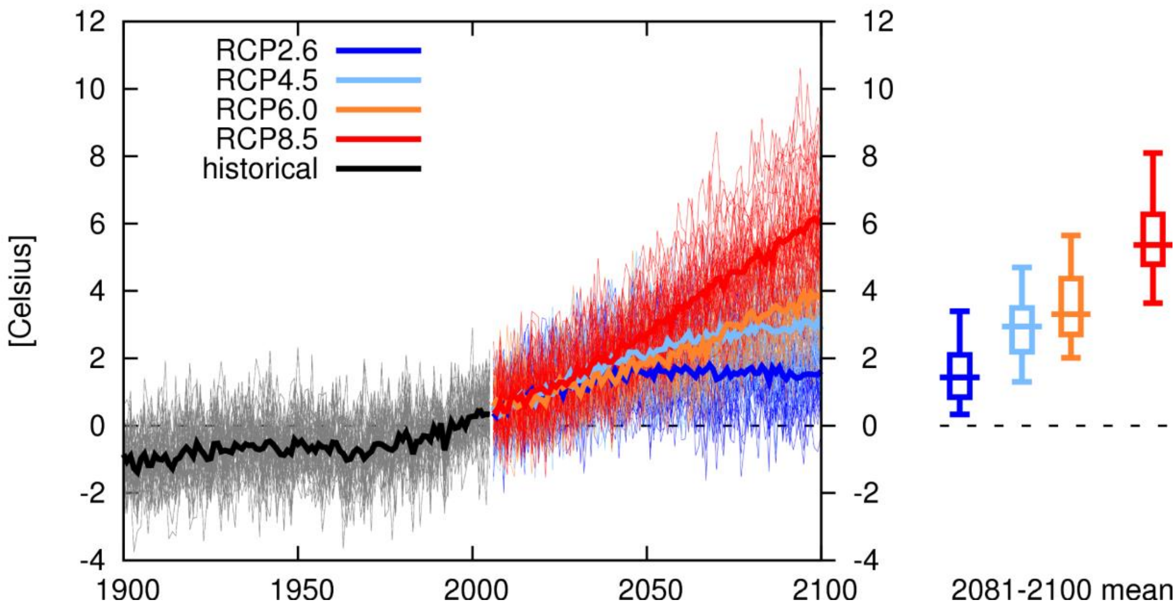
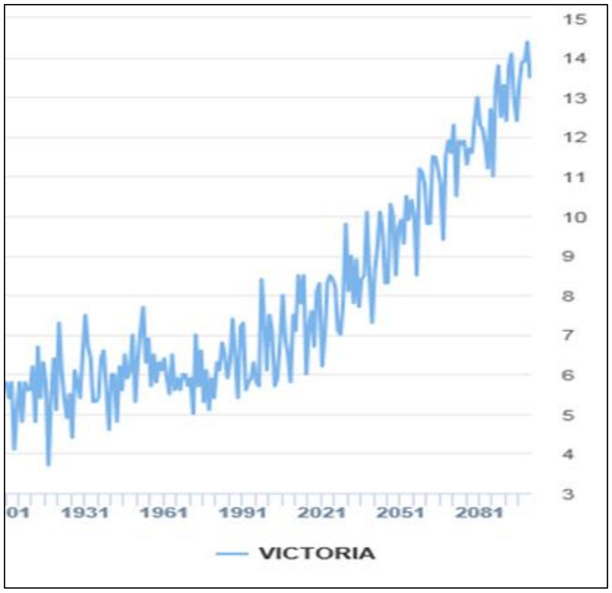


Figure 3.6. Trends in change of yearly mean air temperature in southern Ontario under different GHG emissions scenarios (**Source: York University, 2016 http://lamps.math.yorku.ca/occp/**)

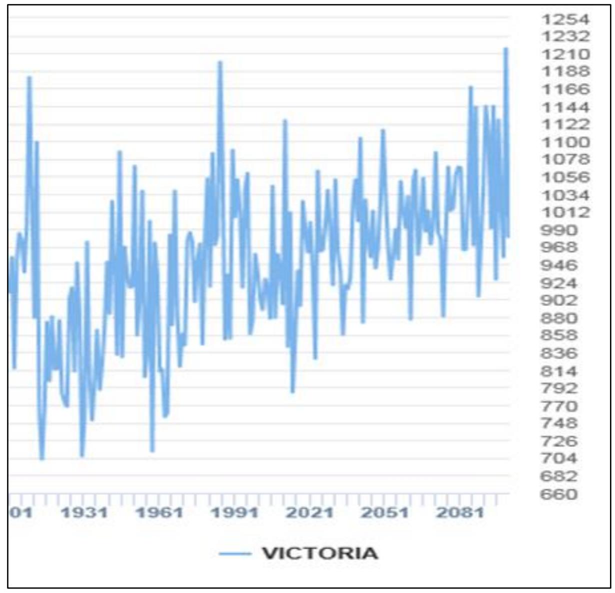
Projected mean annual, summer, and winter temperatures and total annual, summer, and winter precipitation are shown for three 30-year time periods: 2011–2040 (the 2020s), 2041–2070 (the 2050s), and 2071–2100 (the 2080s).

Figure 3.7 demonstrates the projected average temperature (a) and precipitation (b) trends for City of Kawartha Lakes jurisdiction under the scenario RCP 8.5 as shown at the Ontario Climate Change Projection data portal (http://lamps.math.yorku.ca/occp/).

As indicated at the "Climate Change Projections for Ontario: An updated synthesis for policymakers and planners" report, it is expected that mean annual temperature will increase for southern Ontario, including the study area under all scenarios **(Table 3.4).** Within the Great Lakes Basin, temperature changes are projected to be largest in the northern portions of the basin. Mean annual air temperatures will increase the most in the Lake Superior sub-basin, ranging from 3.2°C to 8.3 °C above historical levels by the 2080s, and lowest in Lake Erie, ranging from 2.8°C to 7.2 °C above historical levels for the same time period. Winter warming will exceed summer warming.



a) Temperature



b) Precipitation

Figure 3.7. Projected average temperature, °C (a) and precipitation, mm (b) trends for the City of Kawartha Lakes (Victoria County) jurisdiction under the very high emission scenario (RCP 8.5). Source: (Ontario Climate Change Projection data portal, http://lamps.math.yorku.ca/occp/).

Projected precipitation changes also indicate an annual increase in precipitation across the Lake Ontario basins, with the highest potential increases in Lake Superior sub-basin. However, increase in precipitation will be unevenly distributed throughout the year. Summers are projected to be drier, while winter precipitation is likely to increase. Changes in winter precipitation are expected to be more dramatic than summer precipitation, where the greatest change is projected in the Lake Huron sub-basin, averaging up to 85.2 mm above historical levels by the 2080s. As winters become milder, winter precipitation will fall as rain, affecting the hydrological cycle, monthly stream flows, lake levels, and water resources overall.

Table 3.4 Changes in temperature and precipitation for Lake Ontario watershed from 1971–2000 baseline values under three representative emission scenarios and for three time periods (2011–2040, 2041–2070, and 2071–2100). Source: http://lamps.math.yorku.ca/occp/node/113

Change from 1971–2000 baseline			2011–2040			2041–2070			2071–2100		
			Medium-low emissions RCP 2.6	Medium emissions RCP 4.5	Very high emissions RCP 8.5	Medium-low emissions RCP 2.6	Medium emissions RCP 4.5	Very high emissions RCP 8.5	Medium-low emissions RCP 2.6	Medium emissions RCP 4.5	Very high emissions RCP 8.5
Annual	Temperature, °C	Mean	2.3	2.3	2.4	3.1	3.8	4.6	3	4.6	**7.6**
		Range across the watershed	1.8 to 2.6	1.8 to 2.6	1.9 to 2.7	2.6 to 3.4	3.3 to 4.1	4 to 4.9	2.4 to 3.3	4.1 to 4.9	6.9 to 8
	Precipitation, mm	Mean	55.1	22.9	36.3	62.5	61	72.6	74.3	66.7	**102**
		Range across the watershed	16 to 121	-16 to 96	-2 to 105	23 to 142	20 to 141	33 to 154	35 to 143	26 to 144	62 to 186
Summer	Temperature, °C	Mean	1.9	2	2.1	2.6	3.2	4.4	2.6	4.1	**7.6**
		Range across the watershed	1.4 to 2.3	1.5 to 2.4	1.6 to 2.5	2.1 to 3.0	2.8 to 3.7	3.9 to 4.9	2.1 to 3.1	3.7 to 4.6	6.9 to 8.1
	Precipitation, mm	Mean	-0.1	-7.5	-3.3	-3	-4.8	-9.5	5.2	2.7	**-10.6**
		Range across the watershed	- 11 to 17	- 16 to 6	- 12 to 10	- 13 to 12	- 14 to 10	- 18 to 5	- 5 to 21	- 6 to 18	- 23 to 7
Winter	Temperature, °C	Mean	2.7	2.4	2.8	3.5	4.5	5.2	3.5	5.4	**8.1**
		Range across the watershed	2.2 to 3	1.9 to 2.8	2.3 to 3.2	3.0 to 3.9	4 to 4.9	4.6 to 5.6	2.9 to 3.9	4.8 to 5.7	7.3 to 8.6
	Precipitation, mm	Mean	22.2	25	20.9	35.5	26.4	44.3	33.7	38.5	**72**
		Range across the watershed	1 to 46	3 to 48	2 to 40	12 to 62	5 to 49	22 to 71	13 to 57	17 to 65	50 to 105

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 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 5, 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 Head Lake watershed residents.

4.0 Water Quantity

4.1 Summary of Observations and Issues

OBSERVATIONS

- ***The Head Lake drainage area has been experiencing minimal anthropogenic pressure thus far.*** Abundant natural cover, minimal urbanization and agriculture allow for natural flow regime in the Head Lake tributaries
- ***Wetlands and forested areas that are dominant in the Head Lake watershed provide significant benefits for the surface water, moderating stream flow, providing high and low-flow mitigation and assisting in groundwater recharge***
- ***Analysis of flow regime of the Head Lake tributary as well as the Head River downstream of Head Lake (near Sebright) reveals that their water level regime follows well-defined seasonal pattern, reflecting seasonal variations of water inflow.*** The highest water levels in both locations are observed in March-April in response to the spring freshet, often combined with rain events. After peaking, water levels recede through the summer and fall's months, reaching its lowest marks in September-October. Low water levels are also observed in winter months
- ***As there is no officially recognized water level data for Head Lake, it is estimated that water level of Head Lake follows the same seasonal pattern***
- ***A dam on the Head River, located downstream 5.5 km of the lake, was constructed to raise water levels for the upstream private property development on Head Lake, as well as to improve recreation and navigation.*** Currently, dam is in state of disrepair and cannot be operated; established water levels cannot be maintained.
- ***Ministry of the Natural Resources and Forestry is investigating options for the dam's future; consultants have been hired and preliminary report prepared.***
- ***No consumptive water withdrawal, subject to the regulation under the "Permit To Take Water Program" (PTTW) (more than 50,000 l/day) from Head Lake or within its watershed is registered.*** One active permit within the study area issued for wildlife conservation (Ducks Unlimited).

KEY ISSUES

- ***Dam downstream of the Head Lake was supposed to provide means for regulating water levels of the lake.*** However, the poor conditions of the dam, lack of the established ownership and dam management strategy, and acts of vandalism do not allow for consistent dam operation.
- ***Not all local residents are supportive of the elevated water levels, caused by the dam.*** As a result, acts of vandalism and dam mismanagement have been reported.

INFORMATION GAPS

- ***There is no officially recognized data on water levels of Head Lake***
- ***Cumulative effect of water taking that does not require permitting cannot be evaluated accurately because of absence of data***
- ***Annual monitoring data on lake evaporation are not available.*** This adds uncertainty to the calculations of a water budget
- ***Climate change has the potential to impact the flow regime of local watercourses by reducing the duration and intensity of spring runoff and aquifer recharge, and by increasing the potential for dry conditions and/or extreme high-flow events during summer.***

4.2 Drainage Network

Head Lake is a relatively small lake with a surface area of 9.38 km^2 located at the headwater portion of the Head River. Further downstream the Head River converges with the Black River that, in turns, flows into the Severn River and, consequently, into Georgian Bay.

Three sub-watersheds have been delineated within the Head Lake Planning Area **(Figure 4.1).** The Fishog River sub-watershed extends north from the mouth of the Fishog River; the Head Lake Central sub-watershed includes lands that immediately surround the lake; and the Rush Lake sub-watershed covers the southern portion of the study area.

As it was explained previously, Head Lake is located within the transition zone between the older Precambrian bedrock to the north and younger, Paleozoic limestones to the south, and is considered as part of the 'Land Between' region. The Land Between is the intersection zone between the Canadian Shield ecosystem and that of the St. Lawrence Lowlands. The Land Between is considered an 'ecotone' which contains elements of both ecosystems it transverses, but also contains elements entirely unique to the transition zone.

The drainage network reflects the geological differences within the study area. The stream density and channel gradients at the northern portion of the Head Lake Planning area, namely Fishog River sub-watershed, that is part of the Precambrian bedrock region, are considerably higher than at its southern portion (see **Table 4.1**). The values of those characteristics at the Fishog River sub-watershed are compatible with other watersheds situated within the Precambrian bedrock region, such as the Burnt or Gull Rivers. In addition, the northern tributaries to Head Lake demonstrate very complex channel morphology, turning and bending at sharp angles on their way. That usually occurs when watercourses flow in geological formations that are hard to erode, such as Precambrian bedrock. In softer depositions, watercourses typically cut channels that are as close to the straight line as possible, what we see within the Rush Lake sub-watershed area that is mostly located within limestone formation.

Characteristics of the Head Lake Planning Area and delineated sub-watersheds are shown in **Table 4.1**.

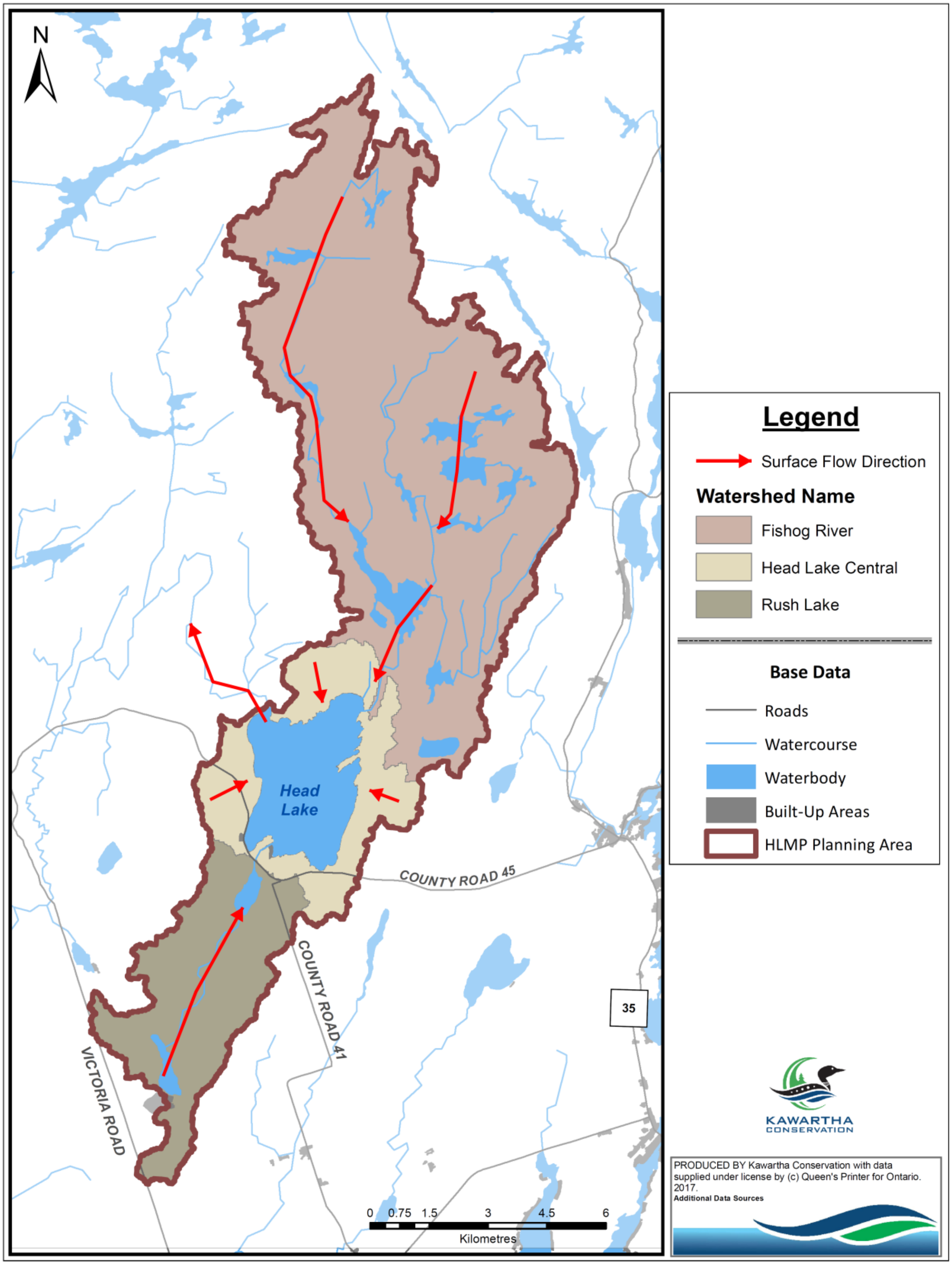


Figure 4.1. Drainage Network and Flow Direction at the Head Lake Planning Area

Table 4.1. Streams and Subwatersheds Characteristics, the Head 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, (%)
Fishog River	77.65	293.45	13.93	2.73	98.61*	1.3	0.1	2.78	6.66
Head Lake Central	24.09	17.8			89.12*	4.2	6.6	0.74	3.47
Rush Lake	19.79	16.68	4.94	0.8	91.37*	6.0	2.7	0.84	1.03
Head Lake Total	121.69				94.82**	3.07	1.68		

* Includes open water: Fishgog Lake – 10.1%, Head Lake Central – 39.5%, Rush Lake – 4.24%

**Excludes open water

Numerous lakes, such as Wolf Lake, Scrabble Lake, Clear Lake, Cranberry Lake and number of other are abundant at the Fishog River sub-watershed. Accordingly, the portion of open water for this subwatershed is more than 10%. Only Head Lake Central subwatershed had a greater portion of the open water, but that is because the area of Head Lake was included into calculations.

Extensive wetlands are located within the study area, especially at its northern portion what is typical for the Canadian Shield settings. Overall, the natural cover at the Head Lake Planning Area is almost 95%. This includes forest, wetlands and meadows.

Head Lake is a regulated water body. A dam that affects water level of the lake is located at ~5.5 km downstream of the lake, on the Head River. It is a two-bay stop-log concrete structure with two sluiceways and an adjoining weir (**Figure 4.2**). Concrete abutments have clear openings of 2.27 and 2.29 m wide. The crest elevation of the concrete dam is at 267.82 mASL and the sill elevation of the sluices is at 267.06 mASL **(Table 4.2).** The dam was constructed in mid-1960th with the purpose of raising water levels upstream to accommodate private property development on Head Lake. The secondary objectives of the dam were to improve navigation and recreation capacity. Operation schedule for the dam includes removal of the two sets of stop logs before the winter to prepare for the spring freshet. During summer, the stop-logs are replaced to hold the water in Head Lake (**Kris Windover, OMNRF, personal communication**).

Figure 4.2. Head River Dam (photo courtesy Chuck Wilkinson, 2014)

Table 4.2. Head Lake Dam Characteristics

Dam Components	Quantity	Width, m	Invert Elevation, mASL*	Crest Elevation, mASL
Stop-log bay	2	2.74, 2.29	267.06	267.82
Concrete Overflow	2	4.5, 1.52		

*- metres above sea level

However, not all local residents have been satisfied with the dam operations. Some have expressed concerns over shoreline erosion and flooding of private properties. As a result, complaints about Head Lake water levels and vandalism to the dam by groups who are not supportive of the elevated water levels caused by the dam have been reported from time to time since the late 1960s. Because of ongoing vandalism activities the dam at this moment is in state of disrepair and cannot be operated; established water levels cannot be maintained (**Head Lake Dam Hydro-Technical Study DRAFT. 2017**).

Currently, Ministry of the Natural Resources and Forestry is undertaking the hydro-technical study for the Head Lake Dam in order to gather information and make an informed decision about the future management of the dam.

The hydro-technical study has considered three options for the future of the dam:

- Dam as it is
- Non-existence of dam, and
- Repair.

Under the 'dam as it is' option, it is accepted that in its current conditions the dam is towards the end of its life. It is very likely to collapse and fail.

Collapse of the dam ultimately will cause water levels in the Head Lake to decline permanently. Most likely that will not go well with property owners who are used to normal summer holding levels. It may be more suitable to some residents (under high water regime), but a drought condition would be unfavorable to a majority of them. Hydraulic modeling indicates that the surface area of the lake will be reduces by 0.5 km^2 (~5.33%) and this would likely have an ecological and environmental impact.

The repair and consequent maintenance will expend the lifespan of the existing structure. The restoration and effective management of water levels would allow the continued use of lake by the owners of the cottages and for their recreational activities. This option may be considered due to the social and economic impacts. It would involve a management plan for the lake levels and also finding a range of water levels that suits the needs and the interest of the majority of users (**Head Lake Dam Hydro-Technical Study DRAFT. 2017**).

4.3 Water Levels and Flow Regime

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.

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 the watershed's natural cover. Water level monitoring data also provide information for flood forecasting, warning and emergency management.

Assessment of water level regime in Head Lake and flow in its tributaries for the purpose of the Head Lake management planning project has been performed using two monitoring gauge stations **(Figure 4.3).** Hydrometric station on the Head River near Sebright 02EC002 is a component of the Canada-wide hydrometric monitoring network that is maintained by the Water Survey Division, a division of Environment Canada. Station was established in 2014 and provides data on water levels and flow. It is a permanent monitoring location with a real-time connection capacity.

An additional monitoring location was established and operated by Kawartha Conservation specifically for the purpose of the Head Lake Management Planning project. It is a temporary station located on the tributary that connects Rush Lake to Head Lake, at County Road 45. The gauge provides information on the inflow from the southern portion of the Head Lake planning area.

Both monitoring locations consist of a sensor that measures the water level at pre-set intervals and a data logger that records measured values. Details on the flow monitoring locations are shown in **Table 4.3.**

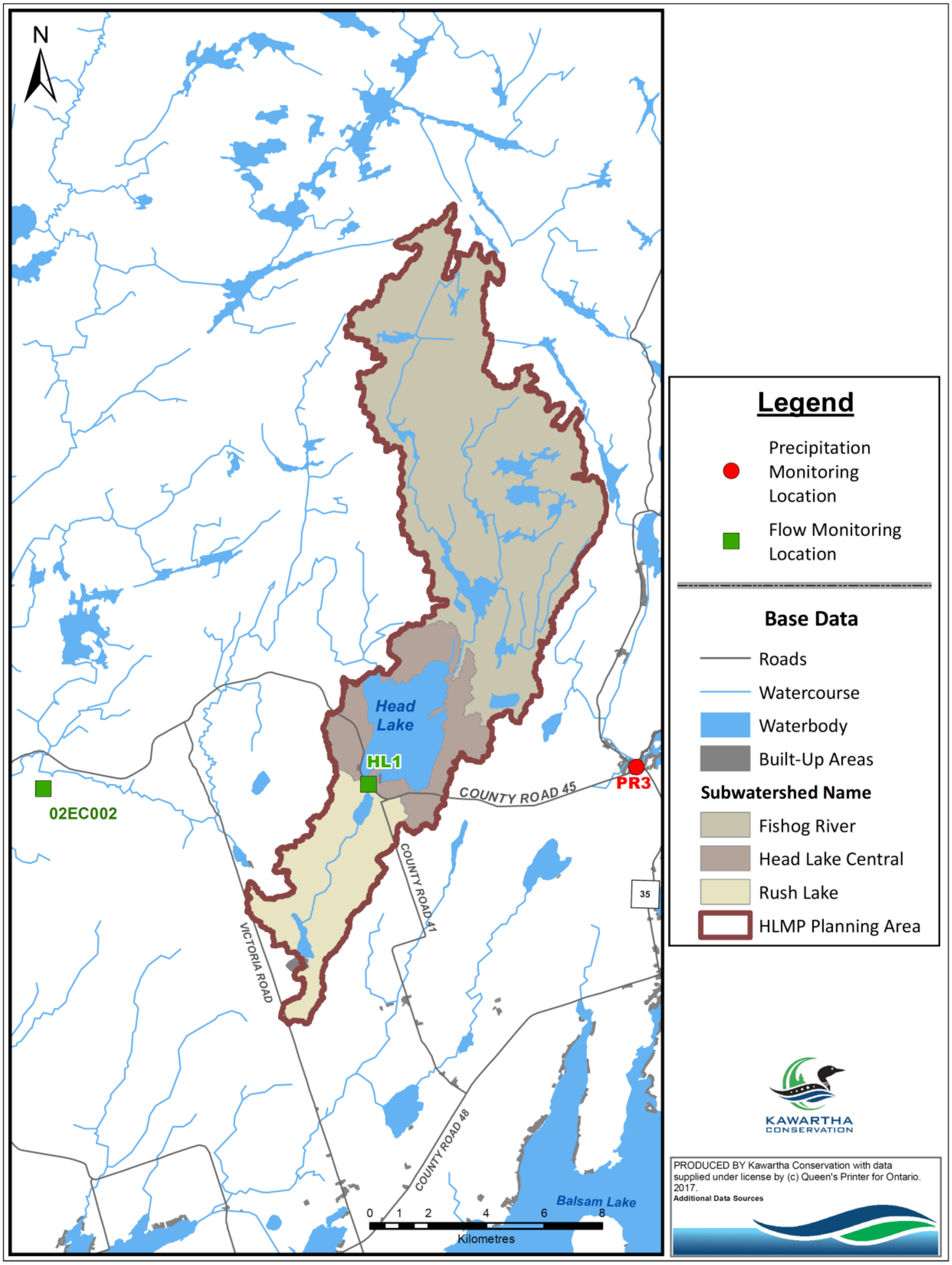


Figure 4.3. Flow and Precipitation Monitoring Locations within and around the Head Lake Planning Area.

Table 4.3 Continuous Water Level and Stream Flow Monitoring Locations within the Head Lake Planning Area

Water course	Location	Drainage Area, km^2	% of total Sub watershed Area	Time Interval	Data Record	Regulation	Type	Ownership
Head River	Sebright	233	N/A	15 min	2014 - 2017	Regulated	Permanent, pressure transducer	Water Survey Division – Environment Canada, 02EC022
Unnamed Tributary	Monck Rd.	19.8	100	1 hour	2014 - 2017	Unregulated	Temporary, pressure transducer	Kawartha Conservation

Water levels represent the 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 the amount of pollutants carried with water into a lake, data on the volume of water that flows through the watercourse is required. In order to convert observed water level data into flow information, a rating curve has to be developed. 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 to develop a relationship. A wide range of water levels and flow (from the highest to the lowest) are targeted in order to establish a reliable relationship. Once a rating curve and an equation that describes it are developed, water level values are converted to discharges that characterize water quantity at the gauging location.

Recorded data for two monitoring locations utilized in this study confirm that both the Head River downstream of Head Lake, as well as the Head Lake tributary demonstrate well-defined seasonal pattern, reflecting seasonal variations of water inflow. During the period of monitoring, 2014-2017, the highest flows and water levels at both streams have been observed in late March or April in response to the spring freshet, often coupled with rain events (**Figures 4.4 and 4.5**). After peaking, flow in watercourses recedes through the summer and fall's months, reaching its lowest marks in period from August through October. 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 in both monitoring locations were recorded during the summer of 2016. Southern tributary has demonstrated negligible or reverse flow in July-August 2016; for some time during that period the tributary has gone dry. Extremely low water levels were result of very limited precipitation observed during the summer months of 2016.

Typically, water levels start gradually increasing 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 forms on the tributaries within the Head Lake watershed and the water levels remain low. The major source of water inflow during that time is groundwater. Sometimes cold winter weather is interrupted by milder temperatures and even occasional rains. Especially typical is a thaw in January. When a thaw is significant enough to melt the existing snowpack and create a runoff, water levels and flows in the local watercourses increase, sometimes significantly, as it was observed in February 2017.

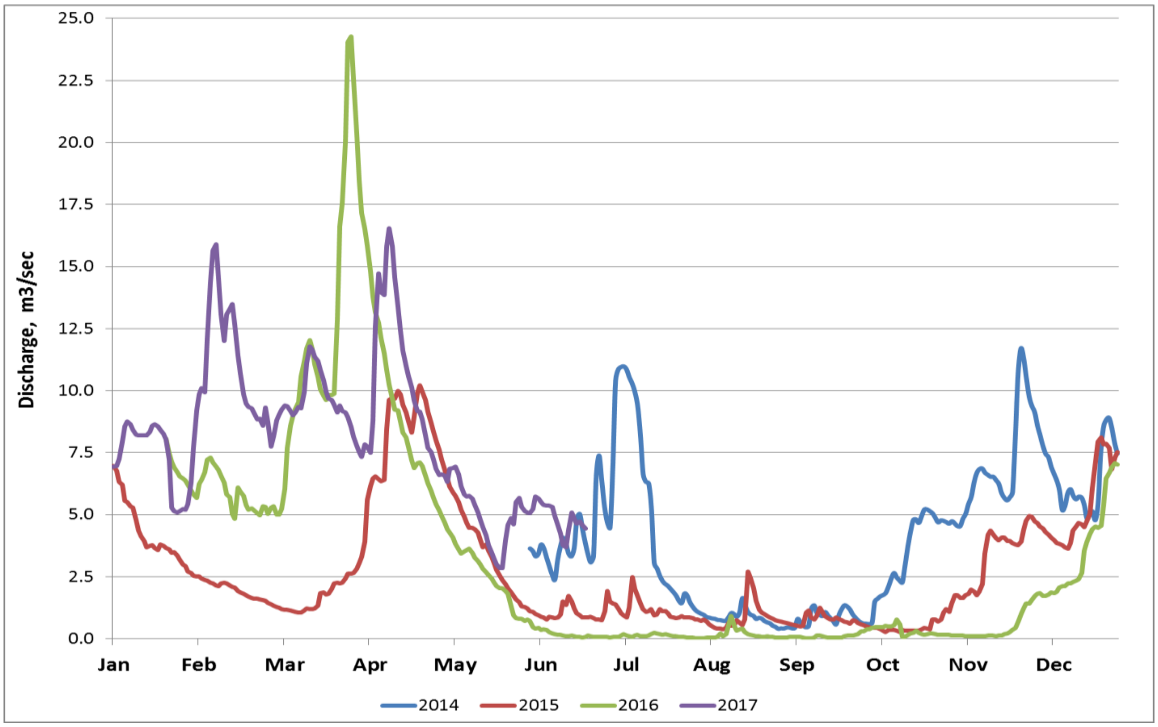


Figure 4.4. Daily Flow at the Head River near Sebright (02EC022) Hydrometric Station, Daily Average, 2014-1017.

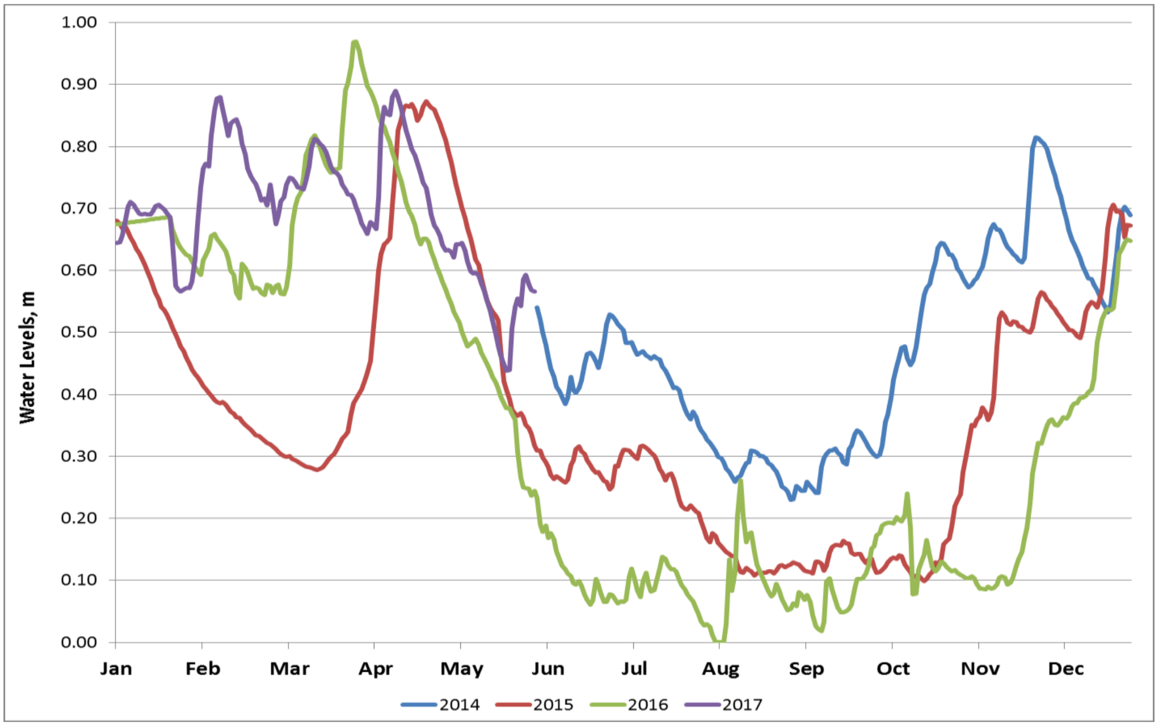


Figure 4.5. Water Levels at the Head Lake Tributary at County Rd 45 Monitoring Station, Daily Average, 2014-1017.

Land use composition 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 and small lakes 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 extents of impervious surfaces alter spatial and temporal distribution of flow, increasing the flood peaks and volumes and decreasing groundwater recharge, storage and discharge.

The Head Lake planning area is characterized by very extensive natural coverage. The headwaters of Head Lake, specifically drainage area of the Fishog River, include the area of the Queen Elizabeth II Wildlands Provincial Park. The Fishog River sub-watershed is characterized by the highest fraction of the natural cover more than 98% among the three delineated sub-watersheds within the study area. Two other sub-watersheds, Head Lake Central and Rush Lake, demonstrate a portion of natural cover no less than 89%.

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

As described in Chapter 2 – Land Use, only a very small portion of the Head Lake watershed lands is used for agriculture and more than 94% of the watershed area is occupied by natural areas, including forests, wetlands and meadows.

4.4 Head Lake Morphometry Characteristics

Head Lake has a rectangular-like shape with rocky shorelines and numerous rock outcrops throughout the lakes surface area. The deepest depths in Head Lake are within the south-east part of the lake, in-and-around Armstrong Island, and immediately north of Hilton's Point (**Figure 4.6**).

The major morphometric characteristics of Head Lake are as following:

Surface Area:	9.38 km^2
Lake Volume:	32.83 mln. m^3
Mean Depth*:	3.5 m
Maximum Depth*:	8.2 m
Length:	4.857 km
Width:	3.336 km
Shape Factor:	1.46
Flushing Rate:	200 days

*** Broad-scale Fisheries Monitoring Bulletin, Head Lake, 2016**

Lake flushing rate is a rate at which water (or some dissolved substance) enters and leaves a lake relative to lake volume. It is usually expressed as time needed to replace the lake volume with inflowing water. Using inflow volumes, calculated as part of the lake water budget (refer to the section 4.6 Water Budget) the flushing rate is 1.82 times per year. Therefore, on average, the water mass in Head Lake changes every 200 days (6.7 months).

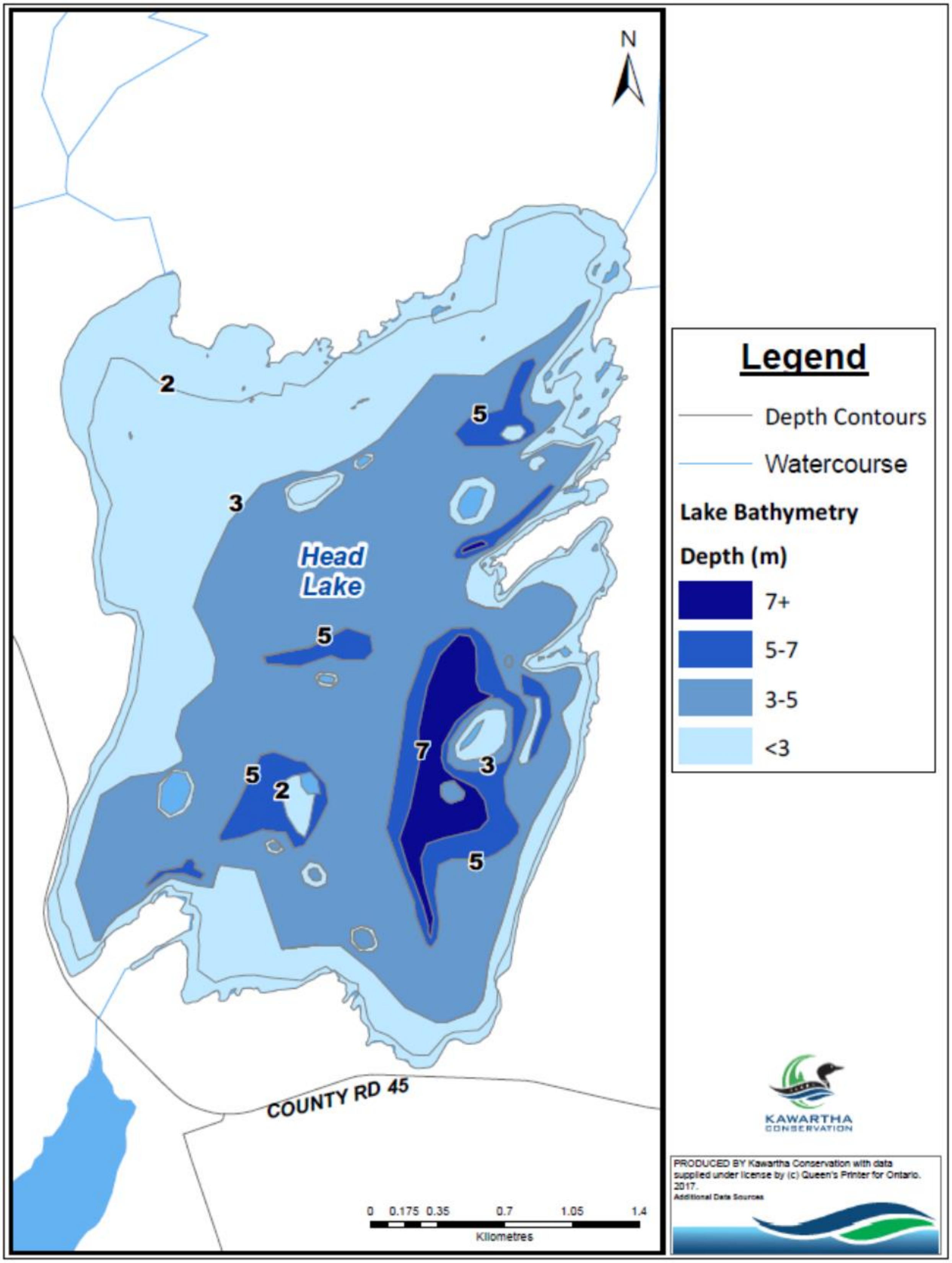


Figure 4.6. Bathymetry Map of Head Lake

4.5 Water Taking

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.

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. Water takings for domestic use, agriculture and emergency purposes (e.g., firefighting) do not require a permit. Major water taking information is managed in a provincial dataset, maintained by the Ministry of the Environment and Climate Change, 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.

According to the provincial database, no large-scale water taking activities that require a Permit To Take Water take place within the Head Lake subwatershed. Only one permit, within the study area, is listed at the database. It is issued to Ducks Unlimited for the purpose of wildlife conservation that is considered as non-consumptive use of water resources.

For private water supply it is assumed that local residents withdraw water from the ground water or directly from the lake for domestic water supply. **Figure 4.7** shows groundwater wells as they are registered with the Ministry of the Environment and Climate Change. The current status of the well (active, abandoned) is not always reflected correctly and withdrawal volumes are not known.

Information on the non-permitted surface water taking (less than 50,000 l/day) does not exist. As water withdrawal from the lake is not required to be reported, data such as number of connections and volume of pumping water is unknown. As a result, because of absence of data, is it not possible to evaluate the cumulative effect of direct water-taking.

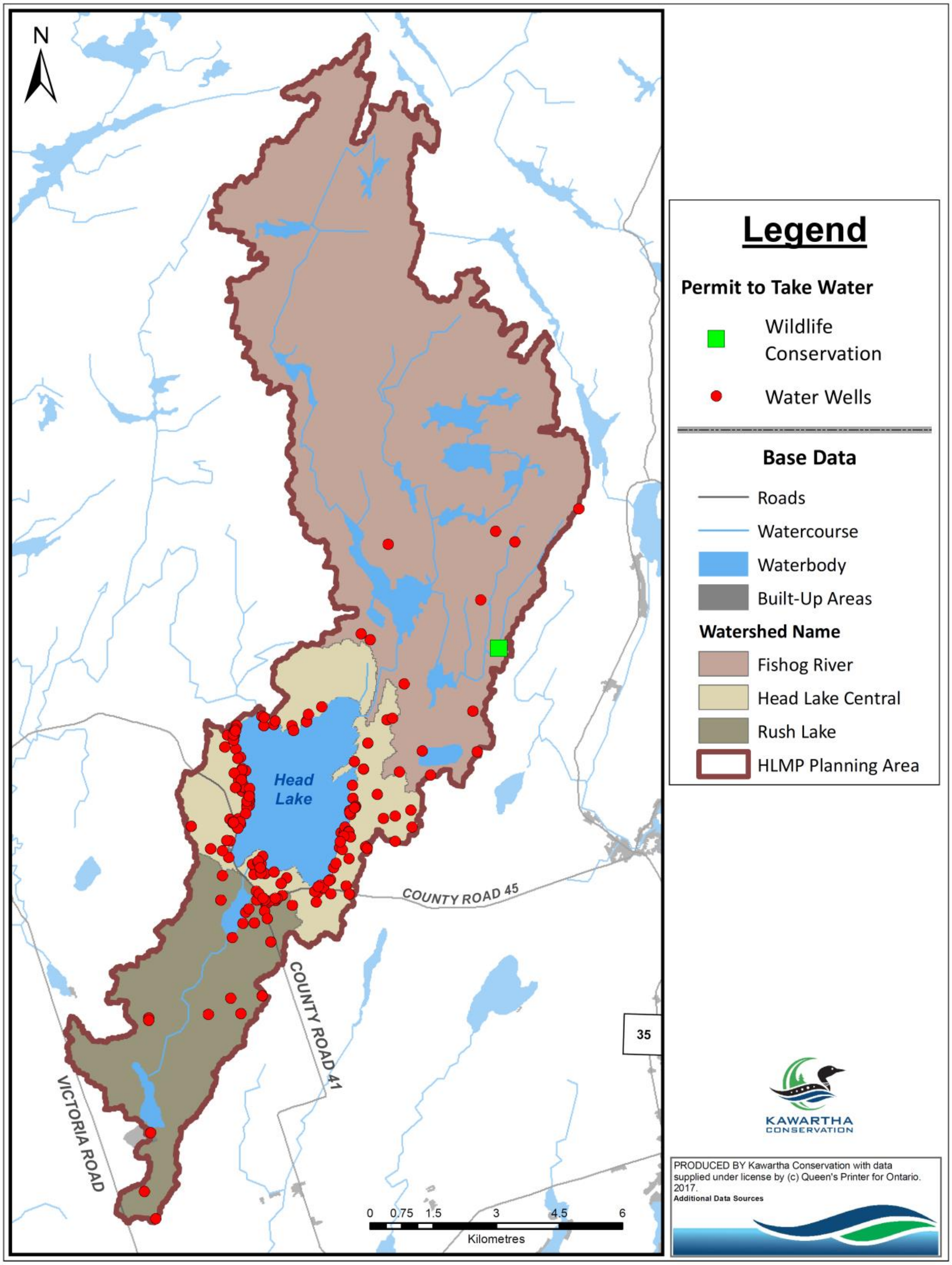


Figure 4.7. Water Wells within the Head Lake Planning Area (as per Water Well Record Database, MOECC).

4.6 Water Budget

A water budget is an essential component of any hydrological and water quality study. In the framework of the Head Lake Management Plan, the water budget can be used for multiple purposes. For example, the water budget and its components are necessary to evaluate cumulative effects of various land uses on water quality in the lakes and their tributaries as well as to determine priority areas for environmental monitoring. Moreover, the accurate water budget of Head Lake is crucial for further calculations of phosphorus and nitrogen loadings and balances 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. Total water input into the lake including sources such as precipitation, surface and groundwater inflows, discharges from sewage treatment plants and septic systems should equal the total water output from the lake such as evaporation and evapotranspiration, surface and groundwater outflows, water extraction for the water supply purposes. Therefore, the water budget equation for a lake is as following:

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

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 septic systems along the shorelines,
A_{out} – anthropogenic extraction from Cameron Lake for the Fenelon Falls Water Treatment Plant,
ΔS – change in lake storage,
$\pm\Delta$ – imbalance.

The Head Lake water budget for the 2014–2015, 2015–2016 and 2016–2017 hydrologic years is shown in **Table 4.4**. The hydrologic year in Ontario begins 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. **Figure 4.8** presents average water budget for Head Lake over period of study.

The total amount of precipitation for the lake management project has been measured outside but very close to the study area, in Norland. A simple precipitation gauge at the location of the dam at the Gull River in Norland was established specifically for this project. In October 2016, the TSW has established an automatic all-weather precipitation gauge at the same location. Recorded data were made available for the Kawartha Conservation project team.

Data demonstrates that amount of precipitation over period of monitoring varied significantly. Only 794.1 mm of precipitation were recorded in 2014-2015, while during the next hydrological year, 2015-

2016, almost 1070 mm were registered at this monitoring location. Although the precipitation amount is usually expressed in millimeters, it was converted into cubic meters for the purposes of convenient comparison with flow components.

Table 4.4. Head Lake Water Budget (based on averages); Hydrologic Years 2014-2015, 2015-2016, 2016-2017

	2014 – 2015		*2015 – 2016*		*2016 – 2017*		*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:	*57.33*	*100*	*62.19*	*100*	*60.11*	*100*	*59.88*	*100*
Precipitation (P)	7.45	12.99	10.00	16.08	10.18	16.94	9.21	15.38
Fishog River	41.62	72.59	44.22	71.10	41.81	69.55	42.55	71.06
Head Lake Central	0.45	0.78	0.51	0.82	0.54	0.90	0.50	0.83
Rush Lake	7.82	13.64	7.46	12.00	7.58	12.61	7.62	12.73
Total water outflow:	***57.33***	***100***	***62.19***	***100***	***65.95***	***100***	***59.88***	***100***
Evaporation (E)	51.50	88.68	53.81	89.17	60.12	90.30	54.05	89.21
Head Lake Outlet	5.83	11.32	5.83	10.83	5.83	9.70	5.83	10.79

Evaporation from the water surface of the lakes is the least studied component of the water budget. Evaporation depends on many weather factors such as 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 or nearby the Kawartha Watershed. 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 of 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 the Head Lake watershed **(Agriculture and Agri-Food Canada, 1997)**. This number was also converted into cubic meters for the convenient comparison.

As it was described before, two flow monitoring stations have being utilized in order to develop a water budget for Head Lake: at the tributary that connects Rush Lake to Head Lake and on Head River near Sebright. Hydrometric station on Head River was used to calculate an inflow into the lake from the headwater's portion of the watershed, namely the Fishog River. The tributary monitoring location provided information on inflow from the southern part of study area. Flow for the lake's central portion was estimated using the data obtained from the Ontario Flow Assessment Tool application.

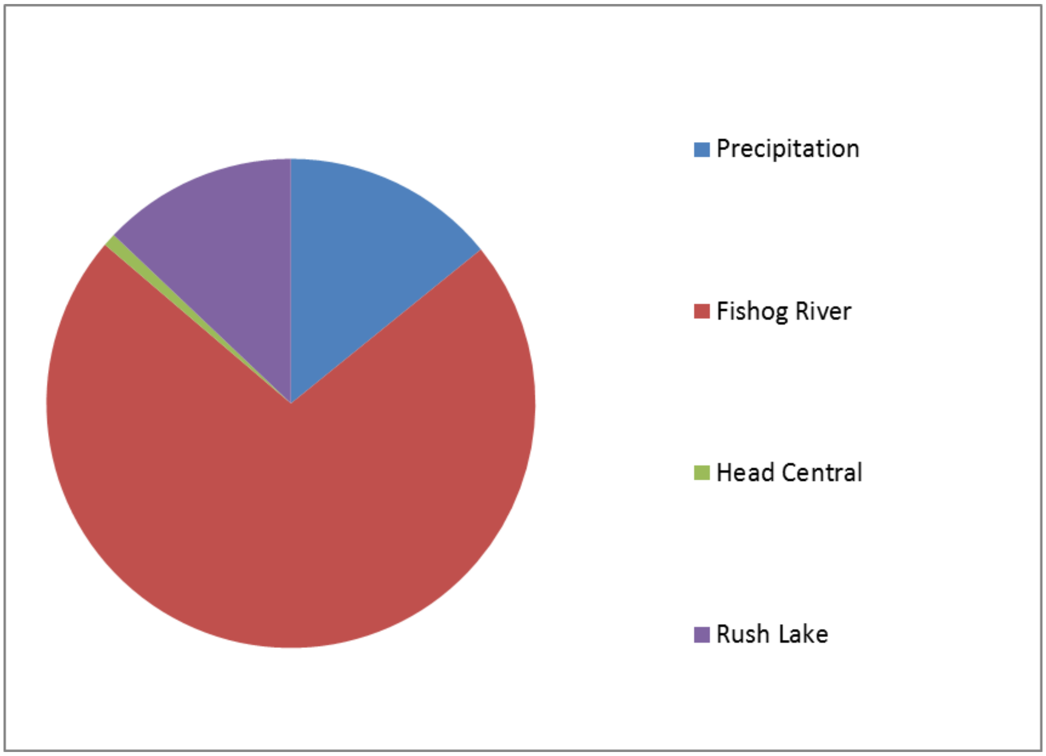


Figure 4.8. Water Balance of Head Lake, Average for the Study Period, 2014-2017.

During the period of observation 59.88 $mln.m^3$ of water on average has entered Head Lake. Majority of the inflow, 42.55 $mln.m^3$ or 71% was produced by the Fishog River. Precipitation encountered for ~15% of total water influx, and 12.7% comes from the southern portion of the study area (Rush Creek). Inflow from the central portion of the watershed, where very few watercourses exists, is almost negligible, less than 1% on average.

5.0 Water Quality

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 2014 and concluded in 2017. The water quality monitoring network in the Head Lake watershed included 3 stations on the lake's tributaries across the study area, including the Rush Lake inflow, Head River outflow, one station on an unnamed tributary to the east of Head Lake, 3 monitoring stations on Head Lake and one precipitation sampler situated at the Norland dam. Citizen science data collected for the MOECC Lake Partner Program was also used in addition to historical MOECC surveys performed in 1972.

OBSERVATIONS

- ***Head Lake can be characterized as a mesotrophic water body with excellent water quality.*** Water quality within the Head Lake watershed is excellent which can be attributed to the large areas of forest cover and wetlands. However, Head Lake is a classified as a shallow productive lake which has the capabilities that can create problematic algal growth, and contribute to the growth of macrophytes reducing recreational enjoyment of the lake and impacting the natural communities that live in and around the lake.

- ***Average phosphorus concentrations in Head Lake are well within the Provincial Water Quality Objectives for lakes (below 20µg/L).*** Long term trends indicate relatively stable moderate phosphorus concentrations for Head Lake which are well within the Provincial Water Quality Objectives.

- ***Nitrogen concentrations are well within the Provincial Water Quality Objectives in Head Lake.*** However, 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 in dissolved or particulate forms as from sources such as tissues from living or dead organisms, bodily waste from animals, 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.

- ***Head Lake Beach E. coli monitoring results indicate that concentrations have exceeded the Public Health guideline of 100cfu/100ml.*** The Haliburton, Kawartha, Pine Ridge District Health Unit beach posting data (due to elevated *E. coli* concentrations) show that the public beach on Head Lake has been posted at least once per season during the monitoring years of 2011-2017.

KEY ISSUES

- ***Lack of water quality data on Rush Lake***
  The focus of data collection for the management plan was Head Lake. The Rush Lake Outlet (HL1) will serve as a proxy for Rush Lake, however a more comprehensive study is needed to better inform decision making and lake management.

- ***Frequency of Public Beach closures.*** According to *E.coli* posting data (2011-2015) provided by The Haliburton, Kawartha, Pine Ridge District Health Unit indicates that the Head Lake public beach has been posted at least once per swimming season since 2011. Results show that the highest number of exceedences of the Provincial Water Quality Objective was in 2014 (18% of samples) while in 2015 only 9% of samples exceeded the Provincial Water Quality Objectives. Current data (2016 & 2017) was unavailable at the time of this draft.
- ***Steep slopes >25% encompassing Head Lake.*** These steep slopes may lead to increased run off, erosion and constrain building and increase the need for the foreign fill to accommodate areas for septics and or buildings **(Garter Lee 2002).**

INFORMATION GAPS

- ***No information on nearshore water quality data***. Water sampling on Head Lake has taken place in the pelagic zone (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 more holistic view of water quality within Head Lake.

- ***No data collected to determine if Head 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.

5.1 Introduction

Water quality, in either surface or ground water, can be defined as an integrated index of chemical, physical and biological characteristics of natural water. Water quality is a function of natural processes and anthropogenic (human) impacts. Natural processes such as the 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 portion of Kawartha Conservation's 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, gray water discharges 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 target for water quality concentrations 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 in addition to planning effectively for mitigation and remedial purposes.

5.2 Methodology

Water quality monitoring plays an important role in meeting the objectives of the Head Lake Management Plan. Water quality data are obtained by collecting water samples at predetermined monitoring sites across the entire study area. Intensive sampling, for the purposes of the Head Lake Management Plan development, was undertaken in 2014-2017 at four tributary/inlet sites and also three open water sampling sites on the lake **(Figure 5.1).** The monitoring stations are dispersed across the entire watershed at key locations covering all major tributaries in a cumulative monitoring approach. The monitoring stations on the lake are located to represent the lake in its entirety (north, southeastern & southwestern portions). At each site, water samples are collected by grab method and then sent to a certified private laboratory (Caduceon, Richmond Hill, ON) to be analyzed for total suspended solids and nutrients including ammonia, nitrites, nitrates, total Kjeldahl nitrogen and total phosphorus. Samples are collected bi-weekly year round from tributaries and monthly from May to September from the lake monitoring sites. Furthermore, pH, dissolved oxygen, conductivity and temperature readings are taken at the time of sampling using an YSI hand held multi-meter.

This report also includes total phosphorus (TP), Secchi and calcium data collected by volunteers through the Lake Partner Program **(MOECC 2016).** Total phosphorus & calcium grab samples are collected at mid lake (deep spot) monthly from May to September. Secchi readings and temperature are taken by a Lake Steward on a monthly basis and recorded and submitted to the MOECC Dorset along with temperature.

An analysis of alkalinity, metals, hardness, anions such as chlorides and other parameters were performed on water samples collected three times over the summer field season in 2015 (June, July & August) for characterizing baseline values. In order to characterize the bacteriological quality of surface water, all tributaries have been sampled during the summer period (2015) for *Escherichia Coli* (*E.coli*). Additionally, surface samples were collected and analyzed for various parameters including alkalinity, metals, hardness, and anions such as chlorides to provide a baseline characteristic of the watershed.

Statistical analysis of data was completed for all YSI handheld meter parameters (conductivity, temperature, dissolved oxygen and pH), 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. Final values were calculated as an average over the sampling period (2014-2017). The use of statistical tests such as a T test and One way ANOVA were performed on surface and bottom lake data as well nutrient data between tributaries to determine if streams were statistically significantly different from one another. **Table 5.1.** provides a breakdown of sites and number of samples collected during the study period.

5.3 Head Lake Tributaries

From a hydrological point of view the Head Lake watershed includes all areas that supply water to the lake. This means that the Head Lake watershed is comprised of small local subwatersheds (Fishog River, Rush Lake, & Head Lake) as seen in **Figure 5.1**.

The Head Lake watershed occupies a relatively small area adjacent to the north-west portion of the Kawartha Conservation watershed. The study area for the Head Lake Management Plan is 130.9km^2 and includes areas adjacent to the lake from the north including the Fishog River subwatershed. The major human land use in the watershed is rural development and agriculture, which is relatively low allocating for 1.68% and 3.07%, respectively, of use within the land portion of the watershed. The low density of development within the watershed provides opportunity for natural areas to occupy the landscape such as forests (95%).

Water quality concerns are negligible within the Head Lake watershed and the water quality is considered excellent. Head Lake is a shallow mesotrophic lake which receives water from two areas of extensive wetland complexes from the north (Fishog River) and south (Duck Lake). There were no exceedences of the Provincial Water Quality Objective guidelines for phosphorus or nitrogen over the entire 3 year study period. Additionally, 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 5.1. Water Quality Monitoring Stations in the Head Lake Watershed

Station ID	Location	Number of Samples	Most Recent Sample
HL1	Rush Lake Outlet at Monck Road (tributary)	68	May 2017
HL2	Head River at Baker Blvd Outlet (tributary)	79	May-2017
HL3	Small tributary at Hilton Point Road West (tributary)	65	May-2017
HL4	Head River Inlet (tributary)	10	May-2017
HL5	Northern lake site	10	July 2017
HL6	South Eastern lake site	13	July 2017
HL7	South Western lake site	10	July 2017
LPP	Mid Lake (Deep site)	30	October 2016

Hydrometric Results

Tributary water temperatures followed a seasonal trend throughout the three year study period ranging from a maximum recorded of 27.5 ^{o}C (HL2) in August 2015 to a minimum of 0.6^{o}C (HL1) in January 2016. The tributary pH values varied significantly across the 4 tributaries (One Way ANOVA p<0.001). These variances are mostly due to the local geologic influence of the study's tributaries. Conductivity ranged from 37.6 to 554 µS/cm and varied significantly (One Way ANOVA p<0.001) following the similar expected pattern observed in pH due to geological influences. Water hardness (as CaCO3) varied significantly and supported the diverse geology from the highly mineralized southern areas (HL1 Inflow-Rush Lake) to the north shield area (HL4 Inflow Fishog Lake) as seen in **Figure 5.2**.

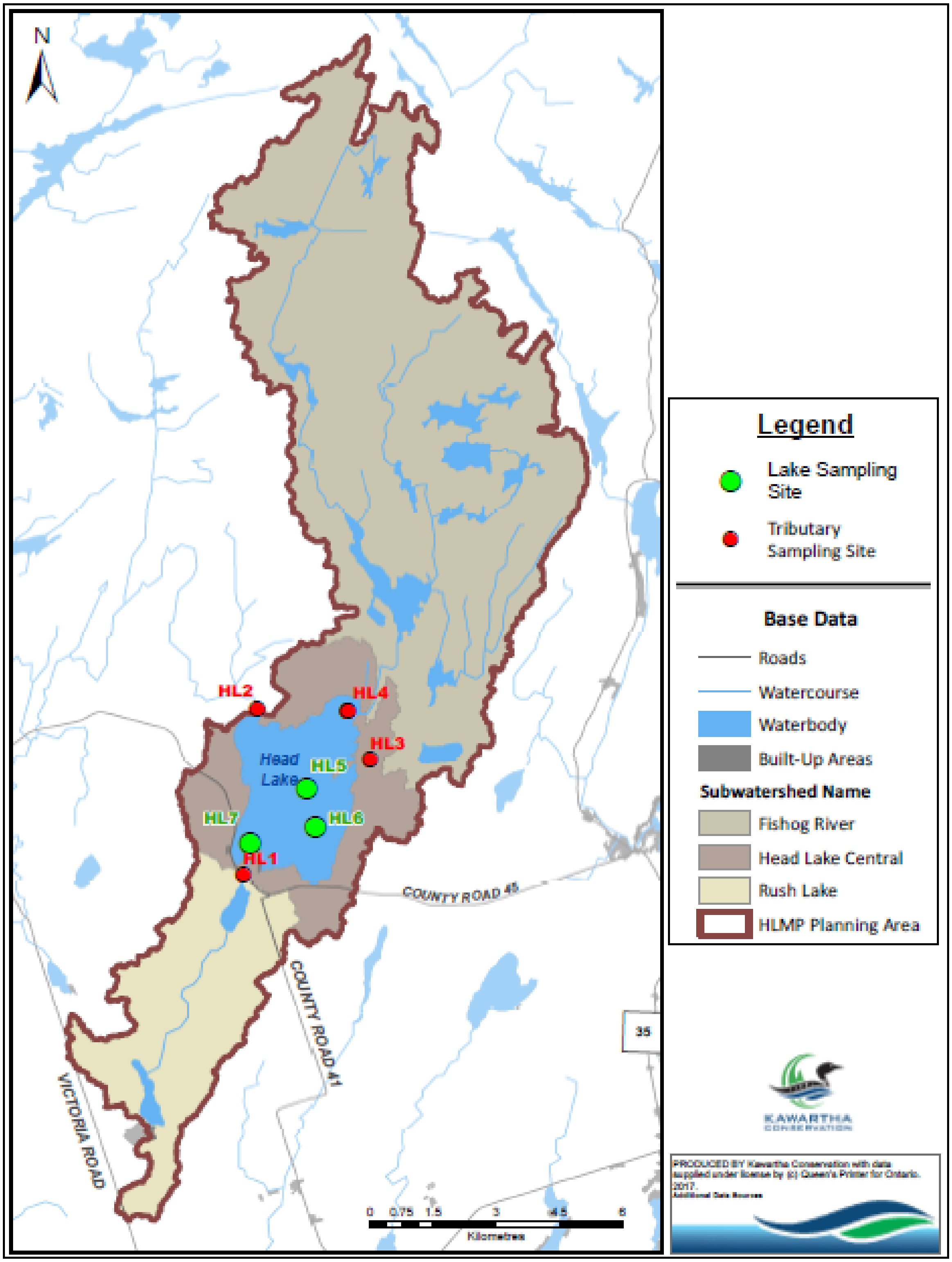


Figure 5.1. Water Quality Monitoring Stations in the Head Lake Watershed

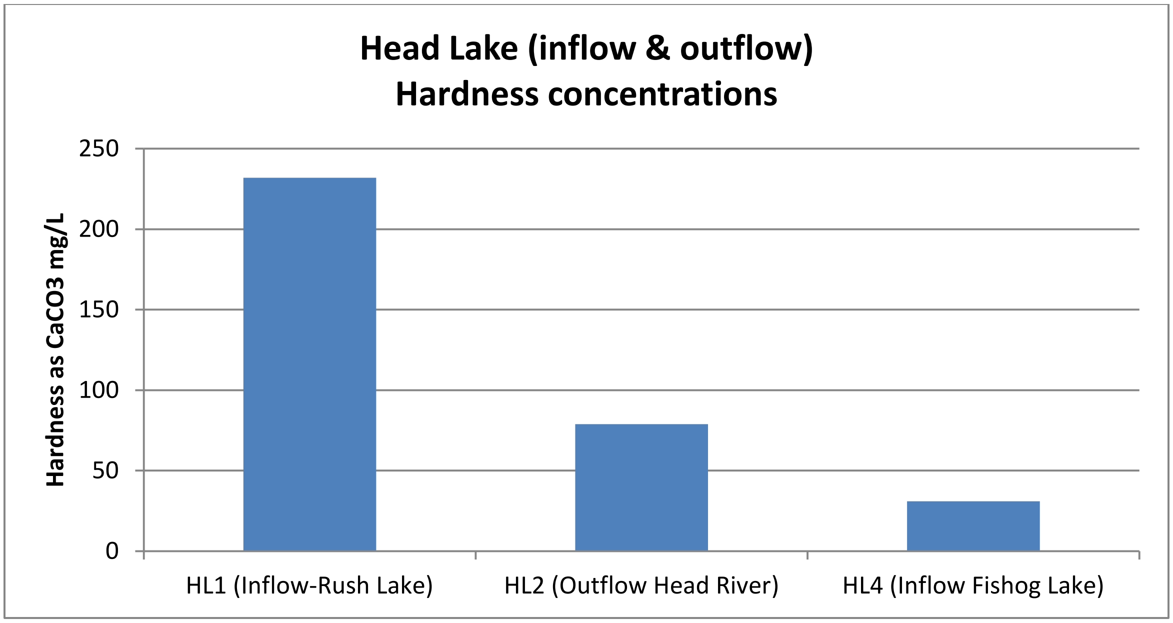


Figure 5.2. Range of water hardness within the Head Lake Watershed

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 algal growth, and a corresponding depletion of dissolved oxygen in the water column. The PWQO for total phosphorus (TP) concentrations in tributaries is set at 30µg/L, in order to prevent nuisance algae and aquatic plant growth **(MOECC, 1994).** The PWQO for TP concentrations in lakes is 20µg/L and/or 10µg/L for those lakes with a natural TP level below this value **(MOECC, 1994).** Head Lake has historically recorded TP concentrations above 10µg/L, therefore the PWQO of 20µg/L applies to Head 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 Head Lake watershed, tributaries maintained average phosphorus concentrations that were well within the PWQO and there were no exceedances during the three year study period **(Figure 5.3).**

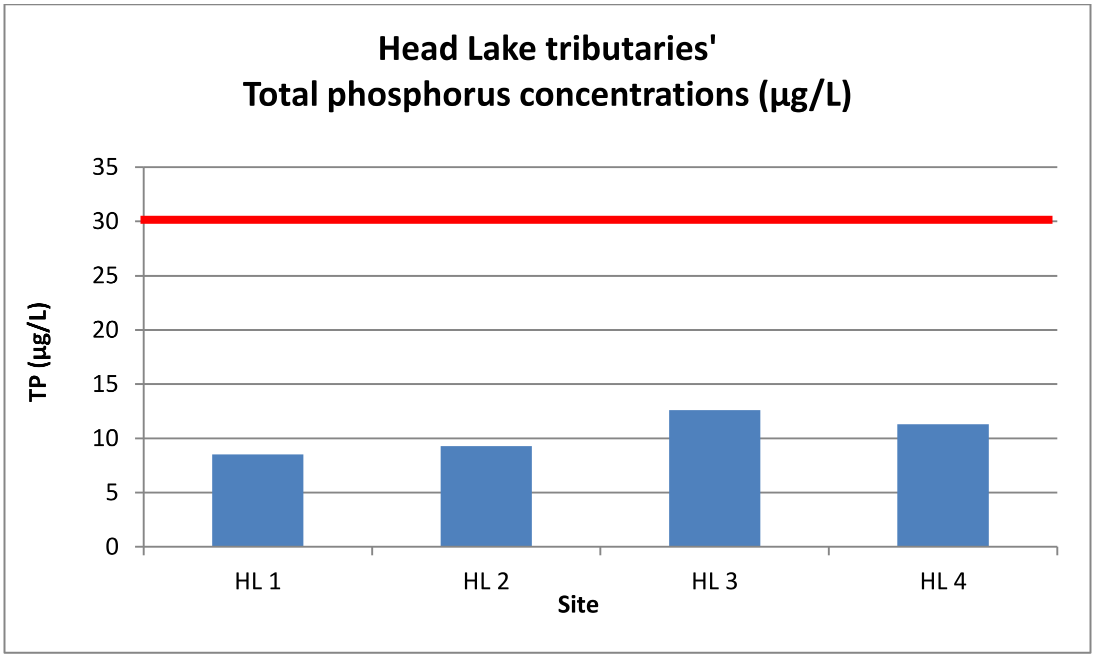


Figure 5.3. Average phosphorus concentrations (µg/L) in the Head Lake tributaries in 2014-2017. The red line denotes the Provincial Water Quality Objective (30µg/L).

Fishog River is the largest watercourse in the Head Lake watershed measuring 13.93 km in channel length. Its origin is located further north on Precambrian Shield bedrock and includes drainage from the area of the Queen Elizabeth II Wildlands Provincial Park as well as many small wetlands, which has very little anthropogenic influences. The Fishog River watershed is characterized by the highest fraction of the natural cover among the three delineated sub-watersheds within the study area (see Water Quantity Chapter 4 for more details).

The Southern portion of the Head Lake watershed consists of a single drainage area consisting of limestone parental rock through the inflow tributary, draining Rush Lake measuring 4.94km in channel length. The Northeast area drains into an unnamed tributary (HL3-Hilton's Point Rd) and is a small second order stream with a channel length of 2.51 km.

Finally, the Head River is the only outflow of Head Lake which converges with the Black River that in turns flows into, Severn River and, consequently into Georgian Bay. All of the inflow tributaries have relatively average low phosphorus concentrations and are well within the Provincial Water Quality Objectives (30µg/L). Total phosphorus concentrations between the Head Lake tributaries did not vary significantly during the time period of the study (One way ANOVA $p>0.05$). Average total phosphorus concentrations ranged between 2.0µg/L to 37µg/L.

Higher concentrations of phosphorus were observed during the Fall season as a result of lower flows and natural decomposition processes.

The Rush Lake outlet (HL1) total phosphorus values ranged from 2µg/L to 18µg/L **(Figure 5.3).** The mean concentration was 10.06 µg/L over the three year study period. The median value was almost identical and was recorded at 9.5µg/L. The low total phosphorus concentrations are indicative of the healthy natural origin of Rush Lake. It originates from a minimally impacted southwestern lake, known as Duck Lake then traverses through a series of wetland complexes and through Rush Lake to the Head Lake at the County Road 45 (Monck Rd) outlet. The Rush Lake outlet is well protected and buffered as it is comprised of 91% of natural cover.

The Northeast unnamed tributary (HL3) has a considerable anthropogenic affect as the 2.51km stream length meanders through built up (Hilton's Point Rd)and agricultural areas of the Head Lake watershed. The total phosphorus concentrations ranged from 2µg/L to 37µg/L and site HL3 had the highest average total phosphorus concentrations within the Head Lake watershed (16µg/L), but still well within the PWQO. The highest concentration was recorded in September 2016 and just surpassing the PQWO (30µg/L) at a concentration of 37µg/L. There were two other similar episodes of exceedances which also occurred in the fall of 2014 & 2015, measuring 32µg/L and 36µg/L respectively. The highest phosphorus readings were observed mainly under low flow 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 which the feeds the creek. The median concentration was similar to the mean and was calculated at 14µg/L. Although the northeastern unnamed tributary held the relatively highest mean and recorded total phosphorus values it was well buffered and filtered by the wetlands it traversed before its termination at Head Lake.

The Fishog River differs geologically from other tributaries within the Head Lake watershed. IT is a naturally flowing river measuring 13.93km in length and draining an area of 77km^2. It originates from the Canadian Shield headwaters and is protected through the Queen Elizabeth II Park plan (Ontario Parks). The Fishog River subwatershed is comprised of 98% natural cover including a large wetland complex with negligible human impact along this watercourse. Total phosphorus concentrations ranged from 4µg/L to 17µg/L over the three year study period **(Figure 5.3).** Mean and median concentrations were almost identical and recorded as 10.5µg/L and 11.1µg/L respectively. No exceedances above the PWQO of 0.03 mg/L were detected in the stream. A special focus and tripartisan effort between Ontario Parks, Kawartha Conservation and the Head Lake Associations should be given to protect the Fishog River complex as it greatly influences the water quality of Head Lake. The Fishog River has the highest volumetric input (42550000m^3 per annum) of all of the tributaries within the Head Lake watershed and contributes over half of the inflow into Head Lake (66%).

The Head Lake River/ Head Lake outlet is located within the Head Lake Central subwatershed **(Figure 5.1).** This subwatershed is encompassed by a natural area surrounding Head Lake (89% forest cover and 6% urban). The only outlet flow occurs via the Head River located off Baker Road at the North western portion of the Lake. The Head River is part of the Queen Elizabeth II Wildlands protected area. The Head

River exhibited overall low TP concentrations throughout the three year study period which ranged with minimum and maximum recorded values at 3µg/L and 28µg/L respectively. The highest value was observed during the fall in 2014. Average TP concentrations (over the study period) measured 12.2µg/L which is well within the Provincial Water Quality Objective (PWQO= 30µg/L). The median concentration, over the three year period was very similar to the average Head River and was calculated at 11.5µg/L. There were zero exceedences of the PWQO during the three year study period. Further analysis will determine the significance of winter TP loading as a result of the number of frost free days and available loading from the snow melt and soil-snow interface as a result of thawing.

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 1000µg/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 293 µg/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 Head Lake watershed, total nitrogen concentrations did not exceed the 1000 µg/L interim PWQO. Over the three year study duration total nitrogen concentrations ranged from 125µg/L to 982µ/L. Average and median nitrogen levels in all tributaries fall below the interim guideline and range from 325µg/L to 498µg/L **(Figure 5.4).**

Looking at the watershed-wide scale, one can see that average nitrogen concentrations are higher in the Rush Lake outlet as opposed to the northeastern unnamed tributary (HL3), situated to the north eastern portion of Head Lake, which has the lowest concentrations of all nitrogen forms. Analysis of the water quality data suggests that an increase in total nitrogen levels in the Rush outlet and Fishog River is mainly associated with very high organic material from the large wetlands which feed both water courses.

The seasonal distribution of total nitrogen at the Rush Lake outlet (HL1) is characterized by higher concentrations during the fall and winter due to low flow conditions and a heavy organic load as a result of naturally occurring senescence patterns of large wetlands upstream (Figure 5.4).

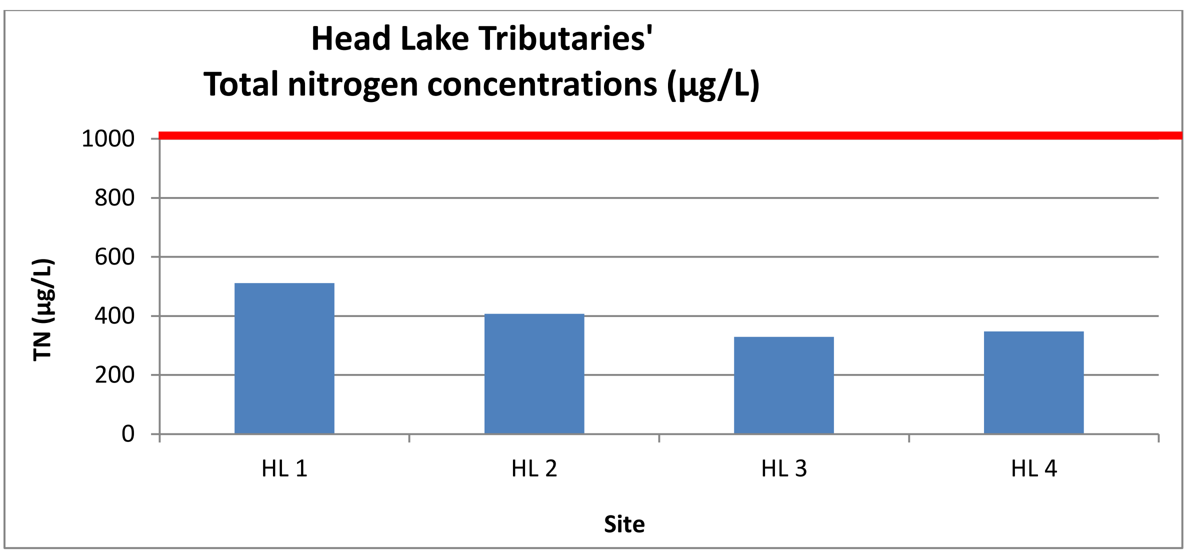


Figure 5.4. Average total nitrogen concentrations (µg/L) in the Head Lake tributaries; Rush Lake outlet (HL1), Head River outlet (HL2), Unnamed northeastern tributary (HL3), Fishog River outlet (HL4). The red line denotes the interim Provincial Water Quality Objective (1000µg/L).

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 average concentrations of total suspended solids in streams located in the study area are usually 1.0-14.0mg/L **(Figure 5.5).** The maximum TSS concentration was recorded in the Northeastern unnamed stream (HL3) measuring 39 mg/L, during August 2016. The TSS concentrations within this stream are higher than the other streams within the study area (average 14.7 mg/L) and may be attributed to the possible sediment release from the adjacent field upstream of the sampling site on HL3. The remaining tributaries, Rush Lake outlet (HL1), Head River (HL2), and Fishog River (HL4) within this study area had average TSS concentrations of 3.5mg/L, 7mg/L, and 2mg/L respectively over the three year study period.

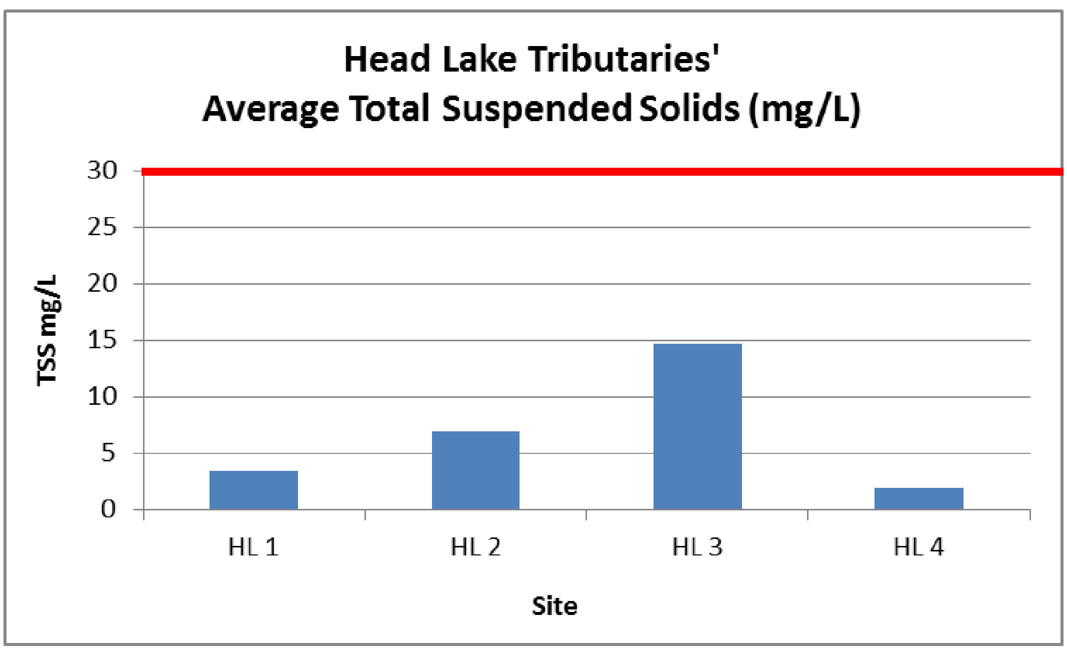


Figure 5.5. Average Total suspended solids concentrations (mg/L) in Head Lake tributaries (2014-2017); Rush Lake outlet (HL1), Head River outlet (HL2), Unnamed northeastern tributary (HL3), Fishog River outlet (HL4). All fell well within the CCME guideline (30mg/L). The red line denotes the CCME guideline (30mg/L).

As mentioned above, average and median TSS concentrations in all monitored streams are well below the CCME guideline. The lowest average TSS concentration was detected in the outflow of the Fishog River (HL4) **(Figure 5.5).**

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 (100cfu/100 mL) and based on a geometric mean of at least five samples **(MOECC, 1994).**

E.coli monitoring results from 2014-2016 have revealed that all of the monitored streams in the Head Lake watershed have had *E.coli* levels well below the PWQO. However, due to a lack of samples a Geomean *E. coli* concentration was not calculated and the recorded values offer standalone values. *E.coli* exceedances generally followed intensive rain events. At the same time, dry weather samples can also observe *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. The Haliburton, Kawartha, Pine Ridge District Health Unit beach posting data (due to elevated *E. coli* concentrations) show that the public beach on Head Lake has been posted at least once per season during the monitoring years of 2011-2017 (details in *Escherichia Coli* at Public Beaches section).

5.4 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, Head 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. The phosphorus concentrations are well within the Provincial Water Quality Objectives for lakes which is 20µg/L**.** Additionally, both bottom (1m off bottom) and surface samples were analysed for total phosphorus concentrations in the northern and southern sampling sites. Secchi disk depth readings usually ranged between 0.9m and 4.0m over the three year study period and averaged a depth of 2.66m which is slightly below the Lake Partner Program recorded value of 3.0m.

<u>Phosphorus</u>

As described in Chapter 1 the majority of Head Lake and the land to the south of the lake is underlain by Paleozoic limestones and is part of the Carden Plain physiographic zone **(Figure 2.5).** Shallower depths of 3m or less dominant the lake while the deepest points of the lake are located in the South Eastern portion of the lake and also immediately north of Hilton's Point reaching 7m. Lake data (surface samples) collected for this study included representative sites in both the north and south and shallow and deep sites, HL5, HL7 and HL6 respectively. The sampling sites in Head Lake consist of similar hydrographic features and hydrological regimes and also influenced to some degree by abiotic anthropogenic factors including the high density of development including private septic systems along the shores. However, there is a higher density of buildings in the south east and west of the lake.

Overall average total phosphorus concentrations for Head Lake tributaries were indicative of a healthy mesotrophic system (12.3µg/L) recording results much lower than historical data from the 1970s which recorded average total phosphorus values at 19µg/L **(MOECC, 1972). Figure 5.6** shows the decline in total phosphorus input concentrations since the early 1970s. HL2 was considered the accepted value for the lake itself **(MOECC, 1972).**

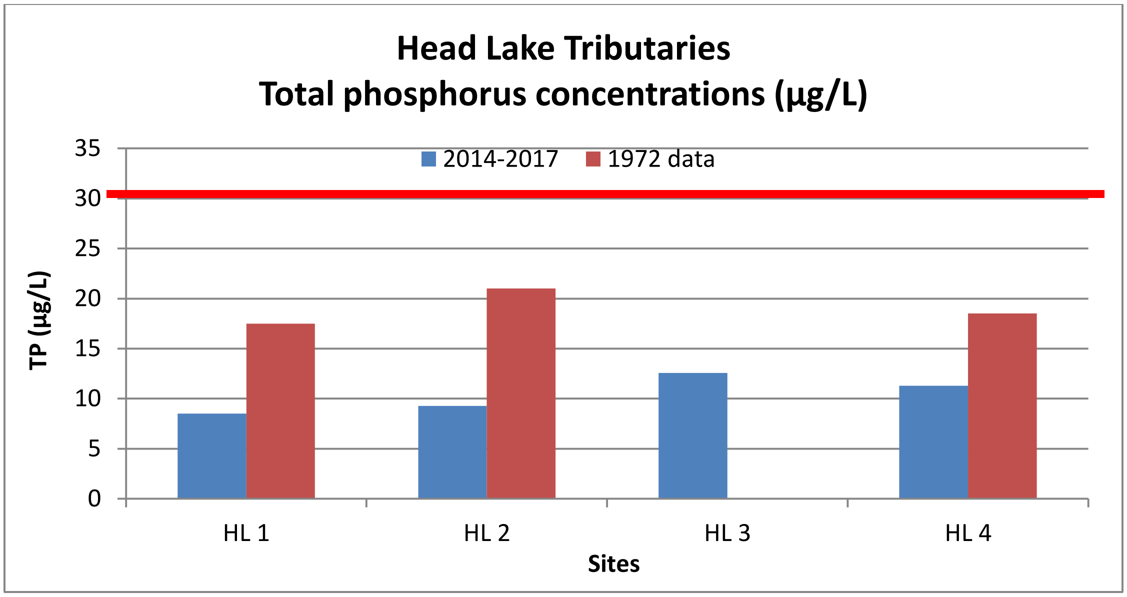


Figure 5.6. Average phosphorus concentrations inputs into Head Lake during the three year study period (2014-2017) in comparison to the available data from 1972. The red line denotes the PWQO (30µg/L).

Over the three-year period, phosphorus levels in the lake followed the same general trend. Concentrations were similar in all sampling sites (HL5, HL6, & HL7) representing the more shallow southern and deeper northern areas of the lakes measuring 11µg/L, 11µg/L and 13µg/L respectively **(Figure 5.7).** The median values for the three lake sites were almost identical and were recorded for HL5, HL6 & HL7 as follows; 10.5µg/L, 12µg/L and 12µg/L respectively. The available data demonstrate that the lowest phosphorus concentrations in Head Lake overall were usually observed in June & September. During the summer months of July and August TP levels increase and reach the highest values in July -August, depending on the weather conditions in each given year. There was one exceedence of the total phosphorus PWQO at site HL6 during June of 2015. However, more information is needed to examine if any weather events occurred simultaneously.

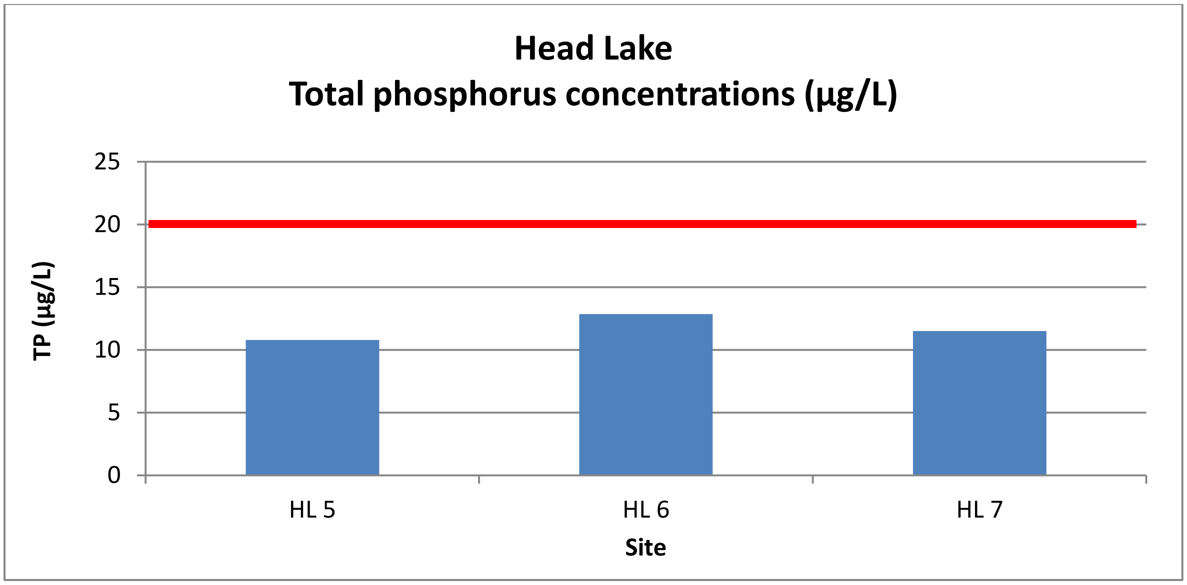


Figure 5.7. Average (surface samples) annual phosphorus concentrations (µg/L) in Head Lake for the study period 2014 – 2017. The red line denotes the PWQO (20µg/L).

The long-term data collected through the Lake Partner Program (LPP) by local lake associations and volunteers since 2002 demonstrate that phosphorus concentrations in the lake are quite stable and well within the Provincial Water Quality Objective (20µg/L) since the beginning of monitoring **(Figure 5.8).** There is one monitoring station in the framework of the LPP on Head Lake. It is located within the deepest spot of the lake which Kawartha Conservation has used as HL6 for the duration of this study to ensure data collection consistency.

Since the early 2000s the average annual TP concentrations were stable ranging from 7µg/L to 12µg/L. Higher TP concentrations recorded in 2013 coincided with a high flooding event during the spring of 2013. It appears that high spring inflow from overland runoff, saturated wetlands upstream and other smaller overfilled tributaries resulted into a small influx of phosphorus into the lake during April – May and may have caused elevated TP levels during the summer of 2013. The 2015-2016 LPP data correlates very well with our own data and follows similar trends **(Figure 5.7).** A basic statistical analysis performed has shown that phosphorus concentrations do not indicate much change between the years. Mean and median values were practically the same over the eleven year duration measuring 11 µg/L and 10µg/L respectively. There were no exceedances reported. During the period of monitoring the number of samples did not vary significantly between years and can be considered reliable data points in the context of this report.

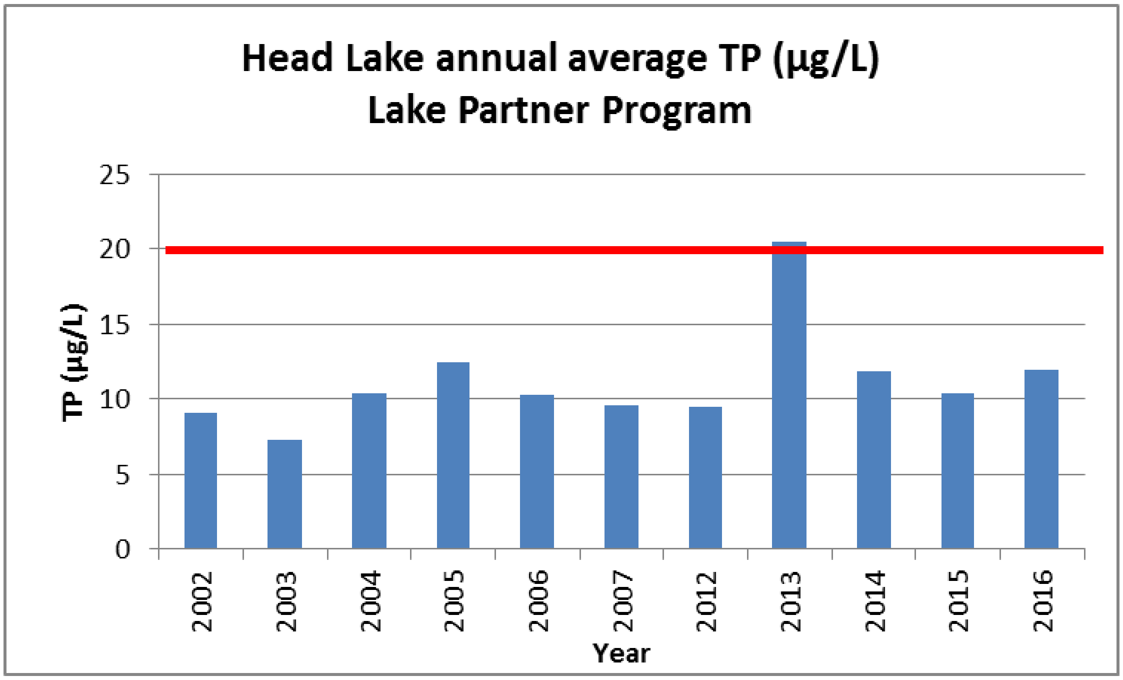


Figure 5.8. Average annual phosphorus concentrations (mg/L) in Head Lake for the period of 2002 – 2016 (Lake Partner Program Data). The red line denotes the PWQO (20µg/L).

In addition to collecting surface water samples Kawartha Conservation also examined bottom water samples (1m above bottom) at all lake sites (HL5, HL6, & HL7). The bottom samples were collected at the same interval as the surface samples and analyzed for total phosphorus and nitrogen including the various fractions.

Sediment in lakes can contain much higher phosphorus concentrations than the water therefore lake bottom water samples are important to quantify as a possible internal loading mechanism via the release of phosphorus from sediment. In highly oxygenated lake bottoms the inorganic transfer of phosphorus from the water column to the sediment unidirectional to the sediment, however in low level or no oxygen situations a combination of low/no oxygen levels and a chemical catalyst (Ferrous sulfide precipitation) which results in a removal of iron from the sediment and thus a release of phosphorus to the bottom layer of water (hypolimnion) which is then circulated throughout the water column during fall turnover (Wetzel 1983). Although minimal, the role of phospholizing bacteria is also a contributor of internal phosphorus loading from sediment sourcing.

Overall Head Lake exhibited on average low total phosphorus concentrations in the bottom samples of the lake (pooled HL5, HL6, & HL7 data) ranging from 9µg/L to 11µg/L over the three year study period **(Figure 5.9).** The average concentration was well within the PWQO measuring 8µg/L. There were zero occurrences of PWQO exceedances and concentrations were well below the threshold (the TP PWQO was applied for the purpose of this report). More investigation into the possible internal loading from sediment should be considered as a future study.

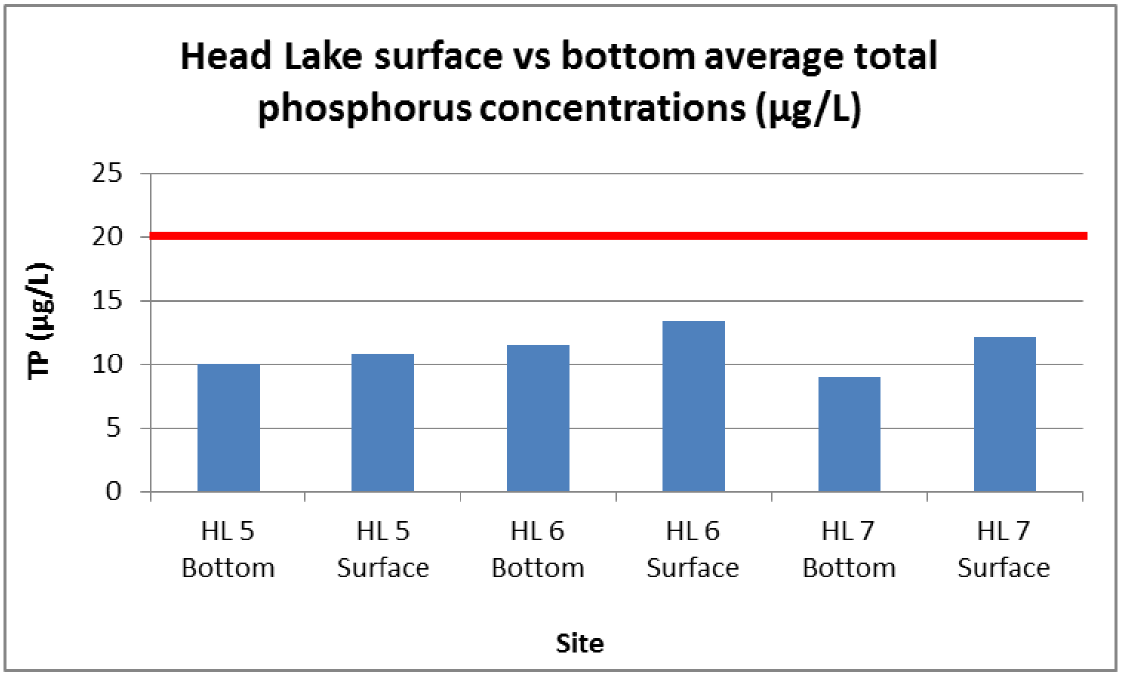


Figure 5.9. A comparison of average bottom and surface phosphorus concentrations in Head Lake during the study period (2015-2017). The red line denotes the PWQO (20µg/L).

Nitrogen

The results of nitrogen analysis in open water sampling sites (HL5, HL6 & HL7) in Head Lake showed values well within the Provincial Interim Guideline of 1.00mg/L of total nitrogen. In Head Lake overall (pooled site data) total nitrogen concentrations fluctuated in the range of 254 – 726 µg/L . Sites HL5 & HL7 very similar results and had recorded average concentrations of 361µg/L and 383µg/L respectively. Site HL6 exhibited slightly higher concentrations than the other two sites and the average concentration over the three year study period was 437µg/L. The highest TN value was recorded at site HL6 with a maximum of 893µg/L, while the minimum recorded concentration was 254µg/L was recorded at site HL5 **(Figure 5.10).** The median of all open water sampling sites HL5, HL6, & HL7 were also very similar and calculated at 344µg/L, 345 µg/L and 349µg/L respectively.

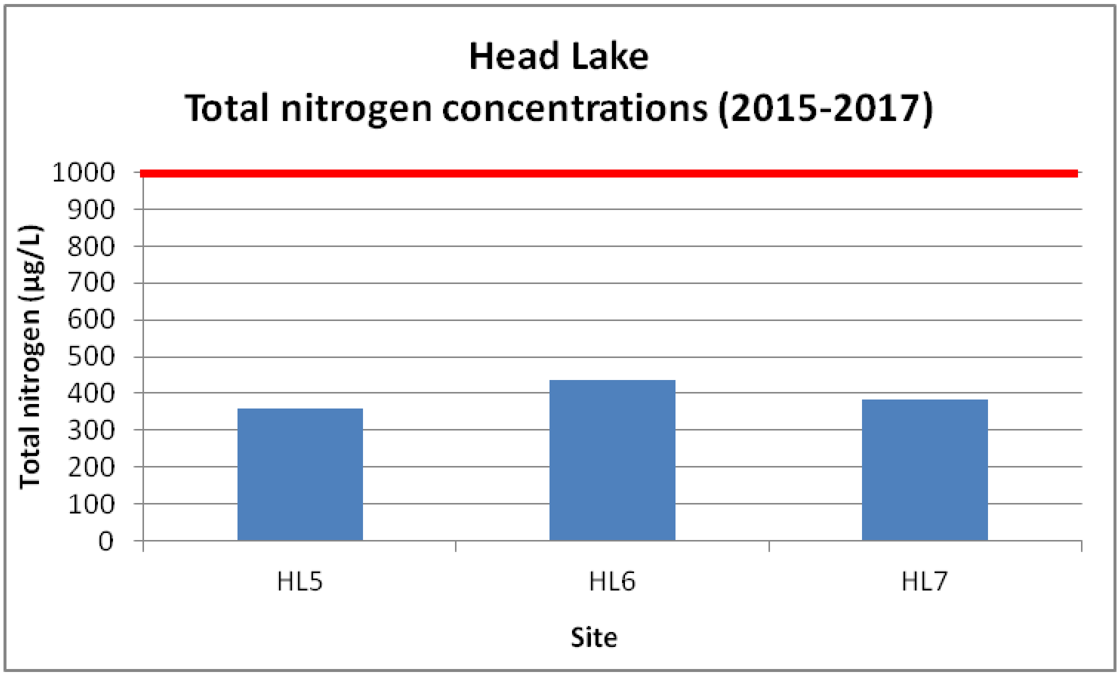


Figure 7.10. Average total nitrogen concentrations (µg/L) in Head Lake during the May-September period in 2015-2017. The red line denotes the interim PWQO.

The low nitrogen levels found in Head Lake may be attributed to the limited amount of agricultural areas as vectors of nitrogen inputs in addition to the vast protected areas surrounding the lakes such as the QEWII Wildlands Provincial Park and north eastern wetlands protecting the lake.

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 lower in the spring and through most of the summer as a result algal utilization and denitrification by bacteria and concentrations during this period were mostly below the laboratory detection limit (200 µg/L) or in the range just above the limit – 200-300µg/L. The maximum nitrate concentration was recorded in August 2016 measuring 820µg/L well within the Provincial Water Quality Objectives (263µg/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 (bottom deep water layers) affecting the well-being of aquatic organisms.

Extremely low hypolimnetic DO levels have a 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 ^{o}C to 7 mg/L at 0 ^{o}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 ^{o}C to 8 mg/L at 0 ^{o}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).** (See Aquatic Health Chapter 6 for more details).

<u>End of Season Dissolved Oxygen</u>

End of season hypolimnetic dissolved oxygen provides good information in terms of fish recruitment and relationship to algal and plant productivity. According to dissolved oxygen and temperature profiles taken in 2015, Head Lake is well mixed and does not stratify during the summer months (see **Figure 5.2** in Aquatic Health Chapter), which is due to its relatively shallow and warm waters. The coldest recorded temperature was 18.5^{o}C at 5m deep. This indicates that Head Lake does not possess suitable habitat to support sensitive coldwater aquatic communities (e.g., lake trout, lake herring, etc.). Dissolved oxygen concentrations are also relatively uniform, with no limitation recorded in its deeper waters. The lowest dissolved oxygen concentration was 4.31mg/L at 5m deep.

Although, Head Lake demonstrates good end of season dissolved oxygen levels it is important to note that shoreline development and other anthropogenic practices will produce a negative effect on the lake's dissolved oxygen levels.

Calcium

Calcium (Ca) is an essential building block for all living organisms. Small microscopic animals called zooplankton such as Daphnia spp. (water fleas) use calcium from the water column to build their protective body covering during the moulting process **(MOECC 2017).** Larger animals such as crayfish, amphipods and clams also use calcium to make their shells. Calcium enters our lake via atmospheric deposition & mineral weathering into the soils and enters the lake by leaching from soil. According to the MOECC the two anthropogenic contributors to calcium decline including acidic deposition and forest harvesting practices **(2017).**

A deficit of calcium entering our lakes began in the early acid rain period (early –mid 1900s) where more calcium was leaving the watershed soils at a faster rate than it could be replenished through weathering processes and atmospheric inputs. At this point in time studies conclude a consequence of accelerated leaching rates calcium levels may have resulted in increased calcium concentrations in some lakes **(Smol et al 2008).** A change in environmental laws was the impetus to a significant decline of acid deposition from rain has declined significantly (approximately 50% less) which translates into decreased calcium leaching to lakes from surrounding watershed soil. According to Smol et al **(2008)** the impact of little to no calcium replenishment has resulted in decreased concentrations in some lakes within central Ontario.

Additionally, climate change has been identified as potential accelerator to calcium level declines due to the warming of the lakes **(MOECC 2016).** Part of the Ministry of the Environment and Climate Change's citizen science program, the Lake Partner Program includes volunteers collecting calcium samples for analysis on a monthly sample collection (MOECC 2016). The calcium threshold for ecological consequences such as zooplankton community shifts (i.e cladocerans) is 0.5mg Ca/L whereas the threshold for crayfish is a bit higher at 1-2.5mg/L. Head Lake is well above this threshold and has calcium levels measuring 21.1mg/L on average over the last 6 years **(MOECC 2016).**
It is essential to maintain good forestry practices and monitoring to maintain the current levels to create resiliency as a strategy against climate change.

<u>Escherichia Coli at Public Beaches</u>

The Haliburton, Kawartha, Pine Ridge (HKPR) District Health Unit monitors bacteriological contamination at one public beach, which is located on County Road 45 next to the public boat launch **(Figure 5.11).**

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 Haliburton, Kawartha, Pine Ridge (HKPR) District Health Unit's *E.coli* data for 2013-2017 demonstrate that the beach at Head Lake generally has good bacteriological water quality. Closures have been limited to approximately one posting per year. However some exceedances have occurred over the past five years. The highest *E. coli* concentrations and subsequent increased frequency of postings occurred during the year of 2014 (**Figure 5.12**). The beach was not posted in 2017 and *E.coli* concentrations stayed well within the geometric mean of 100cfu/100ml (Public Health threshold). Data for 2016 from the Haliburton, Kawartha, Pine Ridge (HKPR) District Health Unit is not available.

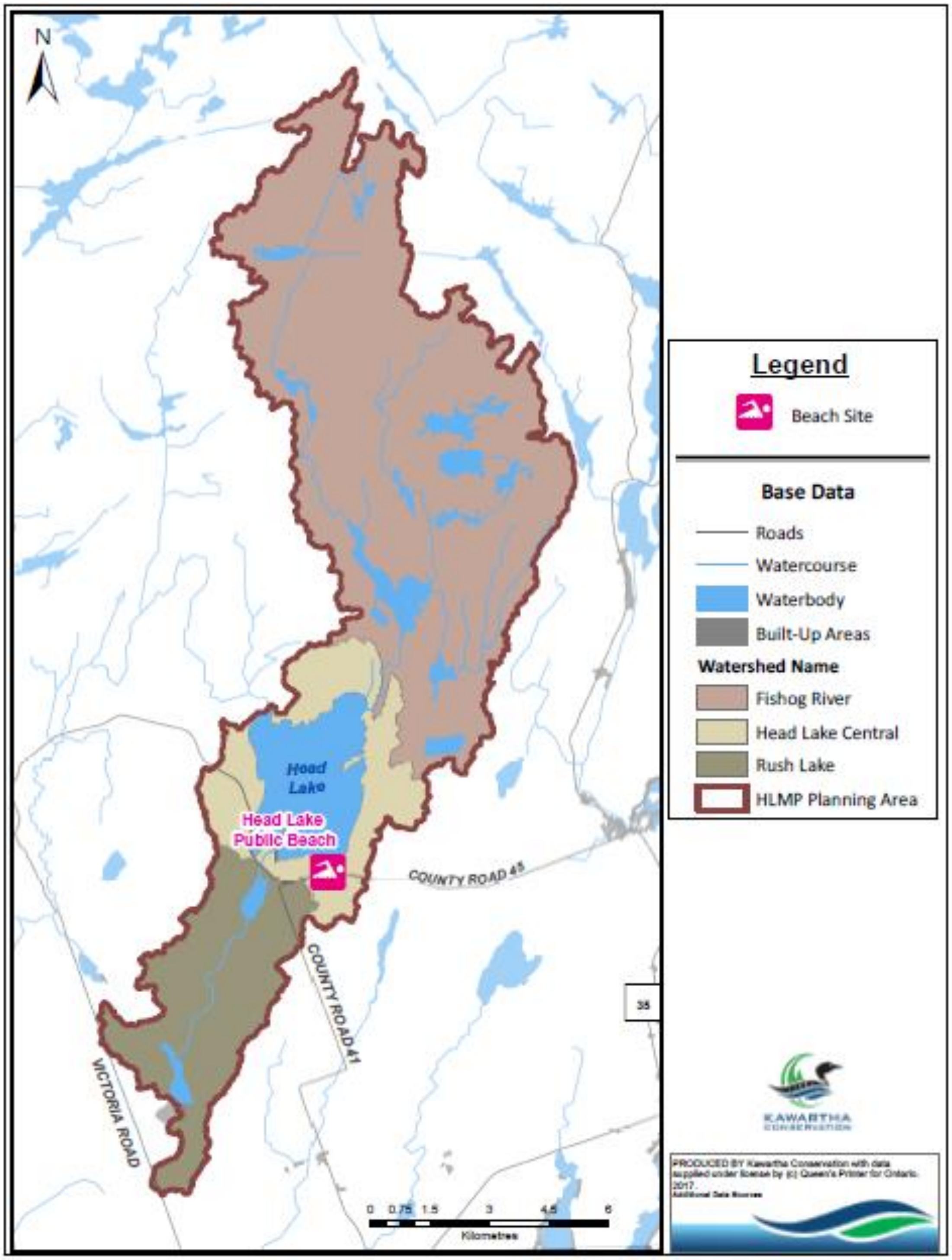


Figure 5.11. Public Beach Location within the Head Lake Watershed.

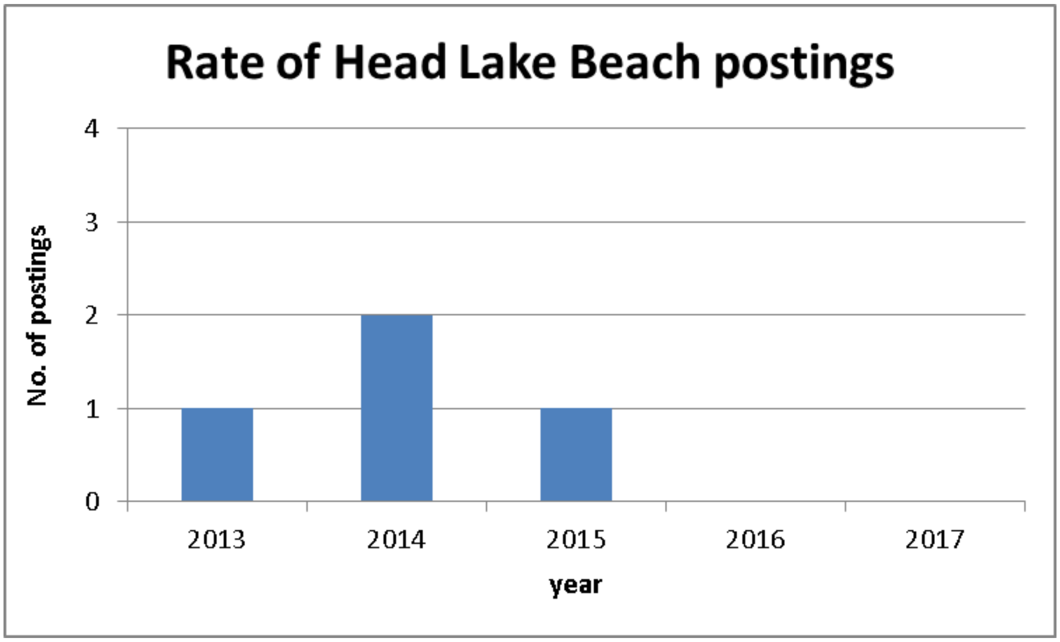


Figure 5.12. Annual rate of beach postings at the Head Lake Public Beach (2016 Is not available and 2017 had zero postings).

6.0 Aquatic Ecosystems

6.1 Summary of Observations, Key Issues, and Information Gaps

OBSERVATIONS

- ***Head Lake support diverse fish communities that contribute to a functioning warmwater recreational fishery.*** Approximately 13 fish species have been documented within Head Lake, most of which are large-bodied fishes recorded through 2 sampling events within the last 10 years. There are no fish community data for Rush Lake. According to the most recent available data (2015), the large-bodied fish community in Head Lake consists of warm- and cool-water species dominated by walleye, yellow perch, white sucker, pumpkinseed, rock bass, and muskellunge. Several fishes are important in supporting a small but apparently viable recreational fishery particularly walleye, smallmouth bass, and muskellunge. Walleye populations are considered one of the most significant of all similar-sized lakes within the management zone (Zone 17). No known fish species listed as Special Concern, Threatened or Endangered have been documented.

- ***Head Lake and Rush Lake are relatively shallow and well-mixed, moderately-productive, warmwater lakes.*** Due to the shallow depths of both lakes, they exhibit uniform water temperatures and do not stratify at depth. As indicated by phosphorus and water clarity conditions, the lakes are considered mesotrophic (moderately productive) trophic status. There are no existing water quality degradations, and there have been no apparent changes in water quality since the early 1970's.

- ***Aquatic habitat conditions along the creeks draining directly into Head Lake and Rush Lake are of excellent quality, owing to the lack of human disturbance.*** Subwatersheds that drain directly into the Head Lake planning area have exceptional coverage of natural areas, particularly forests and wetlands. Along creek corridors, natural riparian areas comprise from 88-100% of their entire length, and are within acceptable guidelines for maintaining aquatic ecosystem health. This is substantiated by exiting benthic macroinvertebrate communities that have moderately-high compositions of sensitive taxa, and average bioassessment results that indicate a status of "fair".

KEY ISSUES

- ***Establishment of non-native, invasive aquatic species that alter the aquatic ecosystem.*** Head Lake and (likely) Rush Lake have been exposed to a variety of non-native aquatic species. There are limited data available for Head Lake and other watercourses in its drainage basin. Records indicate that European frog-bit, Eurasian watermilfoil, European common reed, and banded mystery snail are invasive species present in the watershed. In addition to these existing non-native species, there are others that are at immediate risk of becoming established (e.g., zebra mussels, round goby). The hydrological interconnectedness of Head Lake with QEII Wildlands Provincial Park makes both systems vulnerable.

- ***Climate change has the potential to continue to alter aquatic ecosystem conditions***. The impacts of climate change are not well understood for Head Lake and its watershed. It has the potential to affect physical and biotic attributes and ecological functions within the watershed. 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.

INFORMATION GAPS

- **Limited understanding of sensitive aquatic habitats in-and-around Head Lake and Rush Lake.** Sensitive aquatic habitats including fish spawning areas, wetlands, and nearshore areas, have not been thoroughly described around the lakes. Existing data is limited and have not been updated in several years.

- ***Lack of aquatic community data within tributaries of Head Lake.*** There are limited data available for aquatic organisms that live in tributaries. Rush Lake and Fishog River subwatersheds in particular are presumably significant in terms of biodiversity. There are large tracts of relatively natural streams, rivers, wetlands, and small lakes within Head Lake basin that have not been studied. There are no top predator fisheries data for Rush Lake.

- ***Limited understanding of long-term changes in fish communities.*** There are limited fish community data available for fish communities on Head Lake. Only recently has the Ontario Ministry of Natural Resources and Forestry initiated routine netting program on Head Lake (2 sampling events since 2008). It will be sampled approximately every 5 years moving forward through the Broad-scale Monitoring Program. Tracking trends in top predator fishes that contribute to the recreational fishery and aquatic biodiversity are particularly important.

- ***Limited understanding of how stressors such as climate change, cumulative development and invasive species will impact the aquatic ecosystem.*** Aquatic communities within the lake have been altered throughout the years in response to various pressures, particularly from the introduction of invasive species. It is important to have a comprehensive understanding of how stressors interact within the lake and its watersheds, for example, by determining lake capacity thresholds. Currently, no known standards exist for determining what constitutes a "healthy aquatic ecosystem" that is specific to Head Lake or its tributaries. There are opportunities to study minimally disturbed aquatic ecosystems, for example those in QEII Wildlands Provincial Park.

6.1 Introduction

This chapter provides an overview of important components of the aquatic ecosystems of Head Lake. An aquatic ecosystem consists of biotic or living things within water bodies and their relationship to, and connection with, other living and non-living components. Maintaining healthy aquatic ecosystems is integral in maintaining healthy lakes.

Below is a characterization of aquatic life (communities of species, particularly fishes) and aquatic habitats (features and functions that maintain life) that exist/interact within the lake and its tributaries.

6.2 Lake Ecosystems

6.2.1 Aquatic Habitat

Head Lake is a shallow lake, having a maximum depth of approx. 7.0m and a mean depth of approximately 4.2m **(OMNRF 2017).** The lake is hydrologically connected to Fishog River, which includes several small lakes along its length, Rush Lake, and the Black River watersheds. The water levels and major flows through the lake are largely determined by the amount of water entering through Fishog River as well as the dam along the Head River (see Chapter 4: Water Quantity).

Based on recent water quality sampling (see Chapter 5: Water Quality) Head Lake and Rush Lake are considered mesotrophic, or moderately-productive waterbodies. Data indicate water quality within the lakes is considered in a good state, having waters that are relatively clear, and unenriched. For Head Lake, this is due in large part to the quality of the water into the lake from the Fishog River inputs, which drains lands from the Canadian Shield as relatively nutrient poor, clean and clear waters. This major inflow subwatershed is also a protected area, Queen Elizabeth II Wildlands Provincial Park, which has limited development. For Rush Lake, this is likely due to the lack of disturbance within its watershed. There have been no major changes in water quality in Head Lake according to nutrient and water clarity records from the early 1970's. The lake to our knowledge did not become degraded from acid rain, because its underlying limestone bedrock and calcareous shallow soils provide good buffering. Relatively high calcium concentrations also help reduce the risk of proliferation of *Holopodium glacialis* (freshwater jellyfish), a phenomenon associated within the decline of Daphnia zooplankton experienced by several lakes within the Canadian Shield region (**Jeziorski et al., 2014**) that have calcium deficiencies.

There are no publically available bathymetry data for Rush Lake. The deepest depths in Head Lake are within the south-east part of the lake, in-and-around Armstrong Island, and immediately north of Hilton's Point (**Figure 6.1**). The majority of the lake (approx. 66% of its surface area) is at or less then 3m deep. Most of the shoreline has relatively gradually sloping nearshore areas, except for the southeast shore along Sunset Beach Rd. and the southwest shore along Monck Rd. which have relatively narrow and steep nearshore areas. There are limited data available regarding substrates on the lakebed, and aquatic plants.

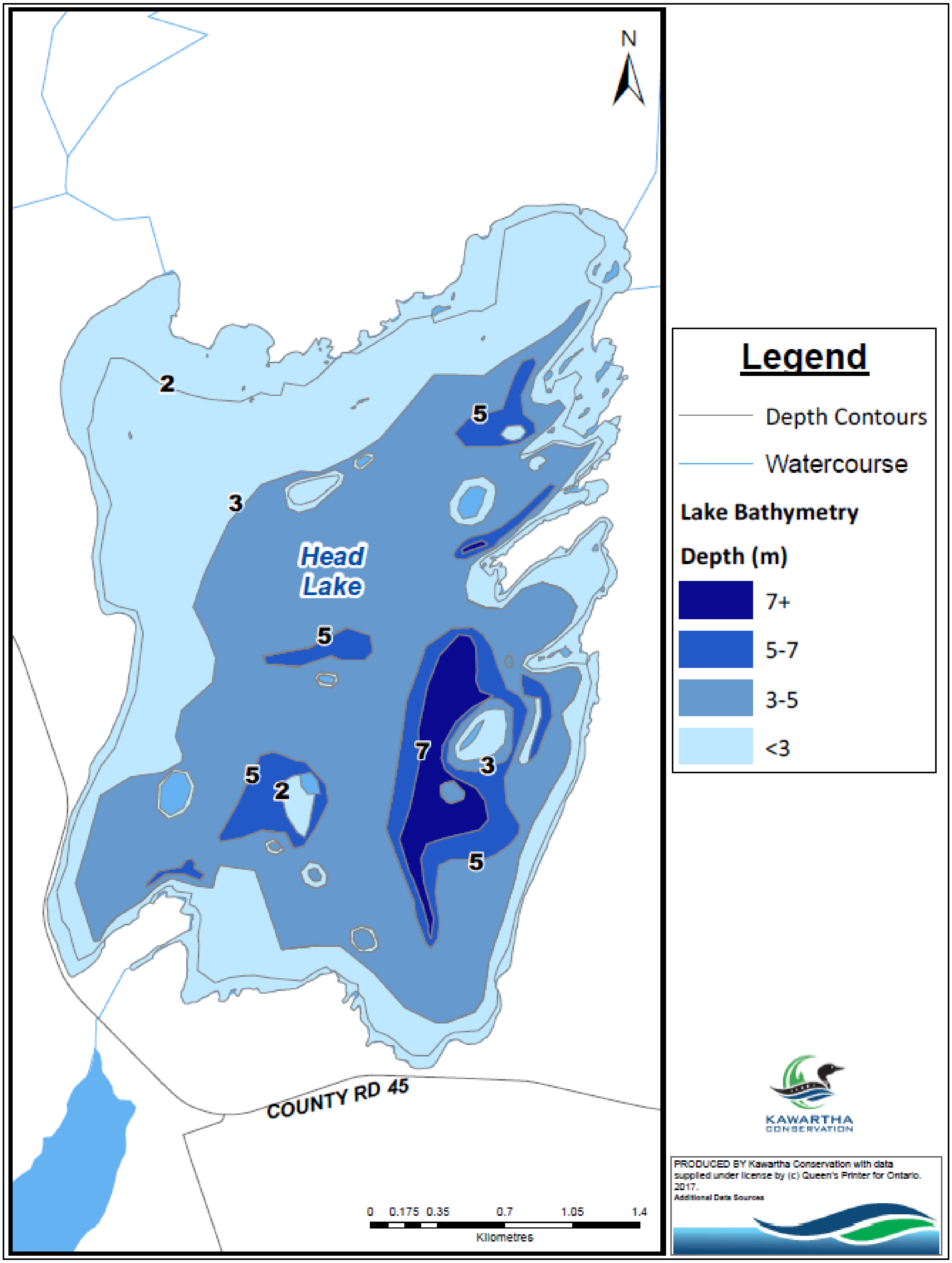


Figure 6.1: Bathymetric map of Head Lake.

According to dissolved oxygen and temperature profiles taken in 2015, Head Lake is well mixed and does not stratify during the summer months (**Figure 6.2**), which is due to its relatively shallow and warm waters. The coldest recorded temperature was 18.5°C at 5m deep. This indicates that Head Lake does not possess suitable habitat to support sensitive coldwater aquatic communities (e.g., lake trout, lake herring, etc.). Dissolved oxygen concentrations are also relatively uniform, with no limitation recorded in its deeper waters. The lowest dissolved oxygen concentration was 4.31mg/L at 5m deep.

There is limited information on aquatic habitat such as substrate, and aquatic vegetation. According to available mapping by the OMNRF (LIO 2015), muskellunge spawning habitat has been documented in the following areas: northwest shore near the outlet of the lake, northeast shore along the mouth of the Fishog River, and south shore along the Rush Lake tributary that exists within the Rush Lake Provincially Significant Wetland. Walleye spawning habitat has been documented along the shore of Hiltons Point, and near the mouth of the Fishog River. Due to the importance of the habitat along the Fishog River outlet, the stretch of river from the lake to approximately 1.5km upstream to the waterfalls has been designated a provincial fish sanctuary to protect the staging and spring spawning walleye and muskellunge **(OMNRF 2016).** A comprehensive survey of fish spawning locations has not recently been conducted on the lake, or within its connecting tributaries which also likely support migratory habitat.

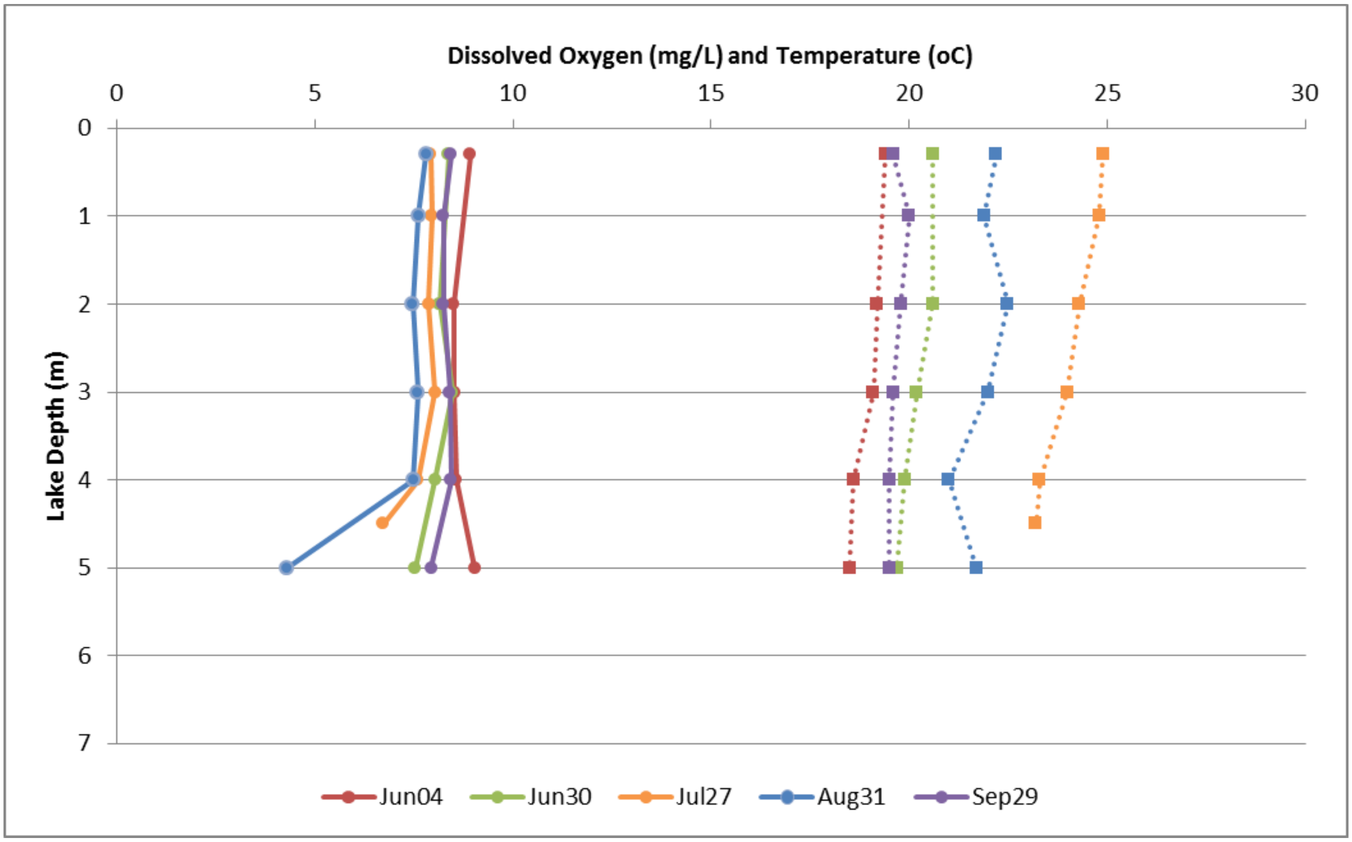


Figure 6.2: Dissolved oxygen (mg/L, solid lines) and water temperature (°C, dotted lines) profiles during 2015.

6.2.2 Fish Communities

There are limited long-term aquatic community data available for Head Lake. Available fisheries data comes from three main sources: OMNRF sampling in the late 1980's related to Walleye stocking assessments (**Haxton, 1989),** and OMNRF sampling in 2008 and 2015 related to their Broad-scale Monitoring Program. This information helps to characterize the fish community and aquatic habitat conditions in the lake but does not permit the characterization of long-term changes.

Routine aquatic community sampling was initiated in 2008 by the OMNRF, through its Broad-scale Monitoring program. This 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). Head Lake is considered a fixed lake, and as such is scheduled for sampling approximately every 5 years. Two surveys have been undertaken to date in 2008 and 2015.

According to available data, Head Lake supports diverse coolwater and warmwater fish communities. Approximately 13 fish species have been confirmed documented in the lake (**Table 6.2**). Sampling effort is relatively low for Head Lake, and the number of resident small-bodied fish species is likely significantly higher than documented. There are no known species of conservation concern, including mussels, but as mentioned sampling has been limited. Several of the existing fishes are thought to be non-native to the lake, including walleye (stocked as early as the late 1930's), smallmouth bass (stocked as early as 1930's), largemouth bass (stocked as early as the 1940's), and rock bass (**A.Challice, personal communication**).

Table 6.2. List of all documented fishes within Head Lake. Bold indicates large-bodied species important to the recreational fishery. Italics indicates fish that are non-native.

Species Common Name	MNR_BsM2008	MNR_BsM2015	Haxton_1989
Yellow perch	x	x	
Walleye	x	x	x
Smallmouth bass	x	x	
Rock bass	x	x	
White sucker	x	x	
Pumpkinseed	x	x	
Muskellunge	x	x	
Blackchin shiner	x		
Bluntnose minnow	x	x	
Largemouth bass	x	x	
Spottail shiner	x	x	
Golden shiner		x	
Brown bullhead			x

According to the most recent lake-netting programs (2015), the most large-bodied fish species found in Head Lake, in terms of relative abundance, are walleye, yellow perch, white sucker, smallmouth bass, pumpkinseed, rock bass, and muskellunge (**Figure 6.3**). There have been not significant changes in the fish community since 2008 sampling, however there have been changes in relative abundance of existing community including: higher values for walleye, white sucker, and pumpkinseed, and lower values for yellow perch, smallmouth bass, and rock bass.

Several of the documented fishes function as top predators and are important recreational fish species including Smallmouth Bass, Walleye, and Muskellunge. Angling effort is predominately for walleye, based on anecdotal angler feedback in recent years. Based on the most recent Broad-scale Monitoring sampling, Head Lake supports a healthy walleye population that is comprised of multiple year classes and is considered one of the healthier walleye populations relative to lakes of similar size within Fisheries Management Zone 17 (**A.Challice, personal communication**). The reasons for this are poorly understood at this time. Angler effort (for all species, not just walleye) on Head Lake is considered average for its lake size class during the summer months and below average during the winter months. The lower angling activity during the winter months is largely due to the dominant recreational fish community (which includes walleye, smallmouth bass, muskellunge) having closed seasons (**A.Challice, personal communication**). The minimal ice fishing activity is focused towards panfish (e.g., yellow perch and pumpkinseed).

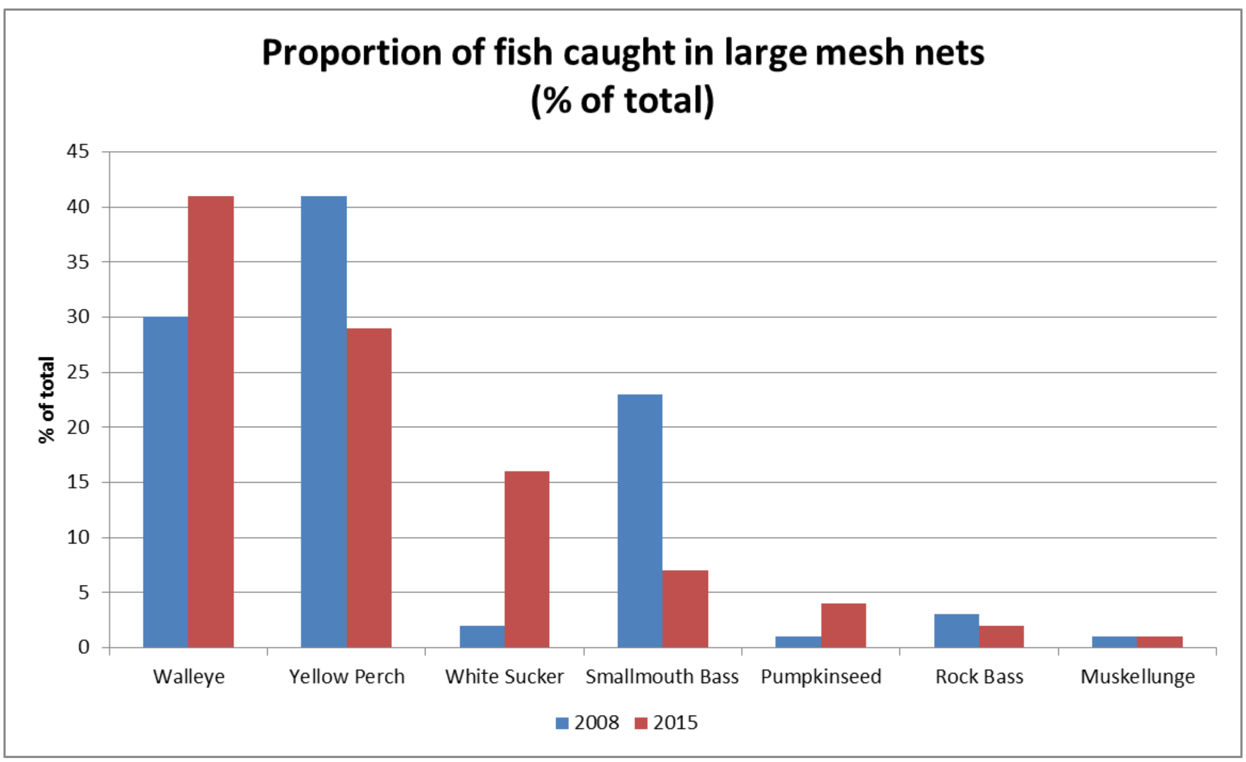


Figure 6.3. Proportion of fish caught in large mesh nets in 2008 and 2015, as per the Broad-scale Monitoring Program by Ontario Ministry of Natural Resources and Forestry.

6.2.3 Exotic and Invasive Species

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.

Head Lake is hydrologically connected to Georgian Bay, through the Severn River and Black River watersheds, as well as through the Fishog River and Queen Elizabeth II Wildlands Provincial Park. Thus Head Lake is somewhat susceptible to exotic species transfer because it exists within a recreational hotspot that is 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.

Four of documented fishes are considered exotic: walleye, smallmouth bass, largemouth bass, and rock bass. However, these species have likely been in the system for decades and are now considered naturalized, as opposed to invasive. According to the invasive species reporting tool EDDMAPs, the following additional exotic aquatic organisms have been documented within the Head River watershed: Europian frog-bit (2007), Eurasian watermilfoil (1998), European common reed (2013), and banded mystery snail (2015) (**EDDMAPS 2017**).

The lake has been sampled numerous times since 2012 for zebra mussels, but according to EDDMAPS none have been detected. However, according to recent anecdotal information zebra mussels have been observed along Sunset Beach Rd. (east shore of Head Lake), an account that has not been verified. Calcium concentrations within Head Lake are in-and-around 20 mg/L, a threshold above which they are known to establish populations **(Wittier et al. 2008)**.

There is concern among local residents of the potential introductions and proliferation of freshwater jellyfish, *Holopedium glacialis*. At present, no documented outbreaks, and lake is likely not vulnerable because calcium levels are relatively high to support native zooplankton (i.e., daphnia). However, their presence has been confirmed in August 2017 through invasive species zooplankton tow-netting undertaken by local residents (**D. Lowles, personal communication**).

6.3 Tributary-Based Ecosystems

6.3.1 Aquatic Habitat

Figure 6.4 and Figure 6.5 shows the best-available mapping of the watercourse network within the Head Lake Watershed planning area. When combined, the watercourse network totals approximately 328 km in length, all of which can be considered as probable aquatic habitat that directly supports or contributes to aquatic life. Almost all streams (approximately 98% of total length) flow through natural lands, primarily through forested areas, marsh wetlands, open waters, and rock barrens. A small percentage (1%) flows through developed areas including transportation network (e.g., roads), rural development, and agricultural areas.

Stream Order

Figure 6.4 shows the watercourse network, and **Table 6.3** 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 tend to exhibit similar biological properties. Stream orders within the Head Lake planning area range from one to six. The majority of watercourses (almost 80% 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. The larger streams sections, of third- to sixth-order, comprise 20% of the total length of the stream network. These sections typically flow continuously, thus providing aquatic habitat year-round.

Table 6.3. Length of Streams Within Each Subwatershed by Strahler Order.

Subwatershed	Stream Length	1st order	2nd order	3rd order	4th order	5th order	6th order
Fishog River	294 km	54%	25%	13%	4%	4%	1%
Head Lake Central	18 km	68%	30%	2%	1%	-	-
Rush Lake	17 km	61%	8%	31%	-	-	-
Stream Order Total	**328 km**	**55%**	**24%**	**13%**	**3%**	**3%**	**1%**

There are 10 mapped tributaries that drain directly into Head Lake. Fishog River is the largest (draining into the northeast of Head Lake as a 6th-order stream), followed by an unnamed watercourse draining the Rush Lake subwatershed (draining into the south end of Head Lake as a 3rd order stream), an unnamed tributary draining a portion of the Head Lake Central subwatershed (draining into the east end of Head Lake as a 2nd order stream), and several unnamed tributaries draining portions of the Head Lake Central subwatershed from the north, south, and west. Most of the aquatic habitat within these tributaries consists of undisturbed and relatively low-gradient forests and marsh wetlands. Although aquatic community data, particularly fish communities, are limited for these tributaries, the outlet sections of these tributaries are likely important habitat of Head Lake because they provide 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, providing a corridor for the movement of aquatic organisms, water mixing, and food and energy transport which all contribute to the aquatic biodiversity and productivity of the lake. Several important fishes, particularly muskellunge, walleye, and/or white sucker likely migrate into these tributaries in early spring to reproduce, however this assumption requires further study for confirmation. Likewise, many tributary-dwelling fish species likely migrate to the lake or refuge pools during seasonal dry periods or to avoid stream freeze-up during winter months. Therefore, unimpeded access to-and-from the lake helps maintain healthy fish populations in the lake. The only confirmed spawning areas along tributaries include the Rush Lake outlet watercourse within the Rush Lake Provincially Significant Wetland (muskellunge), and the outlet of the Fishog River which is a provincial fish sanctuary (walleye and muskellunge).

Riparian Area

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 Head Lake planning area, the extent and type of land cover along the watercourse was interpreted from aerial photography taken in 2013. 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 (**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 6.6**). 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 6.4** lists the percentages of 30 m riparian areas by subwatershed. Natural riparian area coverage within all three subwatersheds is exceptionally high (88-100%), with an average of 98% natural lands along all tributaries within the planning area.

Table 6.4. Riparian Land Use (30m on Both Sides) in Subwatersheds of the Head Lake planning area.

Row Labels	Riparian Area (ha)	Agriculture	Development	Natural
Fishog River	2437	0%	0%	100%
Head Lake Central	142	6%	6%	88%
Rush Lake	121	4%	2%	94%
Grand Total	**2700**	**0%**	**1%**	**98%**

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, cool water 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.). Cool water 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.).

In summer of 2016 the thermal regime of watercourses was assessed at 4 locations at stream-road crossings to identify any potentially sensitive areas. 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, cool water, 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, the thermal regime status of most of the creeks within the planning area was unknown, whereas Fishog Lake, Victoria Lake, and Wolf Lake are considered coldwater, and the remaining lakes are classified as warmwater or cool water. As shown in **Figure 6.7**, 2 of the sample sites were classified as warmwater (Rush Lake outlet, and Head Lake outlet), and 2 sites were classified as dry (unnamed tributaries). Therefore, aquatic communities in close proximity to these sites are likely to be considered non-sensitive warmwater or cool water communities. There remain significant gaps in thermal regime classification of all remaining tributaries.

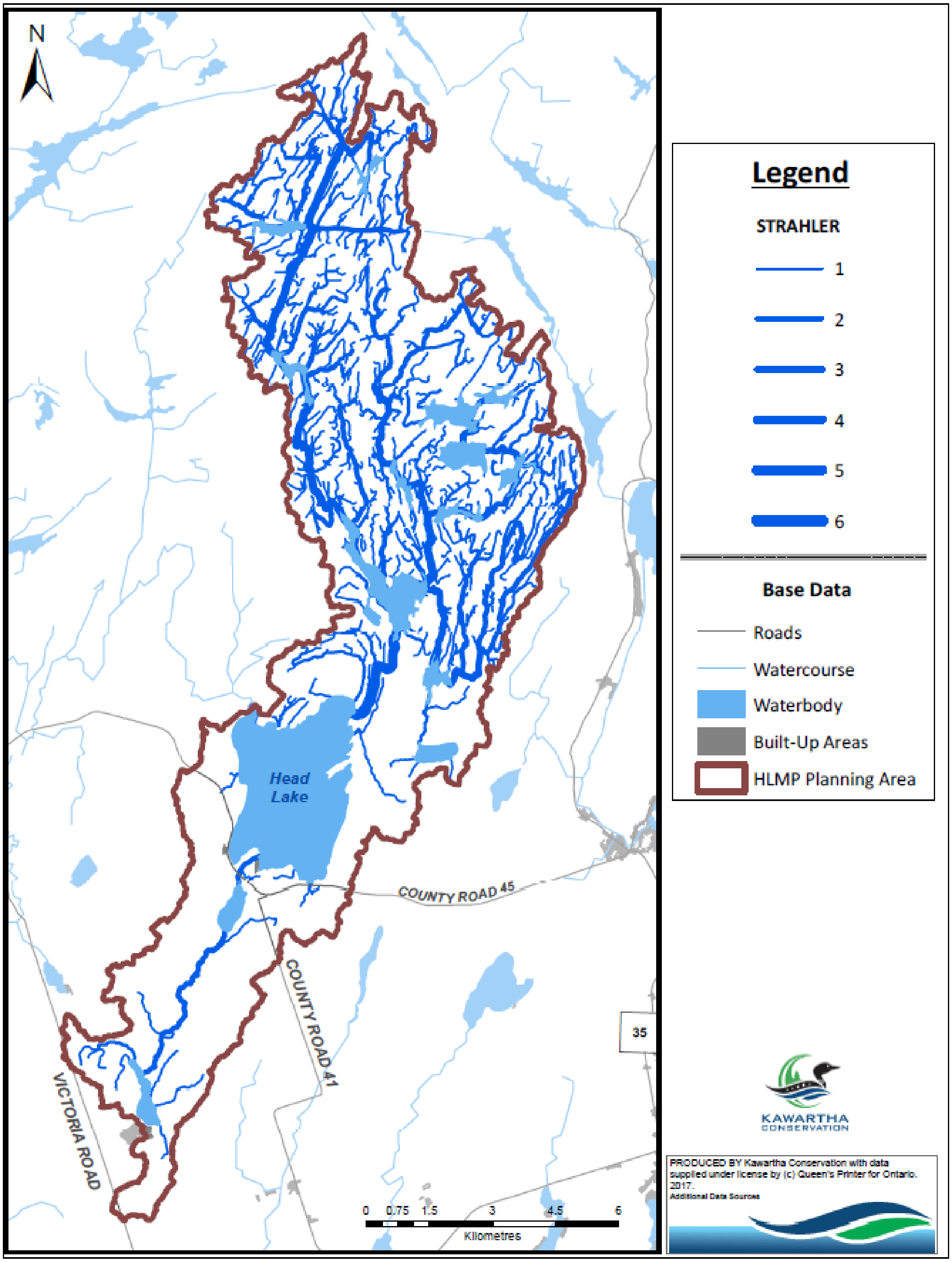


Figure 6.4. Watercourse Network by Strahler Order.

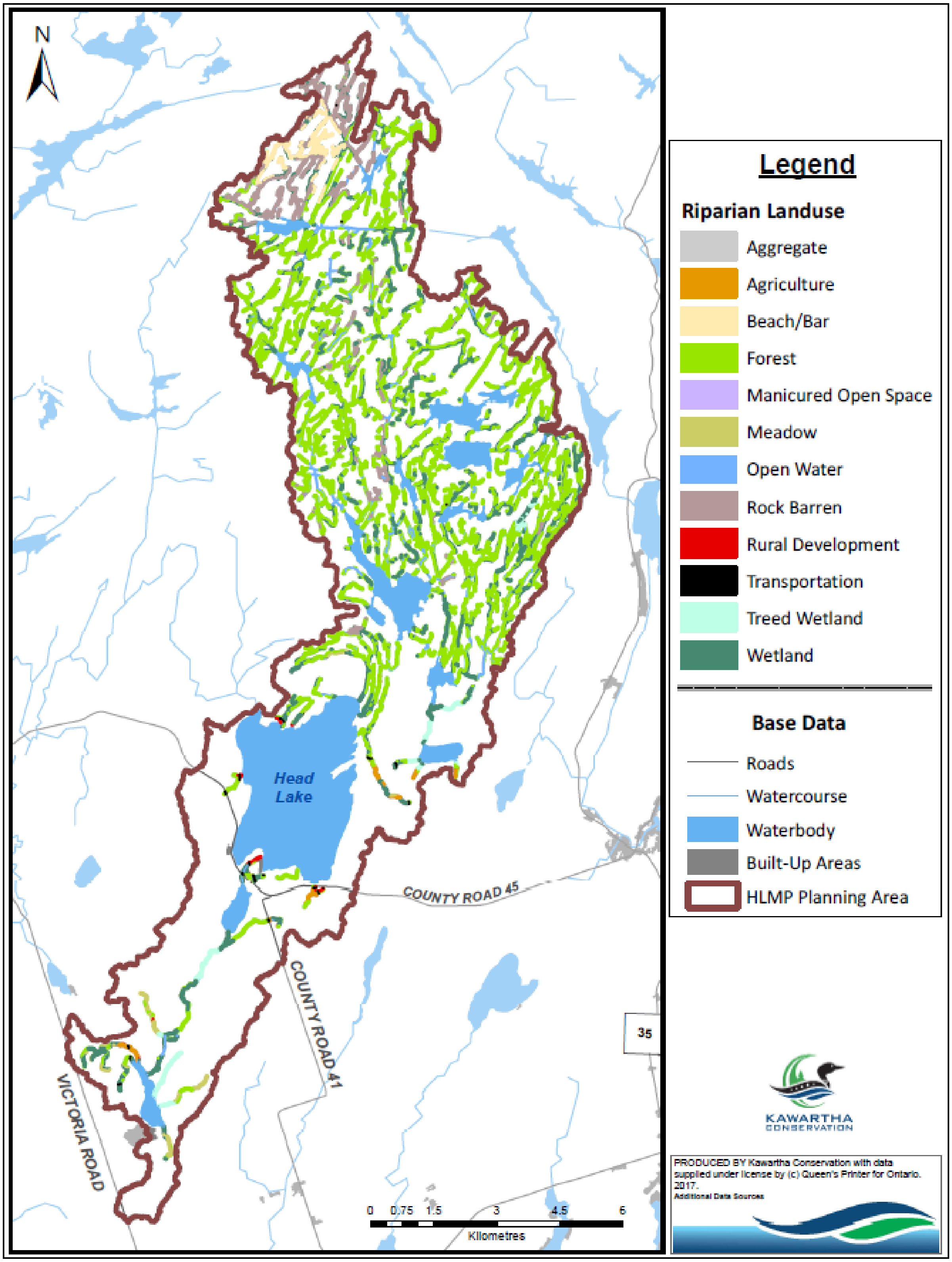


Figure 6.5. Land Use Along Stream Corridors in the Head Lake planning area.

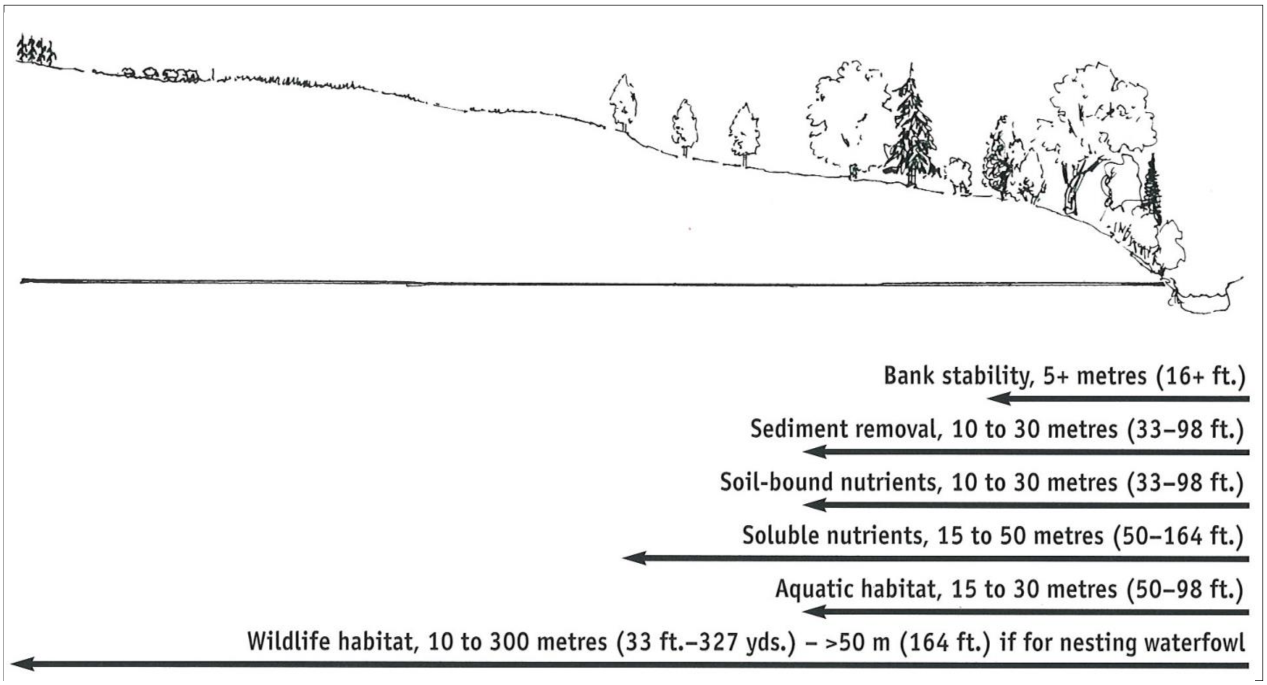


Figure 6.6. Summary of Important Functions of Natural Riparian Areas by Width.

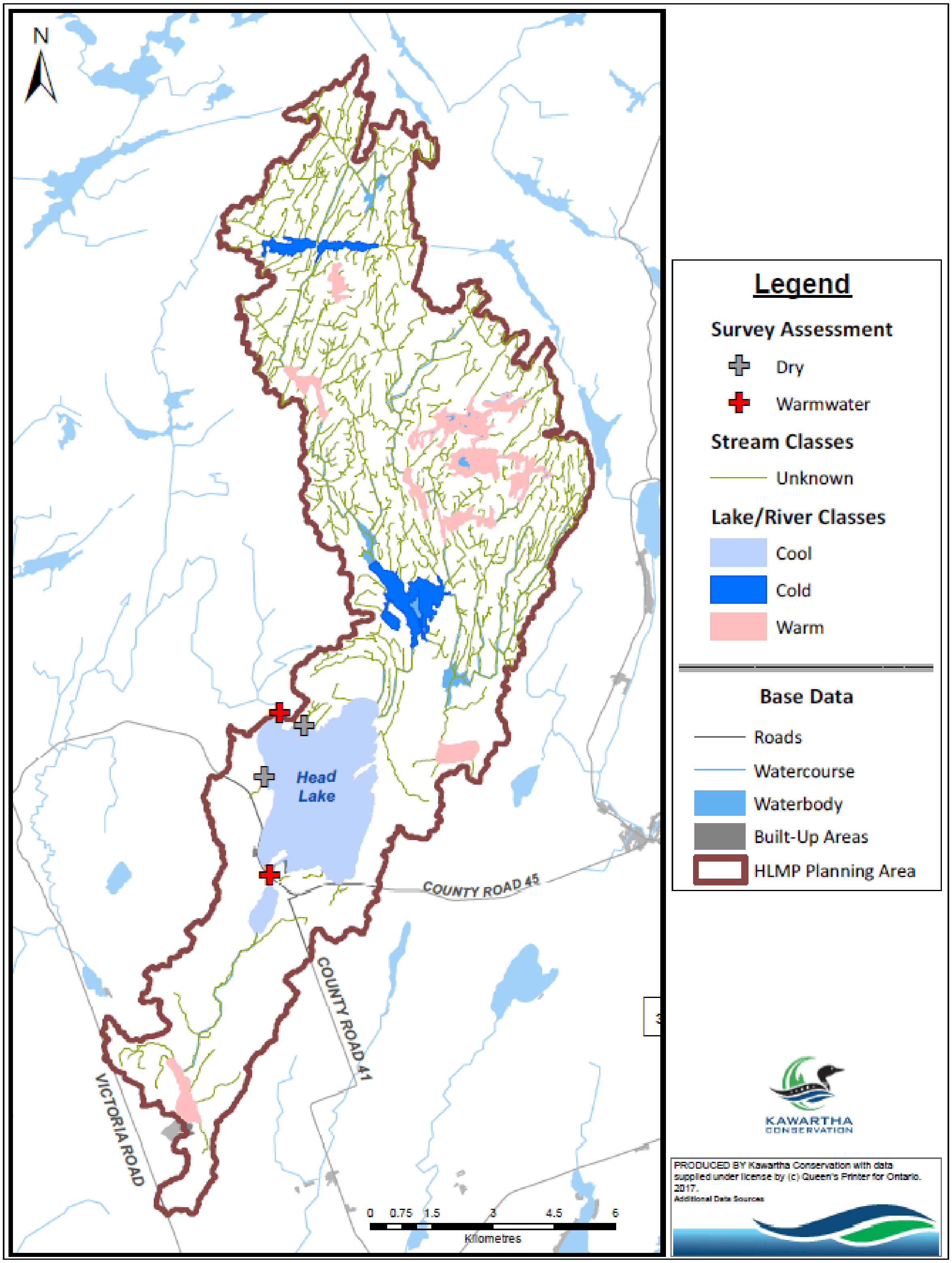


Figure 6.7. Watercourse Thermal Regime.

6.3.2 Fish Communities

Within the tributaries of the Head Lake planning area, there are no known fish community data. There are no known sampling records and no monitoring program.

6.3.3 Benthic Macroinvertebrates

Benthic Macroinvertebrates (benthos) have been widely used 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**).

Sampling methods and Sites

In summer of 2016, 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 Head Lake. Well-defined, wadeable steams that exist near road-crossings within subwatersheds that directly drain into or immediately out of Head Lake were targeted for assessment. In total, 2 sites were sampled in July. Sampling was conducted 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. All bioassessment sites were sampled with water temperatures ranging from 24.0 to 25.5^{o}C. Stream sizes sampled were medium-to-large, having wetted widths ranging from 3.9 to 11.9 m and maximum depths ranging from 520 to 1050 mm. Substrates encountered exhibited sand and gravel. The watercourses are slow moving, having water velocities with 0 hydraulic head.

Benthos Community

Benthos communities as summarized by OBBN taxa groups are shown in **Figure 6.8**. Data indicate a marked difference in benthos communities between the two sample sites. At the Rush Lake Outlet site, the relative composition of benthos were dominated (84%) by Scuds (*Amphipoda*), whereas the benthos at the Head Lake Outlet site were dominated (86%) by a combination of Mayflies (*Ephemeroptera*), Scuds (*Amphipoda*), Dragonflies (*Anisoptera*),Midges (*Chironomidae*), and Mussels (*Bivalvia*).

Benthos data can be used to make inferences into the condition of the local aquatic ecosystem, through summarizing data 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). Currently, no known scientifically-defensible bio-criteria standards exist for all types of streams in the Head Lake watershed. Both sites exhibited coarse substrates but not fast flowing waters, therefore biotic index determinations likely remain meaningful but should be considered preliminary, particularly given these are rapid assessment surveys.

Biotic index values indicate that the Head Lake outlet site is considered "Good" (HFBI value of 4.62), whereas the Rush Lake outlet site is considered "Fairly Poor" (HFBI value of 5.91). Head Lake outlet site is considered in a better state because in large part because its benthos community contains relatively more mayflies, stoneflies and caddisflies within the sample (34.3%, compared to 3.7%). These organisms are considered sensitive taxa, and abundances of benthos within these orders are known to decrease in response to increasing perturbation **(Barbour et al., 1999**). It is not clear what factors are specifically contributing to Rush Lake outlet site being in a worse state, particularly given that water chemistry data indicate that these waters are not nutrient enriched. However, potential influences include the fact that habitat is more favourable to Scuds (e.g., more lake-like than stream-like), degradation of habitat from being in close proximity to a county road (e.g., inputs of road salt and sediments), and/or the index not performing well in terms of accurately determining aquatic health at this location.

When comparing community composition as an average of both sites (i.e., Head Lake tributaries), to data on tributaries of neighbouring lakes (**Table 6.5**), Head Lake tributaries are considered relatively average. However, there substantially lower number of sample sites in Head Lake tributaries (2 sites), than in neighbouring tributaries (5-18 sites), therefore comparison results should be interpreted with some caution. However, due to the lack of human disturbance within the subwatersheds of Head Lake, aquatic community conditions are expected to be relatively healthy.

Table 6.5. Comparison of Bioassessment Results From Head Lake Tributaries to those from other local tributaries.

	Head Lake Tributaries (2016)	Four Mile Lake Tributaries (2015)	Pigeon Lake Tributaries (2014)	Balsam/Cameron Lake Tributaries (2013)	Sturgeon Lake Tributaries (2012)
Number of Sites	**2 (roadside)**	5 (roadside)	16 (random)	16 (random)	18 (random)
Family Biotic Index (average of all sites)	**5.27 (Fair)**	4.90 (Good)	5.06 (Fair)	5.17 (Fair)	6.06 (Fairly Poor)
Sensitive Taxa (%EPT, average of all sites)	**19.0**	44.0	25.1	26.9	11.4

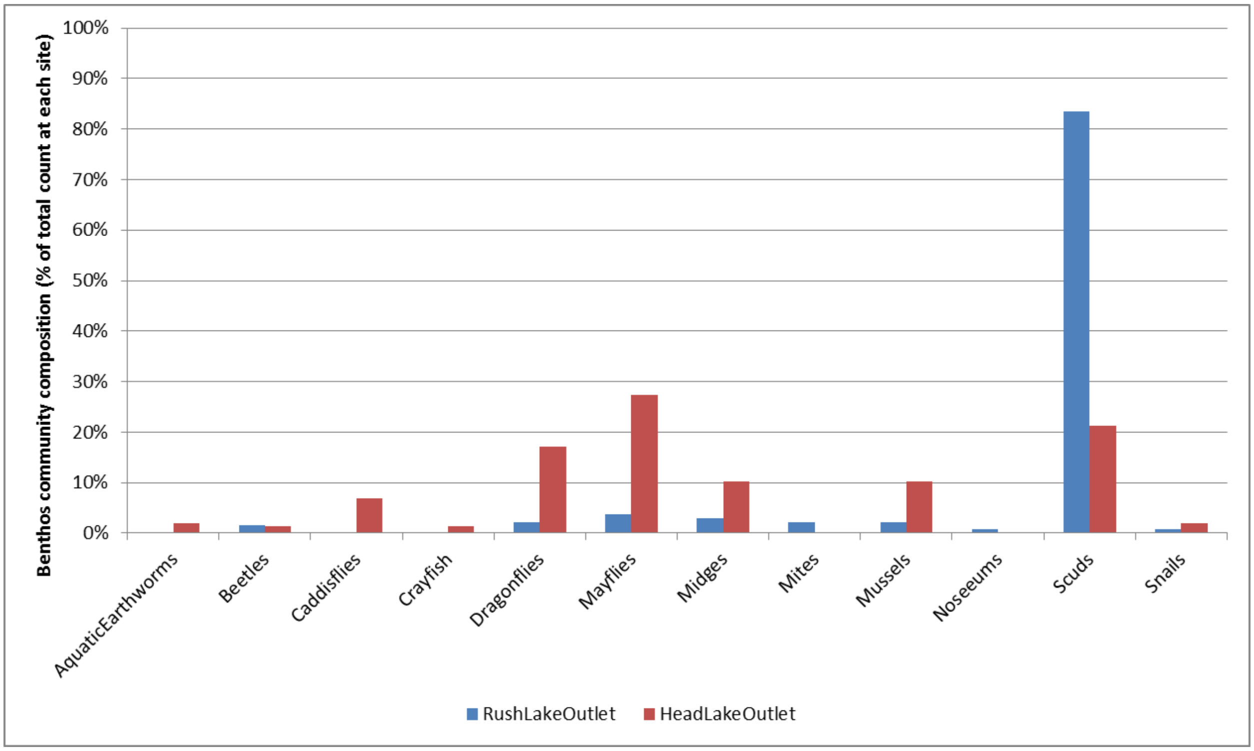


Figure 6.8. Major Benthos Taxa Found in the Tributaries

7.0 Terrestrial Ecology

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

7.1 Summary of Observations, Key Issues, and Information Gaps

OBSERVATIONS

- ***Natural Heritage conditions.*** The area surrounding Head Lake contains large tracts of forests and some areas of 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 and the QE2 Wildlands provincial park.

- ***The Head Lake watershed has an abundance of forests.*** Forests serve a number of functions within a watershed, not the least of which is functioning to improve water quality. Forests act to slow runoff, uptake and transpire water into the atmosphere, allow water to permeate into the ground, help to reduce erosion around lakes while providing habitat for numerous flora and fauna species

KEY ISSUES

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

- ***Natural heritage features need increased study in order to determine their health.*** Much of the Head Lake watershed possesses areas where very little is known about the state of the flora and fauna. Better information through natural heritage studies would help with the sustainable management of this area.

- ***The existing natural heritage features are experiencing some fragmentation around the lake.*** 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.

- ***5 Species at risk have been identified in the Head Lake study area.*** Of the 5 species, 2 are dependent on the lake and/or its tributaries for survival; Blanding's Turtle (threatened) and Snapping Turtle (special concern)

- ***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 and cottages.

- ***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 south of the QE2 Wildlands provincial park.*** 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 much of the Head Lake area.

- ***Poor understanding*** of colonial bird populations nesting on Head Lake and impacts, if any, on the local ecosystems.

- ***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.

7.2 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 Head Lake watershed contains 108 km^2 of natural cover, representing 88% of the total watershed area. This includes only areas classified as forest, wetland, rock barren and open water. There is a further 7% cover found in meadows, thickets, woodlots and plantations. **Figure 7.1** demonstrates the cover types existing within the watersheds that drain into Head Lake. Cultural 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 7.1** illustrates the percentage of each land use type within the watershed.

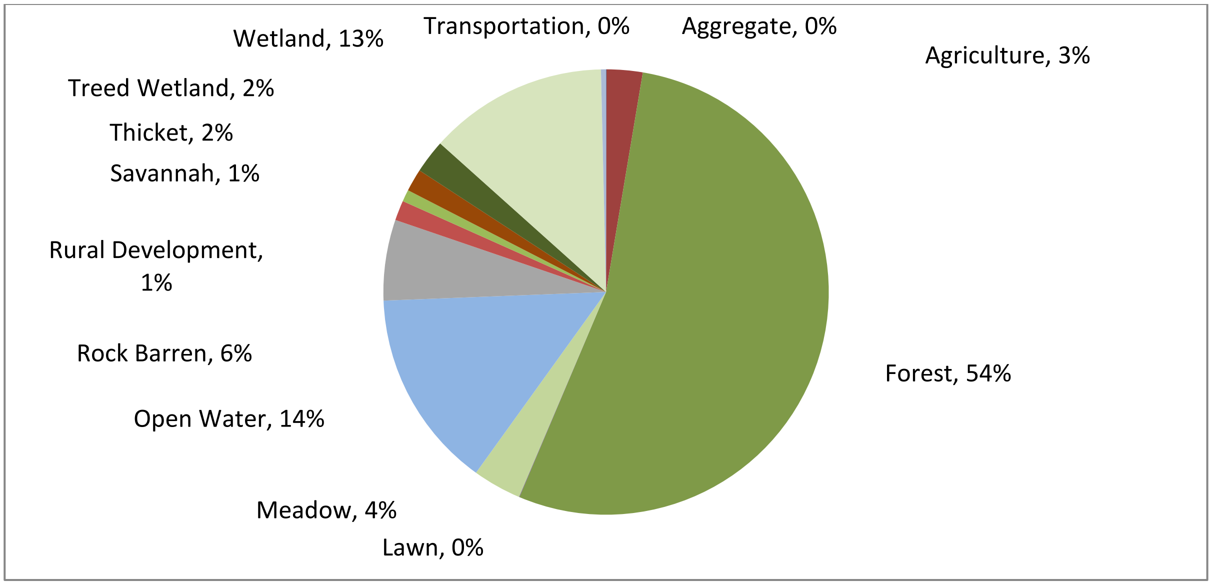


Figure 7.1. Head Lake Watershed Land Cover Based on Ecological Land Classification

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 Head 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-9 represents the Head Lake watershed, while Eco-district 5E-8 includes the area of the Head Lake Watershed that is north of the Lake. Ecodistrict 6E-9's northern boundary follows the southern edge of the Canadian Shield and includes the limestone Carden Plains in the west, the Napanee Plain in the east and the till plains of the Dummer Moraine. Eco-district 6E-9 is primarily deciduous and mixed forests as well as swamp wetlands. The Great Lake Conservation Blueprint would require that 23% of the remaining natural cover, and over 40% of all species and vegetation community targets be set aside in order meet conservation targets.

Ecodistrict 5E-8 is mostly underlain by undifferentiated igneous and metamorphic rock (the Canadian Shield) exposed at the surface or covered by thin soils. Eco-district 5E-8 has 40% tolerant hardwood forests on bedrock, with the remainder a mix of deciduous and coniferous forest, while 6% of the area is wetland consisting of deciduous swamp, open muskeg and tree bogs. Ecodistrict 5E-8 is made up of approximately 8% conservation lands, with nearly 5500 hectares of provincially significant wetlands and 1057 hectares of provincially significant life science ANSI's. The Great Lake Conservation Blueprint would require that 11% of the remaining natural cover, and over 50% of all species and vegetation community targets be set aside in order meet conservation targets for 5E-8 **(B.L. Henson et al. 2005).**

Table 7.1. Area and Percentage of Cover Types in the Head Lake Watershed

Land Use	Watershed Area km2	Watershed Area(%)
Watershed	121.69	100
Forest	65.37	53.71
Forested Wetland	2.96	2.43
Non-Forested Wetland	15.83	13.01
Meadow	4.30	3.54
Total Cover (including plantations, meadows, rock barrens and thickets)	107.53	88.36

Forests

Forests covered more than 90% of Southern Ontario prior to European settlement ***(*Larson et al, 1999*)*** and naturally occurring forests currently account for 55% of the Head Lake watershed (a combination of upland forests (53%) and forested/treed wetlands (2.43%)). 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 Head Lake watershed are mostly regrowth 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. Head Lake is fortunate to have the Queen Elizabeth 2 Wildlands Provincial Park directly to the North. This is reflected in the Head Lake watershed by the fact that the dominant natural area type is forest and that coniferous, mixed and deciduous forests account for over 55% of the Head Lake landscape.

The entire Head Lake watershed is currently 25% higher than the target of 30% forest cover for Areas of Concern watersheds within the great lakes basin **(Environment Canada, 2004)**, and Head Lake is 20% higher than the Conservation Ontario target **(Conservation Ontario, 2011)** of 35% forest cover for watersheds in Ontario. No watershed in the Head Lake study area falls below 51% forest cover.

Comparing the amount of forest cover with target levels suggests that conservation of forest and efforts to monitor and maintain forest health would be beneficial for overall watershed health. The areas of the watershed available for forest restoration are fairly minimal with much of the watershed already under natural cover, and therefore forest stewardship should focus on reducing fragmentation.

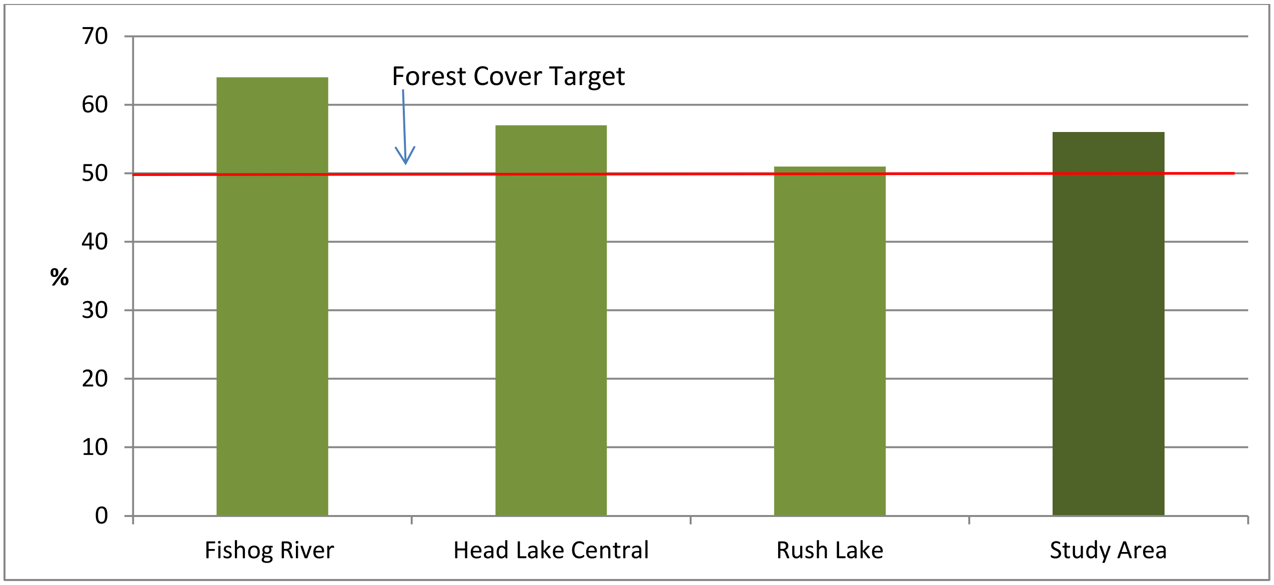


Figure 7.2. Forest Cover in the Head Lake Watershed

7.3 Ecological Land Classification

Ecological Land Classification (ELC) is a method to further classify natural cover types into vegetation community types within the Head Lake watershed. Vegetation communities for the watersheds were classified and mapped in 2016 based on the ELC System for Southern Ontario **(Lee et al., 1998).** All areas of the watershed were classified through interpretation of 2013 aerial photography. In total, 12 unique types of cultural areas, 7 of which are developed and 20 unique types of natural areas, based on the community series level of detail, were identified for the Head 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. Developed areas are in active and continuous use for purposes that do not support or are in direct conflict with naturally occurring ecosystems. 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 resource in supporting healthy ecosytems. Vegetation community types are described in Attachment 7, and mapped in **Figure 7.3**.

The ELC assessment shows that the Head Lake watershed contains 9% cultural community types, 3% developed areas and 88% natural community types. Deciduous forest in the Head Lake watershed, at 21%, encompasses the greatest area of the natural cover community types, with coniferous forest and mixed forest being the next two most dominant community types. Thirteen wetland types have been identified within the Head Lake watershed and account for 15% of the total study area. The watersheds contain mostly coniferous swamp, shallow marsh, thicket swamp and shallow fen. Only minimal areas of aquatic wetland communities are found within the lake area as Head Lake is mostly open water.

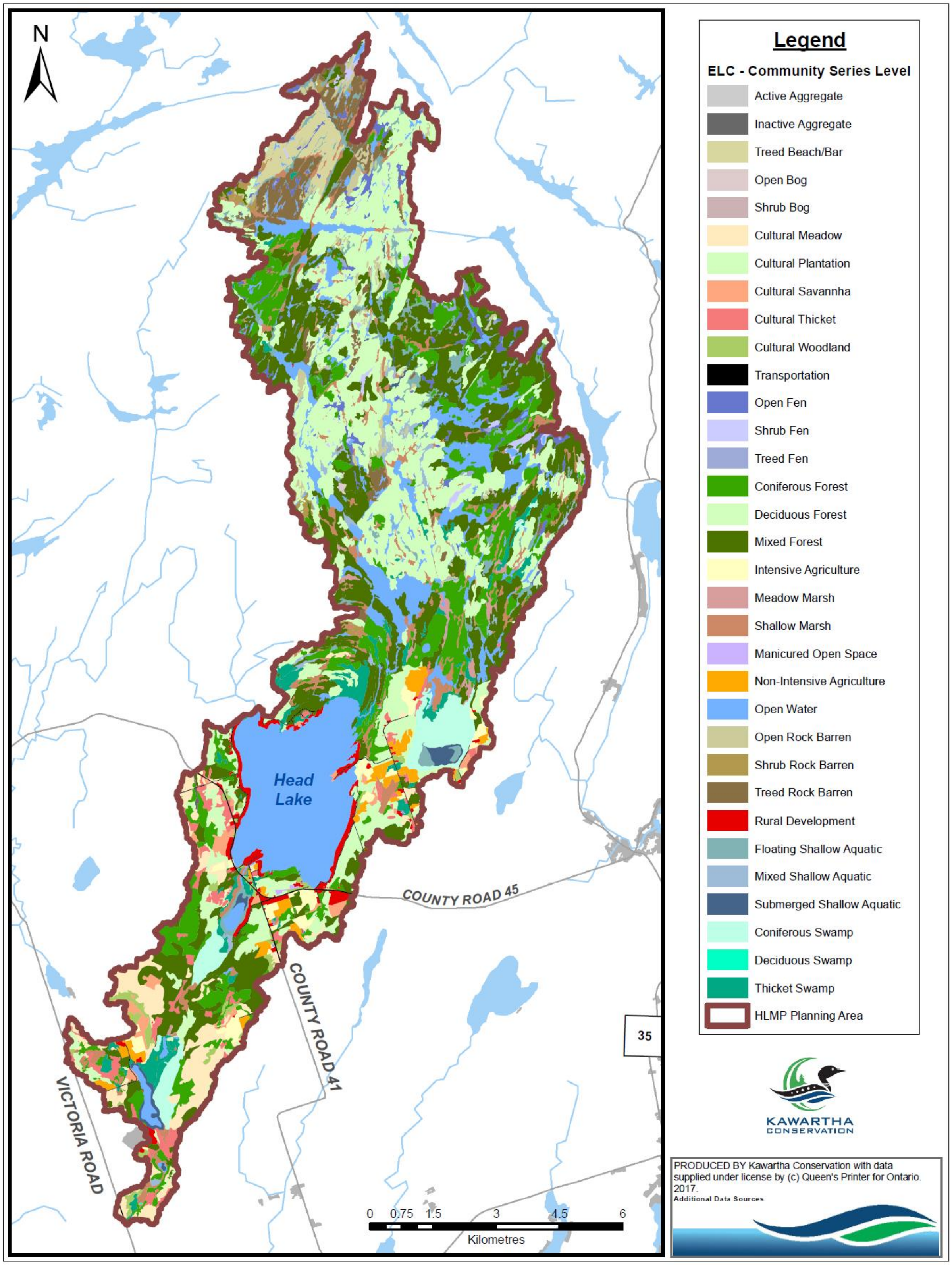


Figure 7.3. Ecological Land Classification of the Head Lake Watershed

7.4 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 20 species at risk as conservation targets within ecodistricts 6E-9 and 28 species in 5E-8 **(Henson and Brodribb, 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 Head Lake watershed. Furthermore, when developing a terrestrial natural heritage system, it makes sense to follow an established blueprint for biodiversity at the Head 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 7.2** lists the general response of species to varying sizes of forest patches. "An "edge" is the boundary, or interface, between two biological communities or between different landscape elements. Edges exist, for instance, where older forested patches border newly harvested cutblocks, or where forests verge on rock outcrops, riparian areas, grasslands, or other different harvest types or seral stages." **(Extension Note, Biodiversity and Interior Habititats: The Need to Mininimize Edge Effects, part 6 of 7, B.C. Ministry of Forests Research Program, Victoria BC, June 1998)**

Table 7.2. 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.

Source: 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%. Head Lake watershed has 8 % interior (>100m) and 0.07 % deep interior (>200m). Therefore the Head Lake watershed is below the targets for both interior and deep interior forest cover. **Figure 7.4** shows the distribution of interior forest areas within the watershed.

7.5 Species and Habitats at Risk

Endangered, rare and threatened species

Blandings Turtle (*Emydoidea blandingii*), threatened,
Eastern Meadowlark (*Sturnella magna*), threatened
Eastern Whip-poor-will (*Caprimulgus vociferous*), threatened
Loggerhead Shrike (*Lanius ludovicianus*), endangered
Snapping Turtle (*Chelydra serpentina*), special concern
Butternut Tree (Juglans cinerea)

The above are species at risk that have been identified in the Head Lake study area. A full list of species, occurrences and detailed information about their life history, status and recovery plans is available on the OMNRF Natural Heritage Information Centre web site.

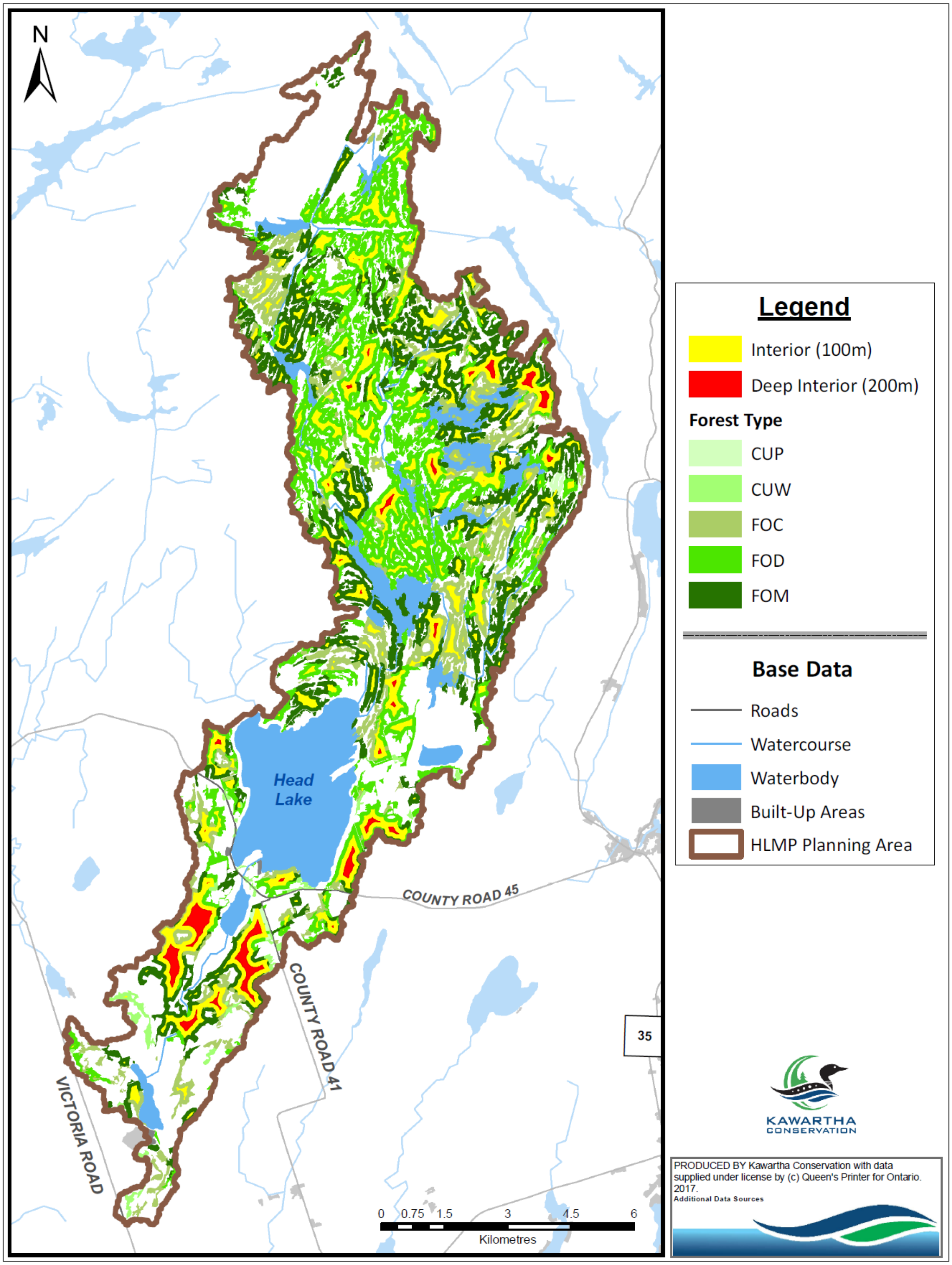


Figure 7.4. Areas of Interior Forest in the Head Lake Watershed

7.6 Herpetofaunal Species

The Ontario Reptile and Amphibian Atlas has identified the following species in the Head Lake Watershed:
American Bullfrog (*Lithobates catesbeianus*)
Blandings Turtle (*Emydoidea blandingii*),
Eastern Garternsnake (*Thamnophis sirtalis*),
Eastern Red-backed Salamander (*Plethodon cinereus*)
Common Five-Lined Skink (*Plestiodon fasciatus*)
Four-toed Salamander **(***Hemidactylium scutatum*)
Gray Treefrog **(***Hyla versicolor*)
Green Frog (*Rana clamitans*)
Midland Painted Turtle (*Chrysemys picta*),
Milksnake (*Lampropeltis Triangulum*)
Mink Frog **(** *Lithobates septentrionalis*)
Northern Leopard Frog (*Lithobates pipiens*),
Northern Watersnake (*Nerodia sipedon*)
Pickerel Frog (*Lithobates palustris*)
Ring-necked Snake (*Diadophis punctatus*)
Snapping Turtle (*Chelydra serpentina*),
Spotted Turtle (*Clemmys guttata*)
Spring Peeper (*Pseudacris crucifer*),
Western Chorus Frog (*Pseudacris triseriata*)
and Wood Frog (*Lithobates sylvaticus*).

7.7 Birds

Head Lake has a small population of colonial birds nesting on Armstrong Island and some of the smaller islands, consisting of primarily Ring Billed Gulls (Larus delawarensis), Double Crested Cormorants (Phalacrocorax auritus) and Common terns *(*Sterna hirundo). Little is known about the colonies found on Head Lake and their place in the local ecology. Recently (June 15th, 2017) biologists from Environment Canada visited Head Lake to inventory Common tern nests and identified 4 breeding islet clusters on the lake. The Common tern breeding colonies represent an important component of tern ecology and tern populations since Great Lake populations have declined by an average of 18% over the last 40 years **(J.M. Arnold and S.A. Oswald, 2017).** Recent research has concluded that the long-term viability of inland breeding common terns in many areas (particularly the Great Lakes, Ontario and Manitoba) may be in jeopardy **(Morris et al. 2010, 2012, Wilson et al. 2014, Szczys et al. 2017. In Arnold and Oswald, 2017)**. Therefore, while there have been concerns about the presence of Double Crested Cormorants on Head Lake, any management of this or any other colonial bird species, would require that detailed studies be undertaken to better understand bird ecology on Head Lake and surrounding area. The Arnold and Oswald study above is the most up to date study on Colonial Waterbird populations on Head Lake.

7.8 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.

Queen Elizabeth II Wildlands Section in next draft

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 no ANSI sites within the Head Lake watershed.

There are a number of locally significant areas of natural and scientific interest located in the Head 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.

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.

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 Head Lake watershed that are natural heritage features such as wetlands and forests, are composed of 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 found widely throughout the Head Lake watershed. The natural areas within the Head Lake watershed tend to be only minimally fragmented; maintaining core areas 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 7.7.**

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 7.6** illustrates the location of wetlands within the watershed. **Figure 7.3** 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.

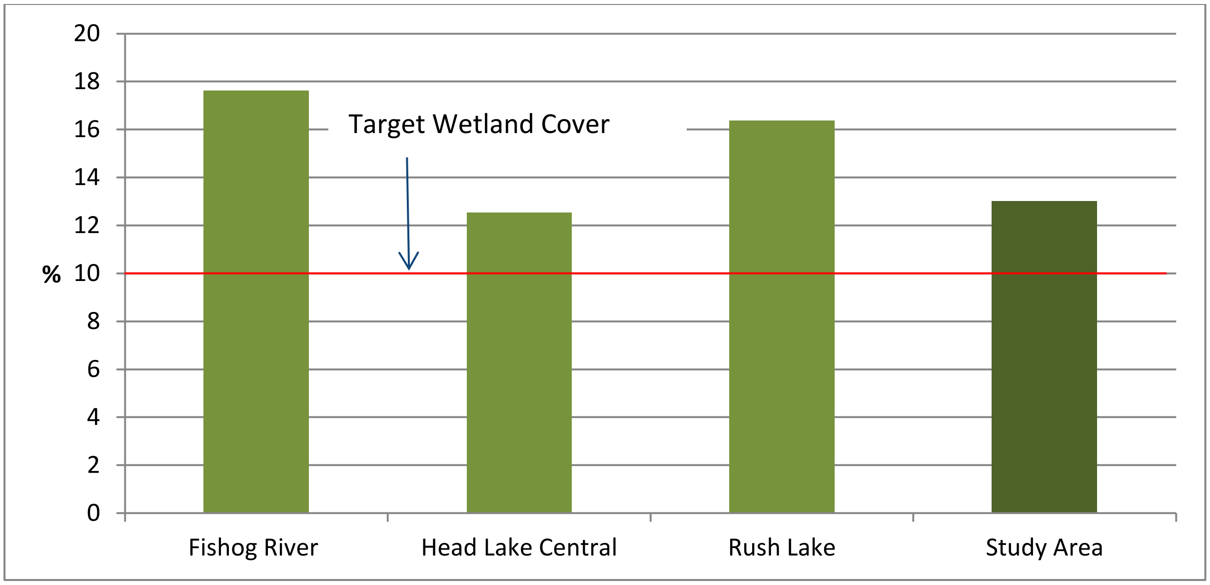


Figure 7.6. Wetland Cover in the Head Lake Watershed

The Head Lake watershed contains approximately 18km^2 of wetland representing 15% of the terrestrial area; this is above the 10% minimum recommended percentage of wetland cover. There is one area of designated as provincially significant wetlands in the Head Lake study area, the Rush/Duck Complex, located in the Rush Lake watershed. All wetlands are illustrated in **Figure 7.7**.

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 B.

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.

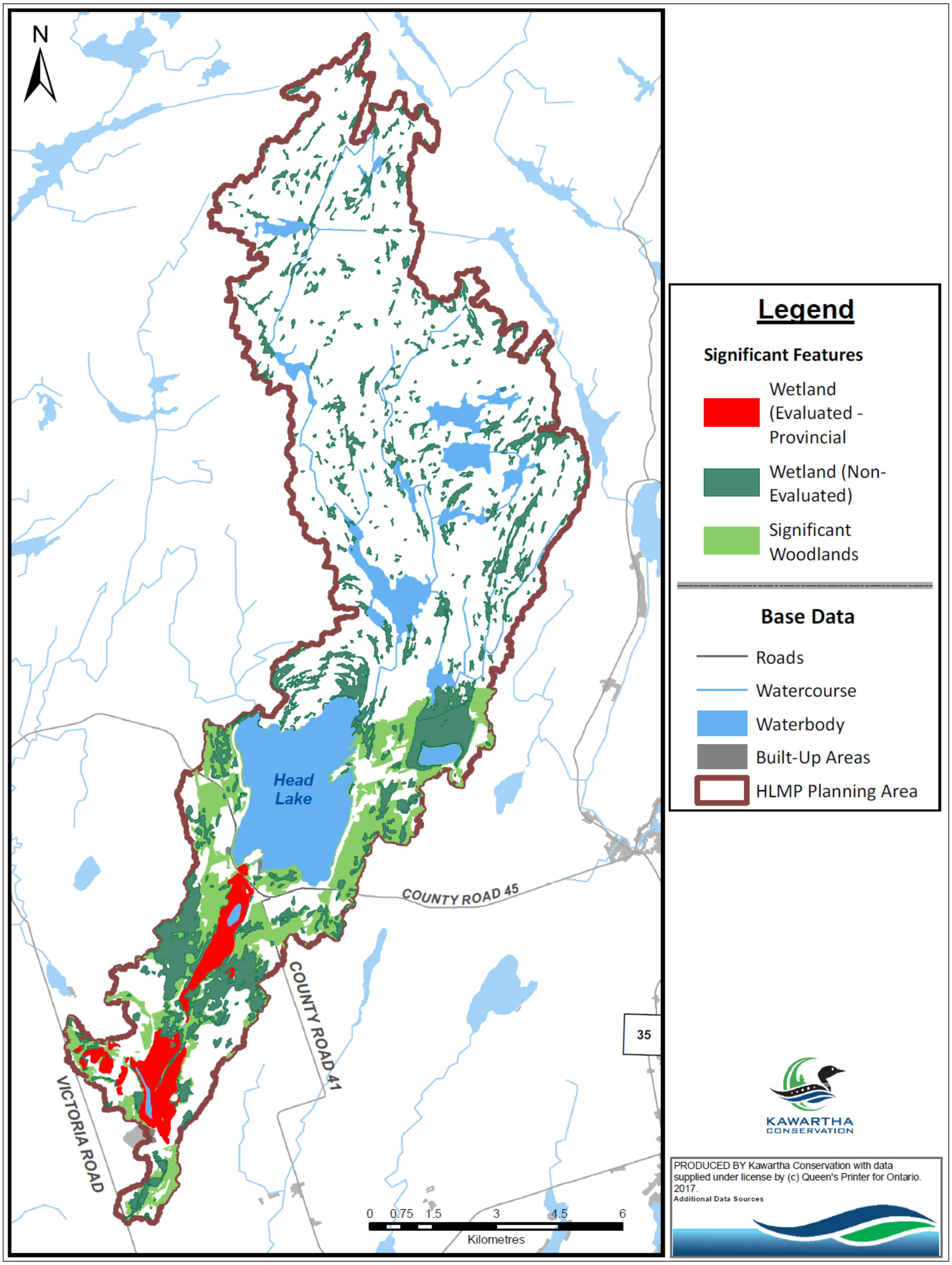


Figure 7.7. Significant Natural Features in the Head Lake Watershed

- 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).**

7.9 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 7.8).**

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/

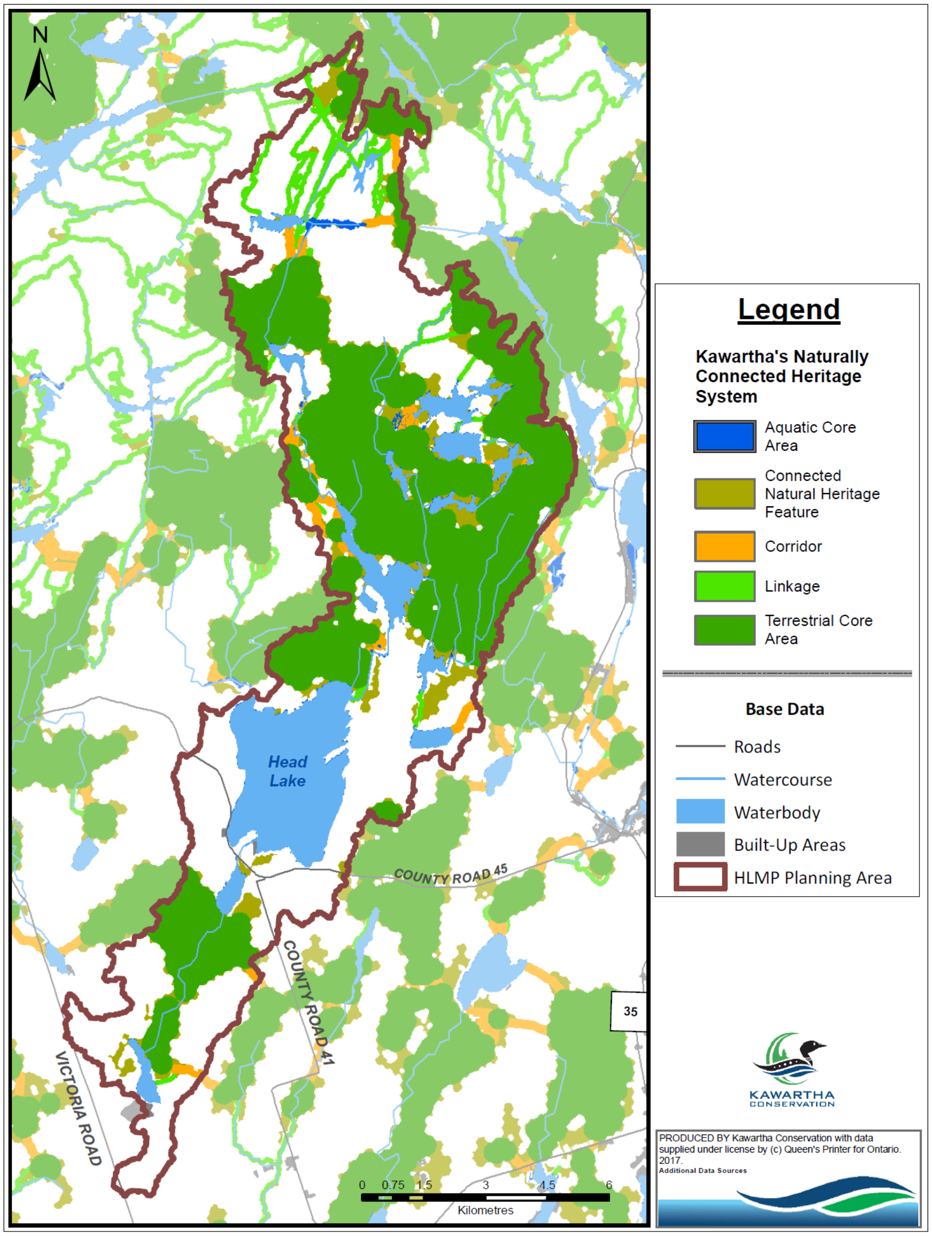


Figure 7.8. Kawarthas Naturally Connected Natural Heritage System in the Head Lake Watershed.

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Appendix A:

Benthic macroinvertebrate raw counts and summary data for bioassessment sites.

DATE				2016/07/06	2016/07/06
OBBN_SCIENTIFIC_NAME	**OBBN_COMMON_NAME**	**FAMILY**	**TOLERANCE_VALUE (WRC2013)**		
Amphipoda	Scuds	Gammaridae	6	112	
Amphipoda	Scuds	Hyalellidae	8		31
Anisoptera	Dragonflies	Aeshnidae	5		1
Anisoptera	Dragonflies	Corduliidae	2	2	24
Anisoptera	Dragonflies	Libellulidae	2	1	
Bivalvia	Mussels	Pisidiidae	6	3	8
Bivalvia	Mussels	Unionidae	6		7
Ceratopogonidae	Noseeums	Ceratopogonidae	6	1	
Chironomidae	Midges	Chironomidae	6	4	15
Coleoptera	Beetles	Elmidae	5	2	2
Decapoda	Crayfish	Cambaridae	6		2
Ephemeroptera	Mayflies	Baetidae	6	1	
Ephemeroptera	Mayflies	Caenidae	6	4	
Ephemeroptera	Mayflies	Heptageniidae	3		34
Ephemeroptera	Mayflies	Unknown Ephemeroptera	-		6
Gastropoda	Snails	Physidae	8		3
Gastropoda	Snails	Valvatidae	8	1	
Hydrachnida	Mites	Unknown Hydrachnida	6	3	
Oligochaeta	AquaticEarthworms	Unknown Oligochaeta	8		3
Trichoptera	Caddisflies	Leptoceridae	4		4
Trichoptera	Caddisflies	Rhyacophilidae	1		6
HFBI				**5.91**	**4.62**
%EPT				**3.7**	**34.3**
Unique taxa				**11**	**14**

Appendix B

Community Series Description

Community Series (Code -Descriptive Name)[1]	Description of Community Series	Head Lake Watershed	
		km²	%
AA - Active Aggregate	Barren, heavily disturbed open pit or quarry	0	0
AI - Inactive Aggregate	Surface cover ≥ 25% or barren, currently unused open pit or quarry	0.03	0.03
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	0
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%	0.08	0.07
BOT – Treed Bog	Bog with 10% < tree cover ≤ 25%	0	0
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%.	4.3	3.54
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	0.28	0.24

[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	Head Lake Watershed	
		km^2	%
	species. These areas are characterized by tree cover > 60%.		
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%.	1.05	0.86
CUT – Cultural Thicket	Areas that have resulted from or are maintained by cultural or anthropogenic-based disturbances and often have a large proportion of non-native plant species. These areas are characterized by tree cover ≤ 25%; shrub cover >25%.	1.99	1.64
CUW – Cultural Woodland	Areas that have resulted from or are maintained by cultural or anthropogenic-based disturbances and often have a large proportion of non-native plant species. These areas are characterized by tree cover between 35% and 60%,	1.07	0.88
CVI - Canadian Vehicle Infrastructure	Roads and highways	0.44	0.37
DIS – Disturbed Areas	No natural cover, areas that have been disturbed by human influences, e.g. trails	0	0
FEO	Areas with an organic substrate and > 40cm of brown moss or sedge peat, rarely flooded but always saturated and pH is slightly alkaline to mildly acidic. Tree cover ≤ 10%, shrub cover ≤ 25%	1.89	1.55
FES	Areas with an organic substrate and > 40cm of brown moss or sedge peat, rarely flooded but always saturated and pH is slightly alkaline to mildly acidic. Tree cover ≤ 10%, shrub cover > 25%	0.58	0.48
FET	Areas with an organic substrate and > 40cm of brown moss or sedge peat, rarely flooded but always saturated and pH is slightly alkaline to mildly acidic. 10% < Tree cover≤ 25%	0.19	0.15
FOC – Coniferous Forest	Areas where tree cover is greater than 60%, and the canopy is comprised of greater than 75% coniferous tree species	13.01	10.69
FOD – Deciduous Forest	Areas where tree cover is greater than 60%, and the canopy is comprised of greater than 75% deciduous tree species	26.69	21.93

Community Series (Code -Descriptive Name)[1]	Description of Community Series	Head Lake Watershed	
		km^2	%
FOM – Mixed Forest	Areas where tree cover is greater than 60%, and the canopy is comprised of greater than 25% deciduous tree species and greater than 25% coniferous tree species	24.31	19.98
IAG – Intensive Agriculture	Annually cultivated, crop fields, gardens, nurseries, tree farms. Variable	1.54	1.26
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.	0.62	0.51
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%.	4.75	3.90
***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	0.04	0.03
***NAG** – Non Intensive Agriculture	No cultivation, grasses, hay, pasture, grazing. Variable	1.64	1.35
OAO – Open Aquatic	Areas with water >2m deep. Plankton dominated with no macrophyte vegetation and no tree or shrub cover.	17.59	14.45
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%	1.66	1.37
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%	0.44	0.37
RBT – Treed Rock Barren	Found where bedrock is broken and cracked or where shallow substrates have accumulated. 25% < tree cover ≤ 60%	5.02	4.13
***RD** – Rural Development	Variable. 0.2 ha < area < 2.0 ha containing development not associated with agriculture	1.76	1.45

Community Series (Code -Descriptive Name)[1]	Description of Community Series	Head Lake Watershed	
		km^2	%
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.	2.97	2.45
SAM – Mixed Shallow Aquatic	Area with standing water <2m deep. No tree or shrub cover, and if emergent vegetation is present is not dominant. Greater than 25% cover of submerged and floating-leaved macrophytes. Often influenced by shoreline energy.	0.96	0.78
SAS – Submerged Shallow Aquatic	Area with standing water <2m deep. No tree or shrub cover, and if emergent vegetation is present is not dominant. Greater than 25% cover of submerged macrophytes. Often influenced by shoreline energy.	0.59	0.49
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%	0	0
SWC – Coniferous Swamp	Areas with variable flooding where water depth is <2m and standing water or vernal pooling makes up >20% of the ground coverage. Tree cover is >25%, canopy height is greater than 5m, and conifer tree species make up >75% of the canopy. Hydrophytic shrubs and herbs present.	2.95	2.43
SWD – Deciduous Swamp	Areas with variable flooding where water depth is <2m and standing water or vernal pooling makes up >20% of the ground coverage. Tree cover is >25%, canopy height is greater than 5m, and deciduous tree species make up >75% of the canopy. Hydrophytic shrubs and herbs present.	0	0
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,	0	0

Community Series (Code -Descriptive Name)[1]	Description of Community Series	Head Lake Watershed	
		km²	%
	deciduous tree species make up >25% of the canopy, and coniferous tree species make up >25% of the canopy. Hydrophytic shrubs and herbs present.		
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%.	3.17	2.60
URB – Urban Development	Variable. > 5 residential units in an area > 2 ha, generally residential	0.63	0.99
Cultural Areas		14.17	11.64
Natural Areas		107.93	88.36
Developed Areas		5.46	4.49
Combined Areas of Cover*		116.23	95.51
Roads		1.76	1.45

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