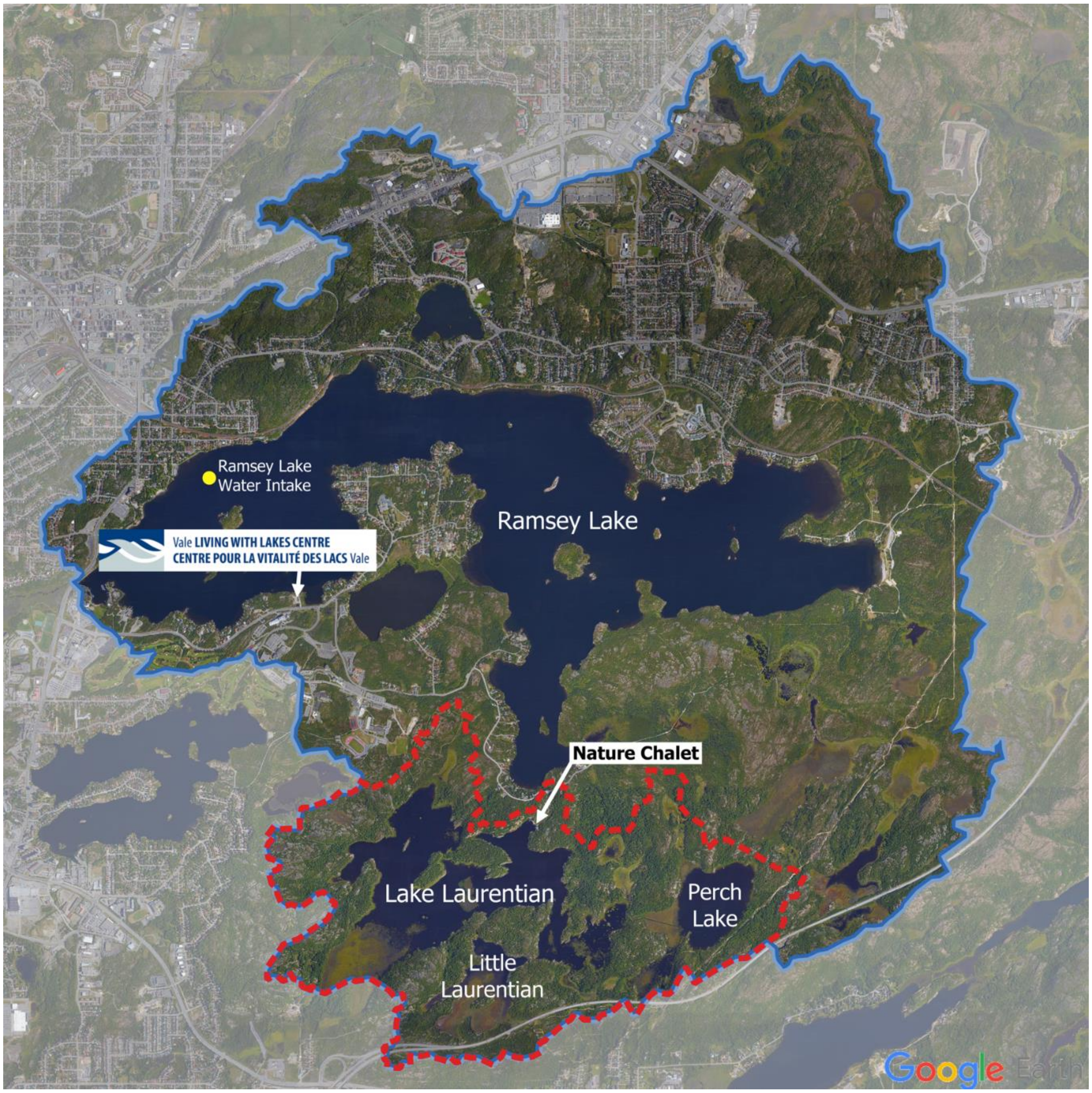
# Past, Present, and Future of Lake Laurentian and its Watershed

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Cooperative Freshwater Ecology Unit / Unité Conjointe D'écologie D'eau Douce

Laurentian University / Université Laurentienne

Conservation Sudbury

NATURE POSITIVE UNIVERSITIES

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**Executive Summary**

Sudbury Ontario, with its highly acclaimed pollution reductions efforts by the local metal smelters (>98% decline in atmospheric emissions of S) and its internationally recognized regreening program (> 10,000,000 trees planted) provides many very positive stories of ecosystem and biodiversity restoration. For this report, we focus on the significant physical, biological and chemical changes that have occurred within the Lake Laurentian Conservation Area that was first set aside in the 1960s to provide water quality and flooding protection for Ramsey Lake (Indigenous name Bitimagamasing), the principal drinking water supply of the municipality at the time. Using aerial imagery that began in 1946 we first see the transformation of the terrestrial landscape from very sparsely vegetated or even barren terrain, with occasional gravel pits and early farming sites, to a diverse wetland and early successional forest landscape, a response to both air pollution reductions and the planting of more than 250,000 trees. However, the main focus of our study was not on the vegetation but on changes in the aquatic environments within the Lake Laurentian watershed. Usually, the changes in the aquatic environment are less visible than those of the terrestrial system, but in our study area we were surprised to see a nearly 4-fold increase in surface water cover as the decades passed, the result of the construction of dams at the outlet and margins of the present lake, as well as the vigorous activity of an increasing beaver population.

Water sampling records produced by Laurentian University's Cooperative Freshwater Ecology Unit showed steady improvements in water quality in recent decades, with substantial declines in both Cu (66.8 % decrease) and Ni (39.3% decrease) between 1990 and 2018, moving these contaminants of concern steadily toward Provincial Water Quality Objectives (PWQO) (i.e., Cu 5 µg/L; Ni 25 µg/L). Parameters associated with impacts from acid rain (e.g., lake water pH) and the effects of acid deposition on organic and inorganic solutes (e.g., DOC, Ca) do not show evidence that toxic water quality conditions exist. However, that can change quite readily. For example, in the early 1980s LU students showed that dam removal and drying out of the wetlands liberated vast amounts of stored acid and metals from the watershed creating toxic conditions that eliminated the suitable habitat for fish and many sensitive benthic invertebrates. This episodic event has now long passed and good conditions have returned, but it draws attention to the need to preserve water levels in an era when climate change is causing drought in many jurisdictions. More localized effects have also been detected in the water quality record. For example, road salt levels in the local lakes have increased in the years since the highway bypass was built across the

eastern part of the watershed. The biodiversity assessments in 2022 and 2023 focused on fish, zooplankton, crayfish, and sensitive benthic invertebrates in three lakes within the LL watershed; Lake Laurentian, Perch and Little Laurentian (a new name we applied to a recently flooded area, created and isolated by a beaver dam).

Available data from the Ministry of Environment, Conservation and Parks showed little change in the offshore zooplankton community in Lake Laurentian in recent decades, with a typical assemblage of both acid tolerant and sensitive species present. However, this assessment is based on only 3 samples taken in 1990, 2003 and 2018, limiting our ability to detect change. Extensive crayfish trapping was conducted in 2023, but we found no crayfish of the sensitive (*Faxonius*) or tolerant (*Cambarus*) forms in any of the three lakes, a finding that suggests here too further monitoring in the future is needed. In contrast to the lack of crayfish there was good evidence of the return of sensitive invertebrates such as the amphipod *Hyalella azteca* which was absent in 1992. The acid sensitive mayflies (*Stenonema femoratum* and *Stenacron interpunctatum* were also present.

The three lakes had a total of 6 prey fish species in 2023 including: yellow perch (*Perca flavascens*), northern redbelly dace *(Chrosomus eos*), emerald shiners (*Notropis atherinoides*), Iowa darters (*Etheostoma exile*), golden shiners (*Notemigonus crysoleucas*) and white suckers (*Catasomus commersonii*). The density of prey fish per minnow trap varied greatly among lakes with a catch per unit effort (# of fish/set of traps overnight) of 111.9 in Little Laurentian, 7.5 in Perch and 1.6 in Lake Laurentian. Many of the species appear to have originated as bait fish brought in by recreational anglers attracted to the lakes by the very successful recreational fishery created by the transfer of pike (*Esox*) (100 fish in 1996) from nearby Bethel Lake by LU's CFEU.

A survey of the introduced northern pike (*Esox lucius*) population in Lake Laurentian was conducted in 2022 using the Ontario Broadscale Monitoring Assessment netting method (BsM), collecting a subsample of 119 pike that ranged in size from 0.11 – 3.2 kg (with a mean of 1 kg). In 2023 we conducted some limited angling efforts and confirmed that pike were still present in Lake Laurentian and also in Perch Lake (a new record for this lake). A very positive aspect of this successfully created recreational fishery was that tissue samples revealed that no exceedances beyond recommended concentrations of metals such as mercury were detected, indicating that the pike were safe to eat.

**Acknowledgements**

This report is a contribution to the partnership agreement recently established between Nickel District Conservation Authority and Laurentian University, an agreement designed to share information derived from student and faculty research projects that can be used to help in the management of conservation lands. It is also a recognition that the two agencies share responsibility for watershed areas, such as the Lake Laurentian watershed, with all of their interconnected trails and other recreational uses.

The report also coincides with Laurentian's joining in 2023 of the Nature Positive University (NPU) initiative, a network led by Oxford University, of universities around the world that are committed to biodiversity conservation and protection. This report will provide baseline data for NPU that can be updated in the future. For the recent field studies and the report preparation, we thank both LU and NDCA for funding support. MECP scientists Dr. Brie Edwards and Bill Keller kindly provided both water quality and zooplankton data for use in this report, and Vale Living with Lakes Centre provided vehicles, boats and sampling equipment.

We would also like to thank Ryan Coady, Chris Bisson, and Alex Lieou for completing field surveys in 2022 and Emma Wright, Naomi Robinson, Adam Lepage and Quinn Elliot for the field surveys in 2023. Without their contributions, this report would not have been made possible. We thank Bill Keller for his editing of the first draft as well as Paul Sajatovic and Jennifer Davidson for checking historic facts related to the Conservation Area.

## Introduction

The Lake Laurentian watershed (LLW) has major significance in Sudbury, supporting a wide array of recreational activities in addition to its role in maintaining a healthy drinking water source for the city in Ramsey Lake (Conservation Sudbury, 2023a). Laurentian Lake is well used for canoeing, kayaking, swimming, angling and educational activities (Conservation Sudbury, 2023a). Our goal in this study was to assess the changes in the biodiversity of the lakes within the LLW over time, and to establish a current biodiversity baseline that can inform future habitat conservation and enhancement work. To accomplish this, we tested water quality and assessed current status of selected biota (fish, zooplankton, crayfish and other selected benthic invertebrates) to compare to past survey results.

## Study Area

The Municipality of Greater Sudbury is located within the area encompassed by the Robinson Huron Treaty of 1850 and within the traditional territories of Atikameksheng Anishnawbek and Wahnapitae First Nations. It is situated on the Canadian Shield but exhibits a rather unique topography because of the massive Sudbury Basin located in the middle of it. The Basin, created by a meteorite impact 1.8 B years ago, is the source of Sudbury's rich Cu and Ni ore deposits. The Sudbury area is also part of the Boreal Shield ecozone and Great Lakes-St. Lawrence Forest Region and the municipality is home to over 330 freshwater lakes (Pearson et al. 2002). Geologically, the 970 ha Lake Laurentian Conservation Area (LLCA) is underlain by rocks of the Mississagi Quartzite formation, including Sudbury gabbro and breccia formations (Ontario Trails Council, n.d.; Dupuis, 1979). This bedrock surface was scoured by the Wisconsin glaciation, forming widespread lakes and wetlands (Amiro and Courtin, 1981).

A study was conducted in 1978 to describe and define the forest community types present in the Sudbury area, identifying a total of nine community types (Amiro and Courtin, 1981). The LLCA contained mainly the birch-maple community type, with some red oak and birch transition communities on the southern edge of the conservation area (Amiro and Courtin, 1981). The birch-maple community type and the red oak community type were classified as sites not severely affected by air pollution. The birch transition community was considered a "disturbed" community type (Amiro and Courtin 1981). Five main habitats along the shores of Lake Laurentian and Perch

Lake were classified as bog-like vegetation mat, marsh, rock shores, poplar grove and lake in the summer of 1980 (Bubelis et al. 1980). In the same year, massive regreening efforts began throughout the municipality (Lautenbach 1985). Between 1996 and 2016, over 250,000 trees were planted within the Lake Laurentian watershed area, greatly increasing the conifer forests of the region (City of Greater Sudbury, n.d)

The majority of the Lake Laurentian watershed is protected by the LLCA (Bubelis et al. 1980). The watershed's boundaries extend nearly 2 kilometers along the Highway 17 SE Bypass, north up to Laurentian University and west towards Nepahwin Lake. Figure 2 shows the boundaries of the Lake Laurentian watershed, which has a surface area of approximately 717 ha (AECOM 2010). The area includes three lakes: Lake Laurentian, Perch Lake, and a smaller body of water created by beaver activity that we have named Little Laurentian Lake for the purposes of this report. Perch Lake and Little Laurentian Lake flow into the southeastern bay of Lake Laurentian which then flows into Ramsey Lake (Bubelis et al. 1980). The watershed outlet is located near the Nature Chalet (2420 South Bay Rd, Greater Sudbury, ON P3E 6H7) where Lake Laurentian drains through a small stream into Ramsey Lake (AECOM 2010).

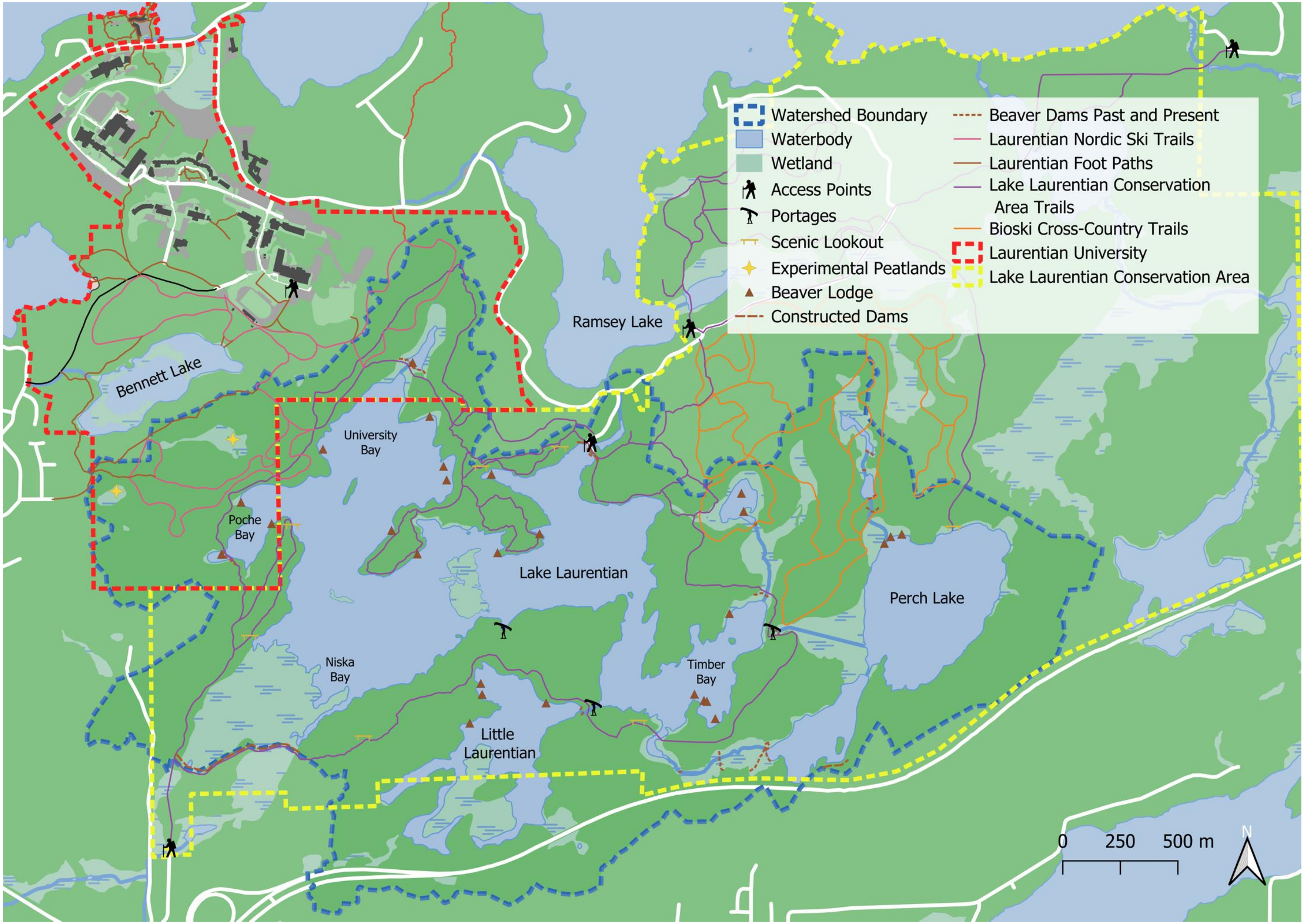
**The History of Sudbury and the Lake Laurentian Watershed (The Early Days)**

Sudbury was one of the most environmentally impacted areas in the world (Amiro and Courtin 1981, Gunn 1995, Winterhalder 1995;). Forest fires, logging and metal smelting have done their damage, creating enormous impacts on the terrestrial and aquatic ecosystems (Gorham and Gordon 1960, 1963, James and Courtin 1985; Winterhalder 1995). When European colonizers first arrived, the Sudbury area was dominated by red (*Pinus resinosa*) and white pine (*Pinus strobus*), with some hardwoods such as sugar maple (*Acer saccharum*) and yellow birch (*Betula alleghaniensis*) in the southern sections (Winterhalder 1995). An early European name of the place, Ste. Anne of the Pines is a reflection of what the Sudbury must have looked like before extensive lumbering began in the early 1870s (Courtin 1994). A significant amount of the lumber from this early period went to rebuild Chicago after the Great Chicago Fire of 1871 (Winterhalder 1995). With the loss of the original forest came the regrowth of early successional species like birches (*Betula*) and poplars (*Populus*) (Winterhalder 1995). However, Sudbury at the northern extent of its area is still home to a portion of the largest known intact old-growth red pine forest in North America at the Wolf Lake Forest Reserve (Anand et al. 2013). This remote area might be considered a model system for what much of Sudbury may have looked like in the past. Although the impact of deforestation on many watersheds in Sudbury has been a common topic of research, there is very little information available on the state of lakes in Sudbury before and after the arrival of the lumber industry in the area. The lumbering industry continued to be widespread in Sudbury until as late as 1927, when mining then rose to dominance in the area (Winterhalder 1995).

Sudbury's metal mining operations began in the late 1800s (Keller et al. 2007). The first official report of vegetation damage was published in 1945 after government representatives met to discuss the problem of sulphur dioxide (SO2) damage in the surrounding forests (Winterhalder 1995). Smelting emissions peaked in the 1960s when Sudbury smelters represented the largest point source of sulphur pollution in the world, with annual emissions exceeding 2 million tons of $SO_2$ per year (Keller et al. 2007). Gorham and Gordon (1960, 1963) were the first scientists to publish journal articles describing the damage. They described the extensive vegetation damage but focused on impacts to ponds and wetlands. Peatland communities within 30km of the smelters were particularly heavily impacted by airborne pollutants, with levels of Cu and Ni in the mosses increasing with the proximity of the smelters (Gignac 1985). Sphagnum mosses and lichens proved highly sensitive with an extensive lichen and sphagnum moss desert extending out from the smelters (Beckett 1995). In addition to damaging the terrestrial landscape, smelting operations also resulted in the acidification of over 7000 lakes near Sudbury, stretching over more than 100 km from the smelters (Keller et al. 2007). The acidification of the lakes caused economic loss as well as the loss of recreational activities in the lakes (OMNRF unpublished data). For example, fishing lodges north of Lake Wahnapitae collapsed in the 1960s as the fish populations were lost.

Government control orders and regulations finally came into effect in the late 1960s and early 1970s to reduce pollution (Potvin and Negusanti 1995). In addition to a major reduction in pollution in 1972, including the closing of the Coniston smelter (closest smelter to the Conservation Area) the 381 m Superstack was built to further disperse the Sulphur dioxide and other smelting byproducts (e.g., metal particles) away from Sudbury (Keller et al. 2007). The government-imposed regulations of the day drove the innovation of new technology that ultimately resulted in a significant reduction (>90%) of smelter emissions of $SO_2$ and other contaminants (Boullion 1995, Gunn 1995). Reducing the release of these contaminants coupled with a strong science-based municipal regreening program kick-started a remarkable chemical and biological recovery across the Sudbury region (Keller et al. 2007; Figure 1).

**Figure 1**. 45 years of Sudbury, Canada’s landscape restoration, then and now (1978-2022)



Watershed Boundary
Waterbody
Wetland
Access Points
Portages
Scenic Lookout
Experimental Peatlands
Beaver Lodge
Constructed Dams
Beaver Dams Past and Present
Laurentian Nordic Ski Trails
Laurentian Foot Paths
Lake Laurentian Conservation Area Trails
Bioski Cross-Country Trails
Laurentian University
Lake Laurentian Conservation Area
Ramsey Lake
Bennett Lake
University Bay
Poche Bay
Lake Laurentian
Perch Lake
Niska Bay
Timber Bay
Little Laurentian
0
250
500 m
N

### *The History of the Lake Laurentian Watershed*

The lake basin that was originally within the area now called Lake Laurentian was called Mud Lake. It was a small body of water that varied in size from 22-42 ha, depending on beaver activity (Figure 3 and Figure 6). The much larger extent of Lake Laurentian was created in 1958 when a dam was constructed at the outlet of 'Mud Lake', raising water levels around 2 m and expanding the flooded lake surface area to 138 ha (Bubelis et al. 1980; Thomas 2010). In 2022, the lake increased to 156 ha of surface water presumably by additional flooding by beaver dams (Coady and Gunn 2022). The attached aerial photos (Figure's 3-25) show the progressive growth of Mud Lake into Lake Laurentian. The first Lake Laurentian dam was created to control the quality and quantity of water that flows into Ramsey Lake, which at the time supplied nearly all the drinking water for the city (Bubelis et al. 1980). Additionally, two backwater dams were created to prevent excessive flooding, on the southwest side of Lake Laurentian near Ida Street and another on the southeast side of Perch Lake (Bubelis et al. 1980). Perch Lake, a 30.5 ha lake within the Lake Laurentian watershed has changed very little in size since 1946 (Sein 1991). The lake consists of one main basin with a maximum depth of 2.6 m (Sein, 1991). However, due to dredging of a drainage channel through the wetland to the west of Perch Lake in the late 50s to early 60s, some slight decreases in water depth may have occurred (Figure 9; Bubelis et al. 1980). The body of water which is now unofficially named Little Laurentian was historically simply a wetland with very little open water. After the construction of a 20 m long beaver dam at the outlet of the lake, the basin now includes around 12.3 ha of surface water and 16.5 ha of wetlands.

Due to the protected status of the area since the late 1960s, there has been minimal development within the Lake Laurentian Conservation area. By using a stereoscope to look at aerial photographs it appears that between 1946 and 1969 on the southeast side of Little Laurentian Lake (hereby referred to as Little Laurentian) there was a farm and two small gravel pits. A third and much larger gravel pit located on the southwest side of Lake Laurentian still partially remains today. The largest development project within the watershed in recent history would be the construction in 1992 of the Southeast bypass, which cut through 2 km of the southern portion of the watershed. The Nature Chalet and its adjacent parking lot is the only developed property on the shores of Lake Laurentian itself. The Nature Chalet opened August 22, 1967 (Bubelis et al. 1980; Conservation Sudbury 2023b). It has since been a hub of nature education opportunities and outdoor

**Figure 2.** Map of the Lake Laurentian Watershed and surrounding area, including trails, access points and other notable locations

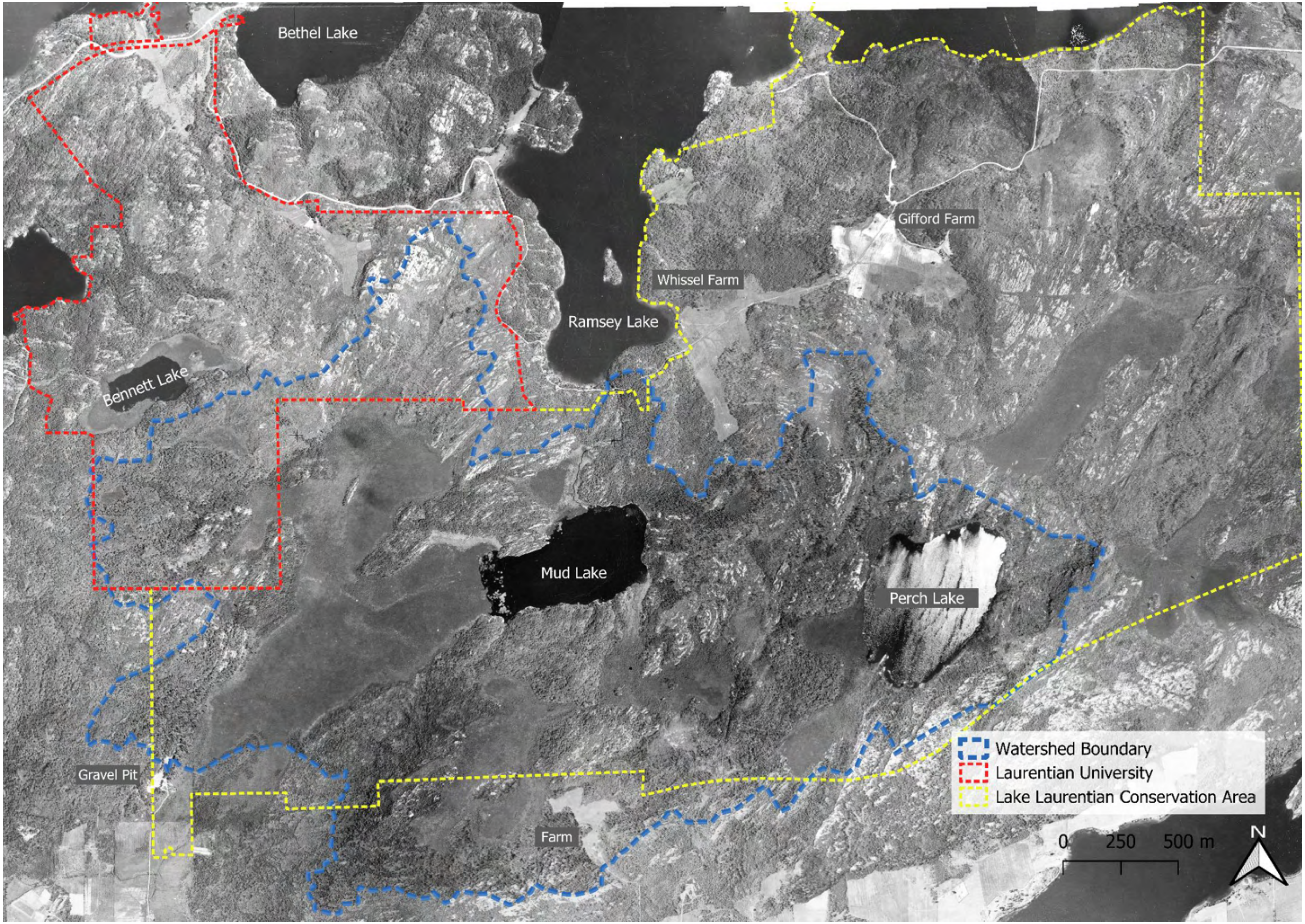
(created by A.Lepage, 2023)

recreation including school trips led by local teachers and summer day camps. The day camp takes place in July and August and provides activities such as canoeing, pond studies, archery, fishing, and hiking for young campers. (Conservation Sudbury 2023a). However, the largest recreational opportunity is probably the public use of the many trails in the conservation area. Throughout the years, 13 trails that total nearly 40 km have been constructed for hiking, biking and walking; There are also additional trails totaling 17 km for cross-country skiing and 5 km for snowshoeing.

The Nature Chalet on South Bay Road is the main access point for Lake Laurentian, acting as a boat launch for non-motorized watercraft and as well as the main trailhead for the LLCA trail network. The LLCA trails extend over a most of the watershed, including to a variety of lookout points over the lake, mainly located along the 10 km Lake Laurentian Loop trail. These trails also intersect with the BioSki Trails to the northeast and the Laurentian Nordic Ski Club Trails to the northwest. The north end of Perch Lake can be accessed via the Perch Lake Trail in the LLCA. The lake can also be accessed by portage from the east end of Lake Laurentian as well as through the wetland that borders the Southeast Bypass (Figure 2). The BioSki trails pass near the western shore of Perch Lake, although there is no direct trail access to the lake. There is also a power line easement along the southern and western sides of Perch Lake, but again there is no public access. Little Laurentian Lake can be accessed via portage from two points on the southern shore of Lake Laurentian as well as from the Lake Laurentian Loop Trail that follows the north side of Little Laurentian, including passing over the drainage of Little Laurentian Lake into Lake Laurentian.

***The History of Lake Laurentian: An Aerial Perspective***

This section provides a visual journey back in time, presented through a series of aerial photographs and satellite images of the LLW from 1946 through 2016. Each full-page image captures a moment in the history of the watershed, allowing readers to witness the transformative changes that have shaped this region over the past 70 years. Complementing these visuals, the opposing pages offer insight into the events of the time; from the founding of the Lake Laurentian Conservation Area, a pivotal step in preserving the natural beauty of the region, to the establishment of Laurentian University, a place for education and innovation, and a key contributor to the regreening of the region. It also sheds light on the triumphant return of the beaver, a symbol of environmental resilience. Moreover, this section showcases the inspiring recovery of the ecosystem from the scars of industrial damage that have been made possible by wide reaching partnerships, an engaged public, scientific initiative, strong regulations, and industrial innovation.


Bethel Lake
Ramsey Lake
Gifford Farm
Whissel Farm
Bennett Lake
Mud Lake
Perch Lake
Gravel Pit
Farm
Watershed Boundary
Laurentian University
Lake Laurentian Conservation Area
0 250 500 m
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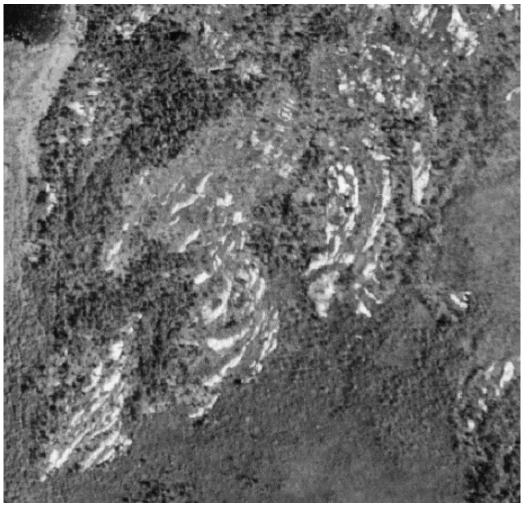


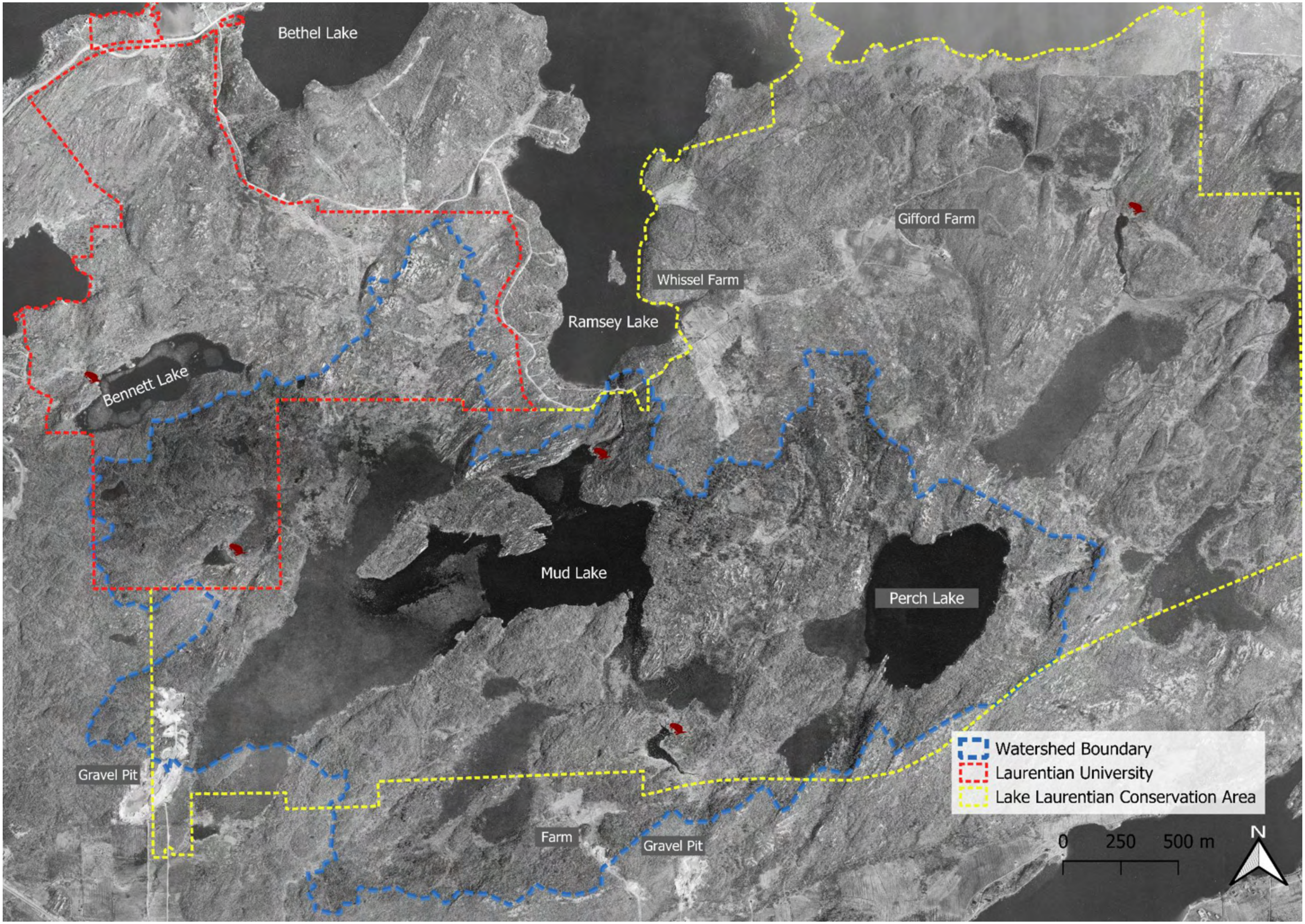
**Figure 4.** Barren hilltops between Mud Lake and Perch Lake.

By 1946, when the first aerial photographs were available, smelting activities in Sudbury were already very active, releasing clouds of pollution that damaged aquatic and terrestrial life, as evidenced by the barren hilltops. Amidst this landscape shaped by lumbering, forest fire, and acidic smelter emissions lies Mud Lake, the precursor to Lake Laurentian, which at the time was a shallow 22 ha lake. Much of the surrounding area was a sprawling complex of wetlands, as well as Perch Lake to the east. Beaver activity seems to have been much reduced at the time, perhaps because of active trapping or maybe loss of preferred tree species.

This view from 1946 also shows the early human impacts on the region, including several farms that today are a distant memory, as well as a few gravel pits. Two farms with known names, Whissel Farm and Gifford Farm, as well as a third unnamed farm, are located within what is now the Lake Laurentian Conservation Area. The unnamed farm, located on the southeastern shore of what is now Little Laurentian Lake, was the only farm to be developed in the Lake Laurentian watershed. The watershed also contains a gravel pit in the southwest corner, accessed from the south side.

**Figure 5.** Earliest aerial image of the Whissel Farm.

**Figure 3.** Annotated aerial photo of the Lake Laurentian Watershed in 1946.
Image: City of Greater Sudbury; annotated by: A. Lepage



Bethel Lake
Gifford Farm
Whissel Farm
Ramsey Lake
Bennett Lake
Mud Lake
Perch Lake
Gravel Pit
Farm
Gravel Pit
Watershed Boundary
Laurentian University
Lake Laurentian Conservation Area
0 250 500 m
N

By 1956 beavers were clearly very active in the watershed. The most notable effect of this activity was Mud Lake's increase in size from 22 to 42 ha. This doubling of water area was due to a beaver dam constructed on the northeastern corner of the lake, where it drains into Ramsey Lake. Several other possible beaver dams are also visible across the LLW in the aerial imagery. Bennett Lake to the northwest also doubled in size over this period thanks to beaver activity.

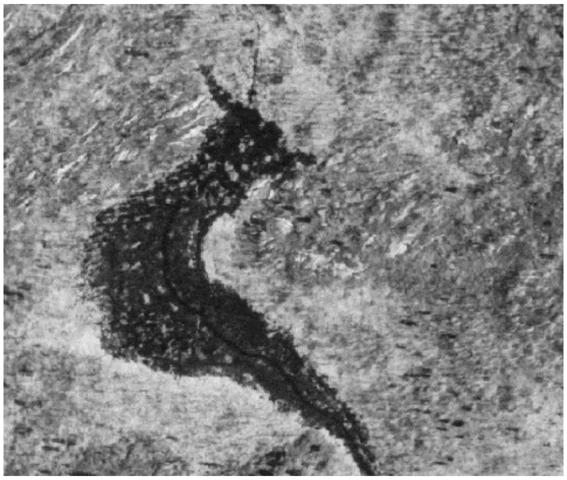
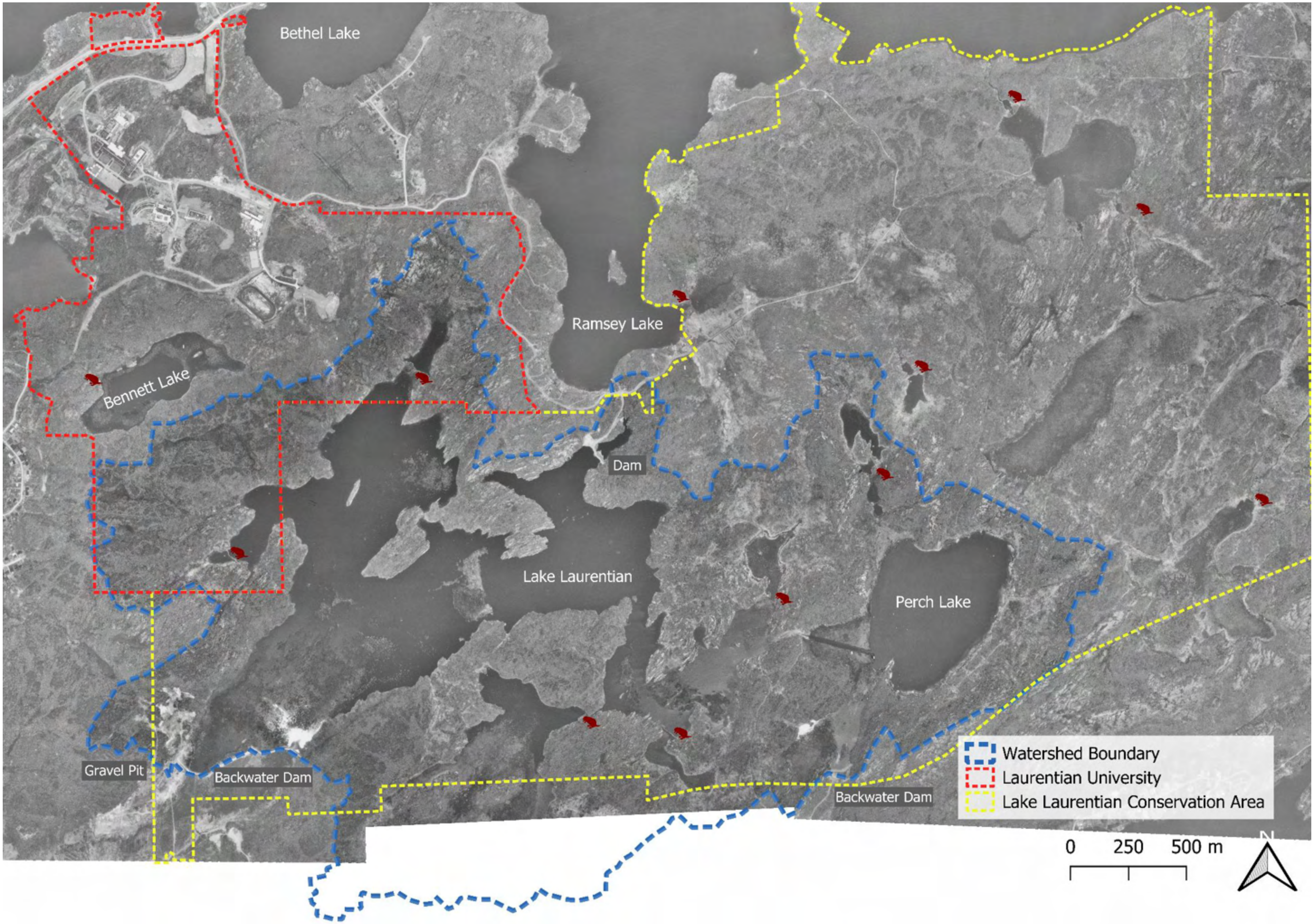


**Figure 7.** One of the earliest beaver dams in the Lake Laurentian Watershed, between Perch Lake and Lake Laurentian.

Beavers were not the only things expanding their activity in the area at the time. Humans were also becoming a more obvious presence based on aerial imagery. Gravel and aggregate extraction became more widespread, with a marked increase in the size of the gravel pit to the southwest of the watershed and a newly developed pit appearing on the edge of the watershed just south of the unnamed farm. The road network in the region also expanded over this time, allowing access for further housing development on the shores of nearby Ramsey Lake and Bethel Lake.

**Figure 8.** Gravel pit on the SW side of Lake Laurentian.

**Figure 6.** Annotated aerial photo of the Lake Laurentian Watershed in 1956.
Image: City of Greater Sudbury; annotated by: A. Lepage


Bethel Lake
Ramsey Lake
Bennett Lake
Dam
Lake Laurentian
Perch Lake
Gravel Pit
Backwater Dam
Backwater Dam
Watershed Boundary
Laurentian University
Lake Laurentian Conservation Area
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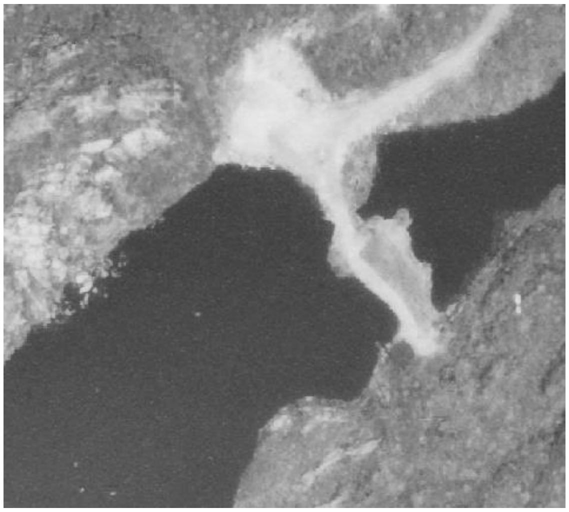


**Figure 10.** Constructed dam at outlet of Mud Lake.

The beaver dam at the outlet of Mud Lake was replaced by a permanent fixture around 1958. Two additional backwater dams were also constructed, one to the southwest of Lake Laurentian and another to the southeast of Perch Lake, to prevent flooding. These dams increased the size of the lake to 138 ha, officially forming what we know as Lake Laurentian today. A drainage channel was also dug through a wetland to the west of Perch Lake, adding another connection to Lake Laurentian. With this increased water area, beaver activity also appeared to expand, with existing dams increasing in water area and a variety of new dams forming, including a large dam complex to the northwest of Perch Lake, and in University Bay of Lake Laurentian.

**Figure 11.** Complex of beaver ponds north of Perch Lake.

In 1960 Laurentian University was founded, with construction and expansion of the campus continuing through the years. Over this period smelter emissions in Sudbury also reached their peak, with the smell of sulphur being a trademark feature of the region. In 1967 the LLCA was established, securing protection for a large portion of the LLW. By this point the farm near Little Laurentian Lake, as well as the Whissel and Gifford farms had been abandoned, with farmhouses disappearing from the aerial imagery. The Nature Chalet building was originally constructed in 1967 and to this day it remains the only building within the LLW.

◀ **Figure 9.** Annotated aerial photo of the Lake Laurentian Watershed in 1969.
Image: City of Greater Sudbury; annotated by: A. Lepage

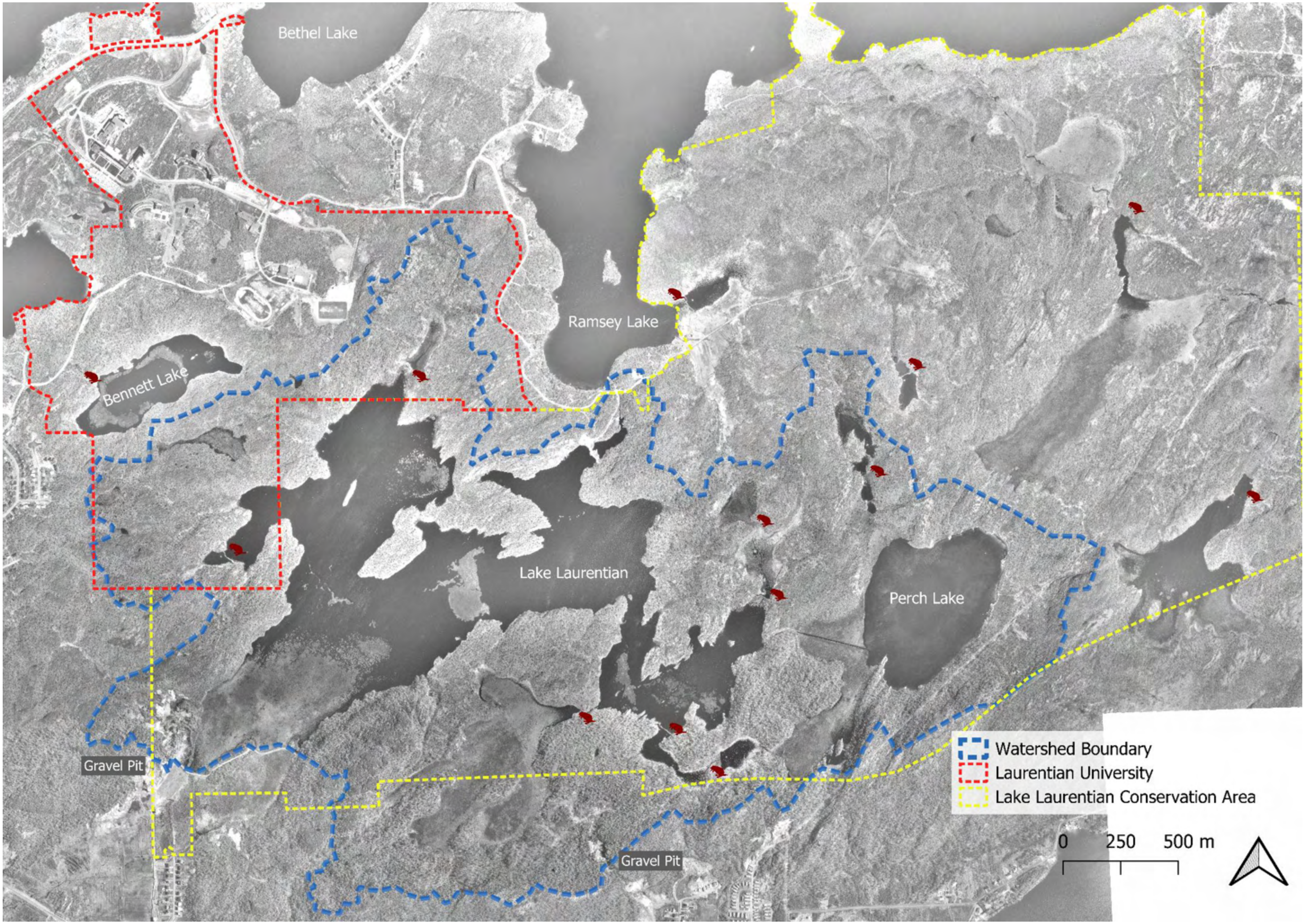

Bethel Lake
Ramsey Lake
Bennett Lake
Lake Laurentian
Perch Lake
Gravel Pit
Gravel Pit
Watershed Boundary
Laurentian University
Lake Laurentian Conservation Area
0 250 500 m

Figure 13. Earliest stages of pine plantation on Whissel farm.

By 1975 the former farmlands of the area have begun to become more naturalized, with trees appearing on the former Whissel farm. Beavers continue to be active throughout the region, with several new ponds forming, as well as some notable ponds disappearing including a large pond in the current site of the Ducks Unlimited Pond.

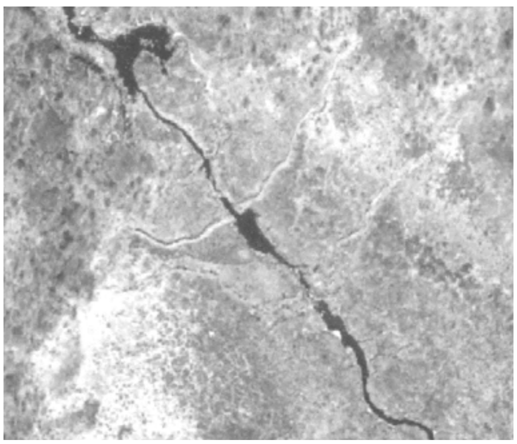


**Figure 14.** Ruptured beaver dams at the Ducks Unlimited Wetland, northeast of Lake Laurentian.

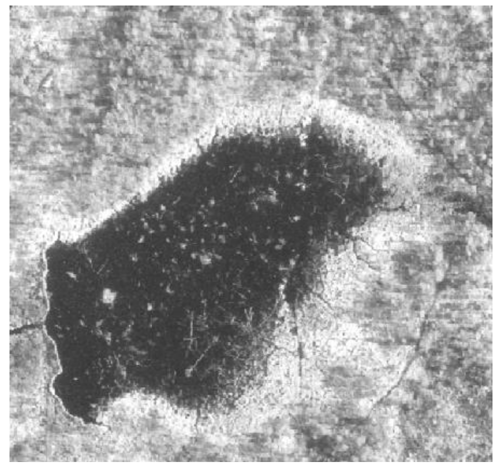


**Figure 15.** Beaver pond between Perch Lake and Lake Laurentian

The BioSki chalet was built in 1974 just outside of the LLW boundary but it remains in the LLCA boundary. Aggregate extraction continues at the pit in the southwest of the LLW.

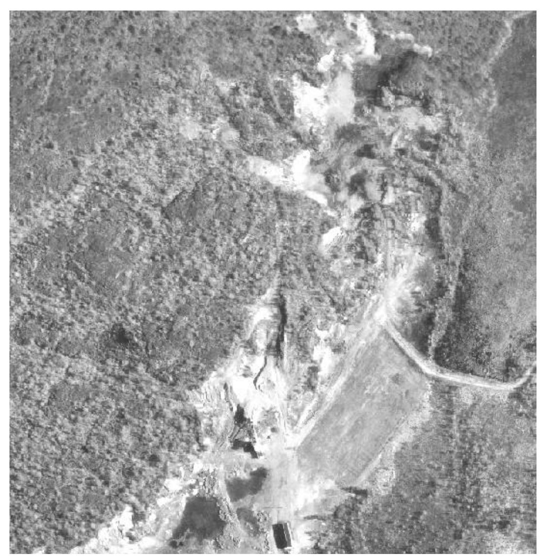
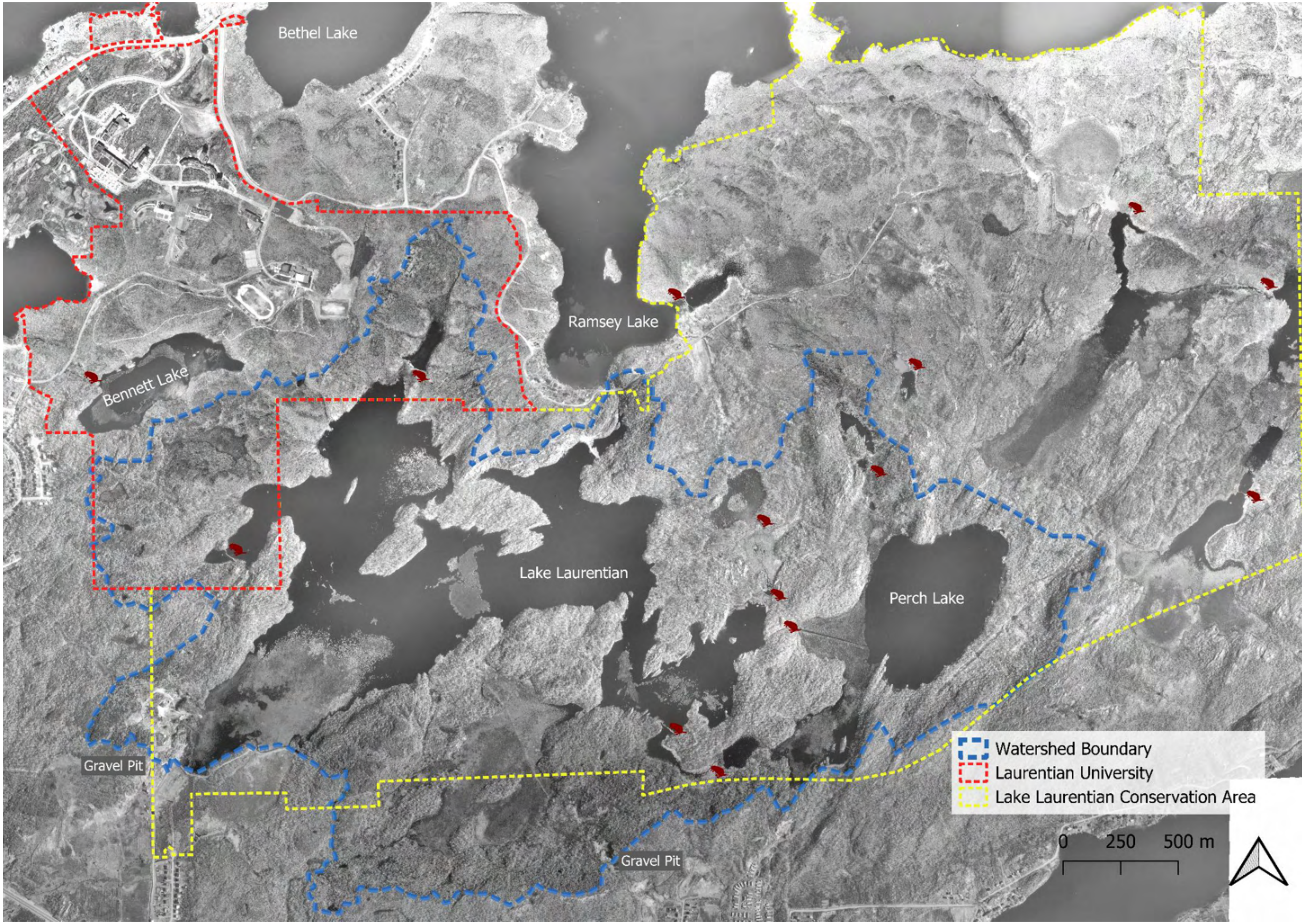


**Figure 16.** Gravel pit on southwest side of Lake Laurentian.

**Figure 12.** Annotated aerial photo of the Lake Laurentian Watershed in 1975.
Image: City of Greater Sudbury; annotated by: A. Lepage


Bethel Lake
Ramsey Lake
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Gravel Pit
Gravel Pit
Watershed Boundary
Laurentian University
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0 250 500 m

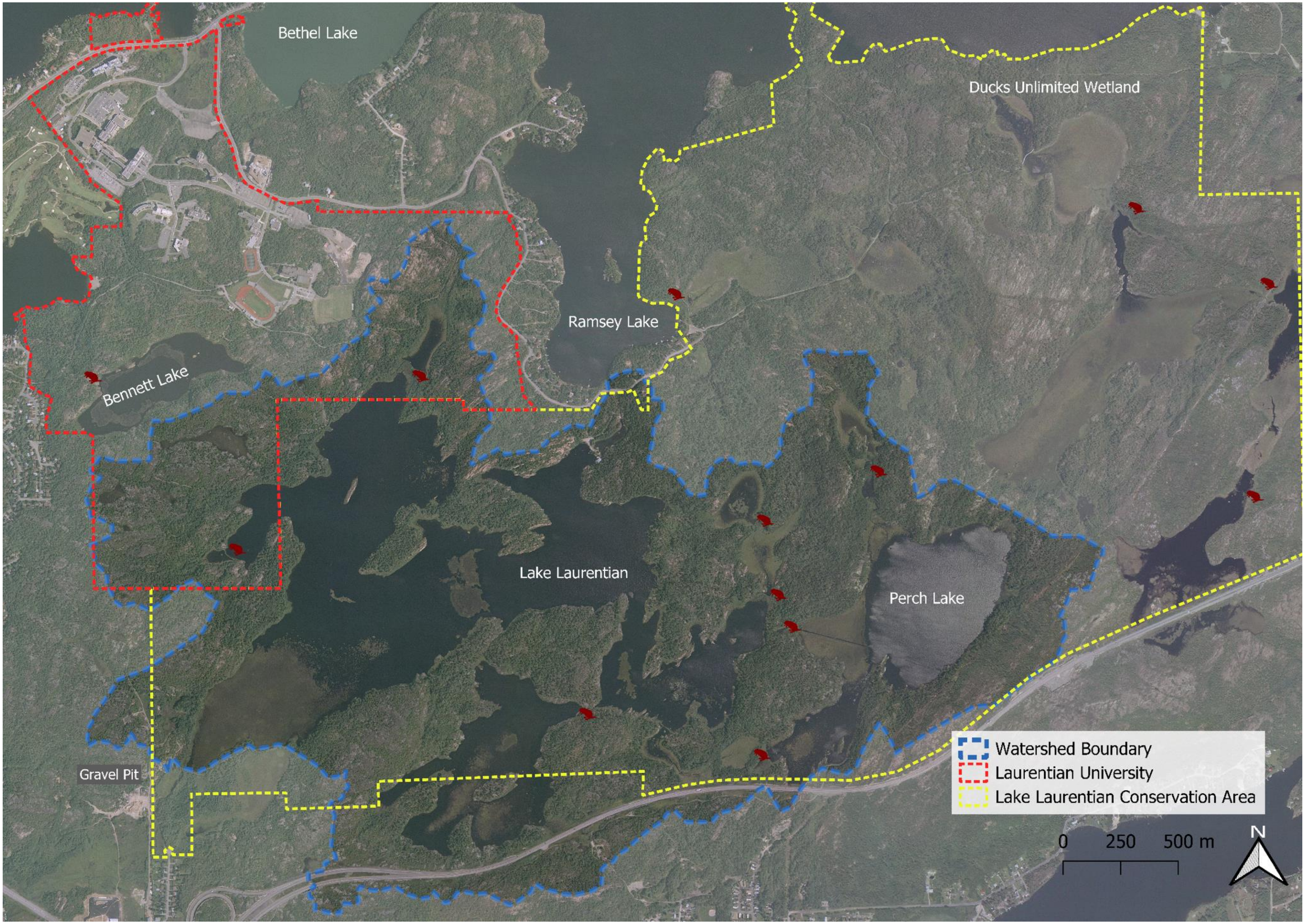
**Figure 18.** Growth of pine plantation on Whissel farm.

By 1980, studies revealed that Perch Lake and Lake Laurentian were completely fishless, a result of past industrial air pollution. However, with rapidly declining smelter emission after the 1970s, environmental recovery was able to begin in Sudbury. In 1978 the municipal regreening program also began liming to treat the legacy of acid deposition and began extensive planting of trees and grasses across the region. Beaver dams were still being constructed throughout, with a notable dam of on the Perch Lake drainage channel which reduced the amount of water flowing out.

The gravel pit on the southwest side of Lake Laurentian peaked in size around this time. Elsewhere in the watershed, trees began to grow again, with the distinctive "pines in lines" of early tree planting programs visible on the former Whissel and Gifford farms. In 1982 Lake Laurentian was purposely drained to replace the existing dam, releasing the heavy metals that were stored in the sediments. This resulted in a temporary reduction in water quality and harmed the biodiversity of the lake.

**Figure 19.** Gravel pit on SW side of Lake Laurentian in 1989

**Figure 17.** Annotated aerial photo of the Lake Laurentian Watershed in 1989. Image: City of Greater Sudbury; annotated by: A. Lepage


Bethel Lake
Ducks Unlimited Wetland
Ramsey Lake
Bennett Lake
Lake Laurentian
Perch Lake
Gravel Pit
Watershed Boundary
Laurentian University
Lake Laurentian Conservation Area
0
250
500 m
N

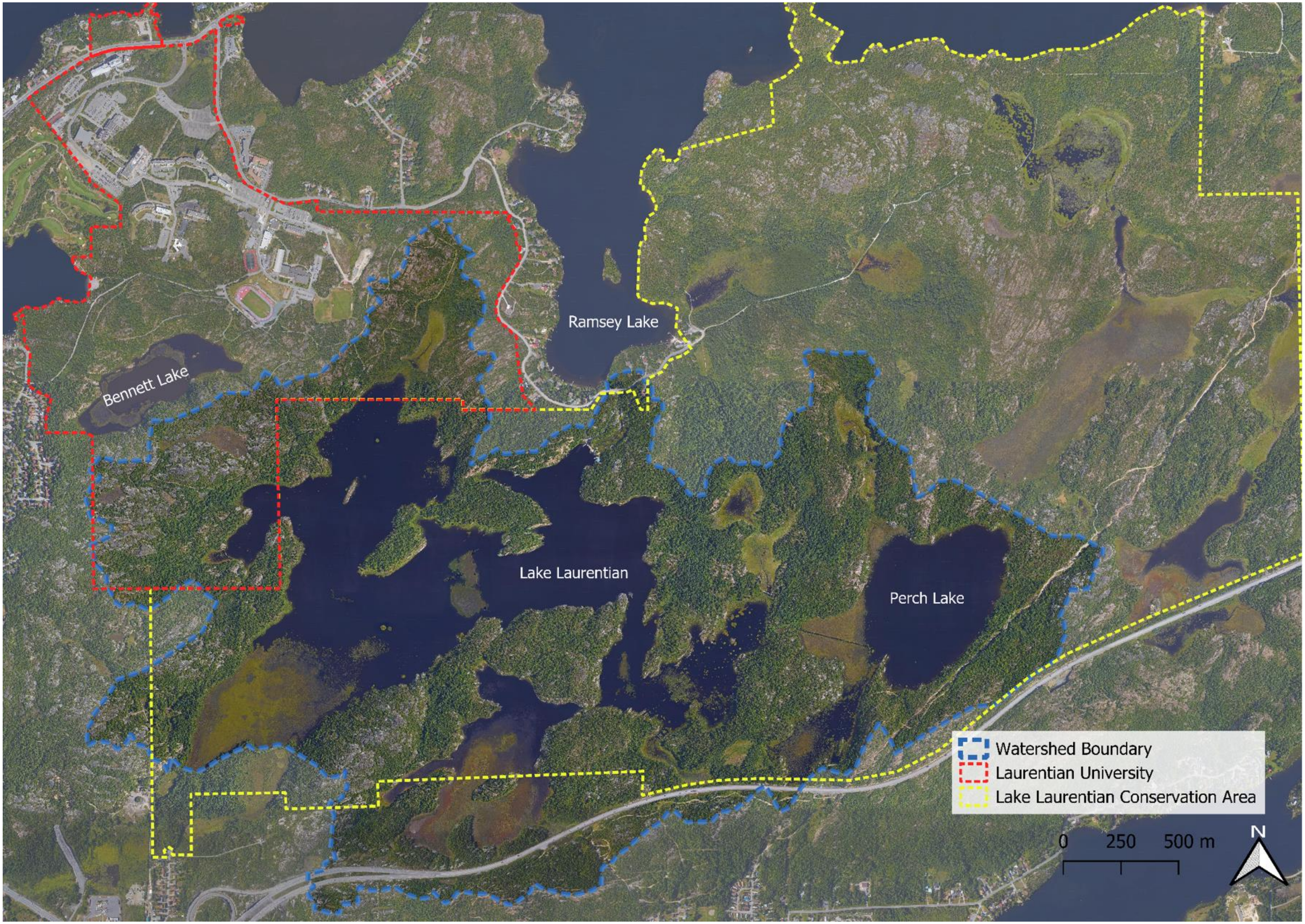
By 2003, the regreening of Sudbury was well underway, as evidenced by the increasingly dense forest covering the formerly barren hilltops between Lake Laurentian and Perch Lake. A new beaver dam between Little Laurentian Lake and Lake Laurentian also increased the size of Little Laurentian Lake. Another beaver-made dam was created in the Perch Lake wetland. The Ducks Unlimited Wetland to the northeast of Lake Laurentian was completed in 1993.

**Figure 21.** Beaver dam located at the Little Laurentian outlet into Lake Laurentian.

**Figure 22.** Abandoned gravel pit on the southwest side of Lake Laurentian.

By this point in time much of the gravel pit to the southwest of Lake Laurentian had been abandoned, with vegetation cover slowly establishing. The highway 17 Southeast bypass was built in 1992 and remains the largest development within the watershed boundaries to date, creating a pathway for both road salt and vehicle pollutants to enter the watershed.

**Figure 20.** Annotated aerial photo of the Lake Laurentian Watershed in 2003.
Image: City of Greater Sudbury; annotated by: A. Lepage


Ramsey Lake
Bennett Lake
Lake Laurentian
Perch Lake
Watershed Boundary
Laurentian University
Lake Laurentian Conservation Area
0
250
500 m
N

By 2016, over a quarter million trees had been planted in the LLW. This remarkable land reclamation effort also improved conditions in the lakes by stabilizing soils, lowering surface runoff amounts, and releasing carbon that can feed aquatic food webs. These improvements, along with the chemical improvements in the lakes have also allowed fish to return to the watershed and begin to thrive again.

**Figure 24.** Image of E.Wright with northern pike caught by angling in Perch Lake on July 27th, 2023.

Regreening activities now have an increased focus on improving biodiversity, not just adding vegetation cover, through new methods such as understory transplants. This innovative new method rescues understory plants from areas slated for development and uses them to improve the biodiversity of nearby regreened forests that often lack understory vegetation cover.

**Figure 25.** Understory transplant located on the Biodiversity Reclamation Trail at the Vale Living with Lakes Center

**Figure 23.** Annotated satellite image of the Lake Laurentian Watershed in 2016.
Image: City of Greater Sudbury; annotated by: A. Lepage

### ***Previous Studies on Biodiversity and Water Quality***

Changes in the biodiversity of the LLW have been assessed several times in the past 50 years. The first official report on the biodiversity of lakes is the 1980 Lake Laurentian and Perch Lake water management study. In 1980, the Junior Conservationist Award Program provided 28 students with the opportunity to study the lakes under the stewardship of the Nickel District Conservation Authority (NDCA; Bubelis et al. 1980). Their goals were to create a biological inventory of Perch Lake and Lake Laurentian, to examine the lakes' potential for recreational use, and to determine if the lakes had suitable habitat for game animals (Bubelis et al. 1980). Their methods included sweep netting, minnow trapping, shoreline surveys, and water testing (Bubelis et al. 1980). No fish were observed in either lake, a fact that the authors attributed to a variety of factors which they thought could have included: lack of oxygen, high water temperatures, insufficient food supply, high concentrations of toxic metals, and shallow depth (Bubelis et al. 1980) (Note that: in retrospect the toxic water quality was likely a principal reason). However, the lakes supported a great diversity of waterfowl, herpetofauna, and mammals which contrasts with the absence of fish (Bubelis et al. 1980). List 1 in the appendix shows a full list of waterfowl, herpetofauna, mammals, and invertebrates observed on Lake Laurentian and Perch Lake in 1980.

Amphipods are often used as a bioindicator for environmental toxicology in aquatic habitats. A study conducted in the mid-1980s examined lake acidification as a limiting factor in the distribution of *Hyalella azteca*, a ubiquitous freshwater amphipod (Stephenson and Mackie 1986). They determined that the minimum pH threshold for survival of *Hyalella azteca* was 5.6 (Stephenson and Mackie 1986). An undergraduate student at Laurentian University repeated this work in the Sudbury Lakes. *Hyalella azteca* was absent from Perch Lake as well as 25 other lakes of the 40 that were sampled (Watson 1992). Watson determined that the minimum pH threshold for *Hyalella azteca* in Sudbury Lakes was 6.4, which was 0.8 units of pH higher than the earlier study, suggesting that perhaps the added effect of toxic metals was limiting survival in our lakes (Watson 1992).

In the summers of 1989-1991, fish surveys were conducted on 43 lakes in the Sudbury region, including Lake Laurentian and Perch Lake, by students employed through the Environmental Youth Corps program in conjunction with the Ontario Ministry of Natural Resources at Laurentian University's Cooperative Freshwater Ecology Unit (Poulin et al. 1991). The lakes were typically surveyed for 3 days netting effort using ten standard wire mesh minnow traps, two plexiglass traps and two trap nets (Poulin et al. 1991). On Perch Lake these techniques yielded 296 brook stickleback (*Culaea inconstans*), 104 iowa darters (*Etheostoma exile*), and 21,352 fathead minnows (*Pimephales promelas*) (Poulin et al. 1991). The total catch per unit effort (number per overnight set trap) for the standard wire mesh minnow traps was 621.09 fathead minnows and 4.16 brook stickleback (Poulin et al. 1991). Following the same trapping methods 7,062 stickleback, 5,646 fathead minnows, 37 iowa darters and 633 yellow perch (*Perca flavescens*) were caught in Lake Laurentian (Poulin et al. 1991). Of the 43 lakes sampled throughout the urban lakes study Lake Laurentian had the highest catch per unit of effort (CPUE) for the plexiglass traps with over 400 brook stickleback in 24 hours, and Perch Lake had the highest CPUE for wire mesh minnow traps with over 600 fathead minnows recorded in 24 hours (Poulin et al. 1991). The results from this study showed that both Laurentian and Perch Lakes had very abundant prey species and the absence of any major predators. Some additional minnow trapping and small mesh trapnet work was done in Lake Laurentian in the summer of 1995, which again revealed no predator species but this time a very abundant perch population was present in Lake Laurentian (CFEU archives, unpublished data).

In 1996 Ministry of Natural Resources staff with Laurentian's Cooperative Freshwater Ecology Unit decided to try to create additional recreational fishing opportunities within the once-damaged Sudbury lakes by introducing northern pike from a dense population in Bethel Lake into area lakes, including Lake Laurentian. Fish were live captured using trap nets and approximately 100 northern pike were transferred by truck and released in Lake Laurentian. This was the source of today's active sport fishery in the lake.

During the summer of 2006, the Cooperative Freshwater Ecology Unit once again assessed the fish species in Lake Laurentian using the International Multi-mesh Netting Standard Method, also known as NORDIC index netting. NORDIC is a standardized method that utilizes multi-mesh gillnets to sample fish (Ontario 2019a). Their total catch was 676 fish (Cooperative Freshwater Ecology Unit, data not published). Yellow perch and northern pike were the only two species found in the lake at the time (Cooperative Freshwater Ecology Unit, data not published).

The most recent fish biodiversity assessment within the watershed was in 2022. The Cooperative Freshwater Ecology Unit performed broad-scale monitoring (BsM) on Lake Laurentian in May 2022 (Coady and Gunn, 2022). Broad-scale monitoring is a common standardized method of fish assessment in Canada. This protocol uses two different types of gillnets; “large mesh” gill nets which target fish over 20 cm in length and “small mesh” gill nets that target smaller fish (Coady et al. 2019). In addition to BsM they also used hoop netting and minnow traps to complete the fisheries assessment. Hoop nets are cylindrical-shaped nets with multiple hoops and tapered entrances so that the fish get entrapped in the net. This method allows for live release with less chance of entanglement or harm to the fish. The combination of these methods yielded 5 species of fish on Lake Laurentian; emerald shiner (*Notropis atherinoides)*, golden shiner (*Notemigonus crysoleucas*), northern pike, white sucker (*Catostomus commersonii*) and yellow perch (Coady and Gunn, not published).

During the water management study of 1980, water quality assessments of Lake Laurentian and Perch Lake were completed, and samples were collected and sent out to the Ministry of Environment for analyses. Perch Lake parameters such as pH, conductivity. nickel, copper, and sulfate had higher values than Lake Laurentian at the time. Nickel and copper levels were relatively high, but sodium, chloride and conductivity levels were within the typical range of a healthy freshwater lake (Bubelis et al. 1980). In 1990, a full water quality analysis was completed by the Cooperative Freshwater Ecology Unit in both Perch and Lake Laurentian. At the time the most notable finding was the high concentrations of nickel and copper, indicating poor water quality conditions of the lake. In 1990 nickel and copper exceeded the provincial water quality objective (PWQO) by over 2 and 6 times respectively. This was likely a result of atmospheric deposition from historical metal smelting in Sudbury. Another important factor to note is the low concentrations of sodium and chloride at 1.26 and <0.90 mg/L, respectively. In 2003, the CFEU completed another water chemistry analysis of Lake Laurentian. Continued water quality improvements allowed them to conclude that there was positive evidence of chemical recovery. More recently the CFEU participated in the NSERC project “Landscape carbon accumulation through reductions in emissions (L-CARE)”. In 2018 this project included Lake Laurentian in a water quality assessment of multiple lakes in Sudbury. Concentrations of nickel, copper, and sulphate have dropped considerably from their peaks in 1990 (CFEU, unpublished data), although the nickel and copper concentrations still exceeded PWQOs. Contrasting the metal declines, this latest survey identified a rise in sodium and chloride concentrations. The construction of the Highway 17 Southeast bypass through the LLW has clearly been responsible for these increasing sodium and chloride concentrations. Road salt can damage ecosystems by affecting the survival of

Cladoceran zooplankton species (e.g., *Daphnia*) that graze on and thus control algae levels in lakes (Sorichetti et al. 2022). To date the chloride concentrations are well below the Canadian Water Quality Guideline of 120mg/L (Sorichetti et al. 2022).

**Table 1.** Changes in water chemistry from 1990 through 2018 in Lake Laurentian (LL) and Perch Lake (PL). Analysis completed at the MECP lab. Red indicates results that are still above the Provincial Water Quality Objectives. No recent data exist-for Perch Lake

| Parameter | 1980[1] | 1990[2] | 1980[1] | 1990[3] | 2003[3] | 2018[4] | PWQO[6]/ Recommended |
|---|---|---|---|---|---|---|---|
| Lake | PL | PL | LL | LL | LL | LL | |
| pH | 7.15 | 6.51 | 6.8 | 6.41 | 6.53 | 6.57 | 6.5-8.5 |
| Conductivity (uS/cm) | 54.4 | 56.0 | 40.7 | 33.5 | 129 | 185.0 | 0-200 |
| Alkalinity | | | | 3.43 | 3.23 | 5.85 | |
| DOC | | 5.0 | | 6.9 | 6.1 | 5.9 | |
| Total Ca(mg/L) | 3.8 | 4.2 | 3.1 | 2.28 | 3.44 | 4.12 | |
| Total Mg(mg/L) | 1.45 | 1.88 | 1.17 | 1.08 | 1.35 | 1.47 | |
| Total Na(mg/L) | 1.1 | 1.56 | 1.5 | 1.26 | 17.20 | 28.1 | |
| Total Cl(mg/L) | 0.63 | 7.0 | 1.55 | <0.90 | 33.01 | 47.3 | |
| Total K(mg/L) | 0.83 | 0.79 | 0.75 | 0.720 | 0.710 | 0.565 | |
| Total $SO_4$(mg/L) | 18.5 | 15.10 | 12.5 | 6.60 | 5.25 | 2.9 | |
| Total As (mg/L) | <0.001 | | 0.003 | | <=0.5 | 0.0015 | |
| Total P (µg/L) | 7.0 | | 25.0 | 39.0 | 33.0 | 28.0 | 20 |
| Total Cu (µg/L) | 38.5 | 18 | 30.5 | 34.0 | 14.0 | 11.3 | 5.0 |
| Total Ni (µg/L) | 215.5 | 86 | 78.7 | 56.0 | 37.0 | 34.0 | 25.0 |
| Total Zn (µg/L) | 19.0 | 6.5 | 5.3 | 7 | 2.0 | 1.5 | 30 |
| Total Fe (µg/L) | 160.0 | 240 | 450.0 | 650 | 585 | 710.0 | 300 |
| Total Mn (µg/L) | 25.0 | 62 | 135.0 | 19.0 | 30.0 | 22.4 | |
| Total Al (µg/L) | 34.0 | 38 | 27.0 | <90.0 | 38.0 | 32.2 | 75 |

1 Bubelis et al. (1980); 2. Poulin et al (1991); 3. Keller et al. (2004); 4 CFEU (Unpublished Data); 6 Ontario. (2021b)

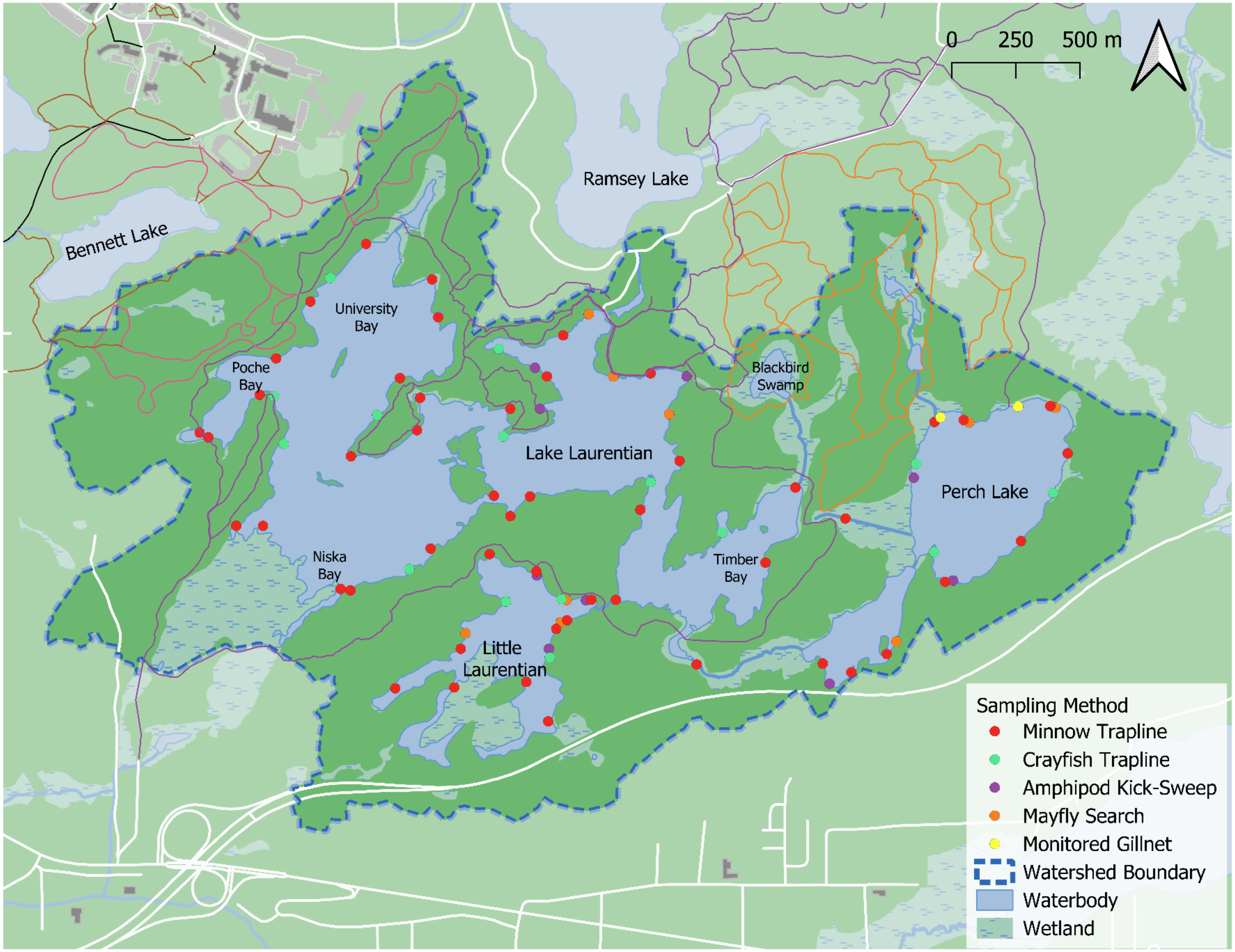



**Figure 26.** Map of all aquatic biodiversity sampling sites within the Lake Laurentian Watershed with sampling method denoted by different coloured circles. The dotted blue line represents the boundary of the watershed.

## Methods For Biodiversity Assessment

### *2022 Fish Sampling*

In 2022, BsM surveys were completed on 5 lakes within the Ramsey Lake Watershed (including Lake Laurentian). The data were used to determine total catch per species, and to assess the size distribution of northern pike in Lake Laurentian.

### *2023 Fish Sampling*

Minnow trapping was carried out on Lake Laurentian, Little Laurentian Lake, and Perch Lake throughout the month of June 2023 (Figure 10). A total of twenty minnow traps and 18 crayfish traps were set overnight (average 22 hours) along the shoreline of the lakes at 10 and 3 different sites respectively. A crayfish trap is a standard wire mesh minnow trap with openings on each side extended to 5 cm in diameter. The minnow traps were baited with a handful of seafood-flavoured dog food and crayfish traps with 1/6th of a can of seafood flavoured wet cat food. This method was repeated for 3 days on Lake Laurentian while Little Laurentian Lake and Perch Lake only required one day of sampling to cover the entire lake. The sample sites were chosen to target diverse habitats including rocky shores, mucky and silty shores, and macrophyte beds. All minnow traps were set from the canoe at around 1 m depth, while the crayfish trap lines (6 traps per line) were set perpendicular to shore with increasing depth along the line. All specimens captured were counted and identified and then released immediately. To supplement minnow trapping, angling was attempted on Lake Laurentian and Perch Lake for a duration of 2 hours per lake. Angling was done from the canoe using a fishing rod with a barbless lure that resembled a yellow perch. To further confirm the presence of large-bodied predators like northern pike in Perch Lake, two North American large mesh gillnets (NA1) were set perpendicularly from shore from 11 AM to 2 PM on July 27th, 2023. All fish captured in the gill net were identified and released immediately.

### *Invertebrate Sampling*

Acid-sensitive amphipods (*Hyalella azteca)* and mayflies (*Stenonema femoratum* and *Stenacron interpunctatum)* were chosen as target organisms in our invertebrate samples. To sample mayflies, field crews conducted searches by wading in the lake and inspecting the underside of nearshore rocks out to a maximum depth of 60 cm. Sampling sites were chosen based on their rocky habitats. The mayflies were removed from the rock, placed into 70% ethanol and later identified. Two-person field crews sampled for 20 minutes at 3 different sites per lake, for a total of 1 hour on each lake. For amphipods; field crews conducted searches with the “Kick and Sweep Method” which consisted of kicking to disturb sediments then using D-nets (mesh 500μm) to collect suspended material in a zig-zag pattern. Sampling occurred in water near thick macrophytes and over fine and moderately coarse organic and inorganic substrate in water around 1 m deep. The materials collected from the nets were dumped into a white tray and amphipods were picked out and placed into 70% ethanol. Specimens were later brought back to the lab to be identified to the species using a dissecting microscope. Two people searched each of the three sites for 20 minutes, totaling 1 hour per lake.

***Random Observation Sampling***

At the same time as invertebrate and minnow sampling, the field crew recorded all other observations including waterfowl, herpetofauna, and aquatic plants. We used this method of observation as presence/absence recordings only and a number of occurrences were not recorded. When possible, field crews used the iNaturalist application on their smartphones to take a photograph of the specimen and share it to be identified by other naturalists in the area. In addition, the Merlin app was also used to identify bird calls. These observations were kept on record to create a final list of our observations in the LLW.

***Water Quality Assessment***

Water samples from 5 locations within the LLW were collected on May 23rd, 2023 (Figure 35). A full set of samples from various outlets into Lake Ramsey and Lake Nepahwin was also collected and provided to MECP scientist Dr. Brie Edwards for analysis at the MECP laboratory in Toronto (these data are not yet available to include in this report). Additional samples were collected in labelled 500 mL containers and brought back to the Lake Center to measure the conductivity, as a simple measure of potential solutes in the water. Using a Model AZ8362 Conductivity meter (AZ Instrument Corp, Taichung City, Taiwan), conductivity and temperature were measured and noted.

## Results and Discussion

### *Recreational Fishery for Northern Pike*

The 2022 BsM Netting survey of Lake Laurentian yielded a total of 119 northern pike that ranged in fork length from 246 mm to 745 mm with a mean of 504 mm. The round weight of pike ranged from 110 grams to 3237 grams with a mean of 1007 grams (2.2 lbs). Northern pike that were 400-599 mm in length comprised nearly 75% of the population and 50% of the population were between 300 and 899 grams. The size distribution is presented in Figures 27 and 28. Northern pike typically reach sexual maturity between 500-600 mm total length (Berry, 2008). Therefore, the majority of the fish captured in Lake Laurentian are expected to be sexually mature. Similar data are also available for the principal prey species in the lake, yellow perch (see Figures A1 and A2 in the appendix for results).

Lake Laurentian was included in the 2022 Guide to Eating Ontario Fish. Within this guide it lists mercury (Hg) as the main chemical of concern, however there are no consumption reductions for the general population for pike between 350-750 mm in length, meaning it is safe to consume up to 32 meals of these fish per month. There is a minor restriction of <16 meals per month for sensitive populations such as children under 15 and people who are or may become pregnant, but only for pike larger than 500 mm (Ontario, 2022c). It is highly unlikely that anyone from these sensitive population would consume more than 16 meals of Lake Laurentian pike per month, so it is probably safe to say that the consumption guide indicates that anglers can enjoy their fish as safe to eat. The introduction of northern pike to Lake Laurentian has therefore created a recreational pike fishery that produces bountiful, safe to consume fish to the community.

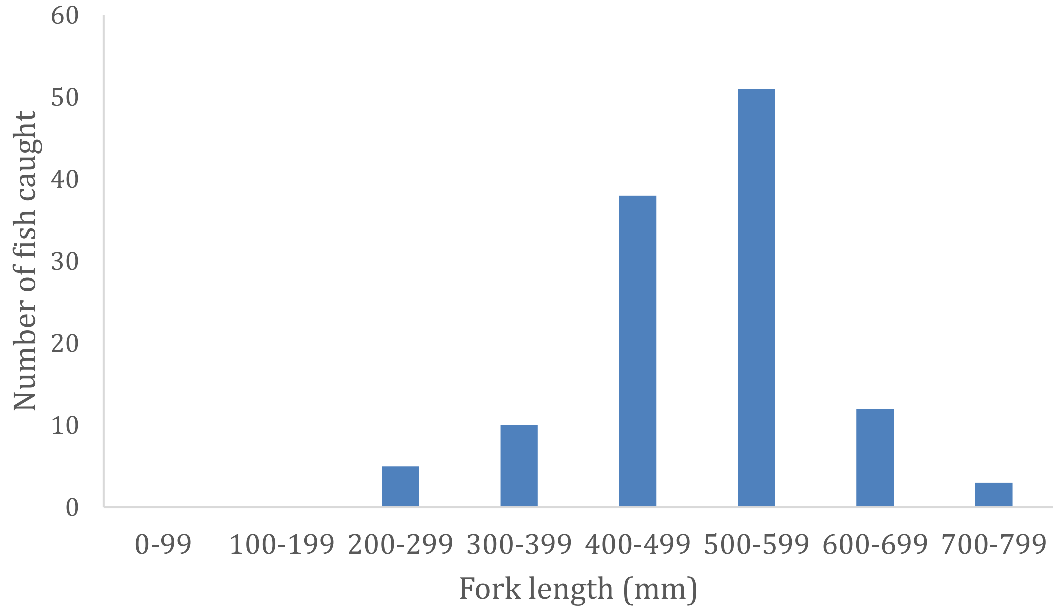



**Figure 27.** Fork length (mm) distribution of 119 northern pike caught in Lake Laurentian in 2022 using the broad-sale monitoring protocol.

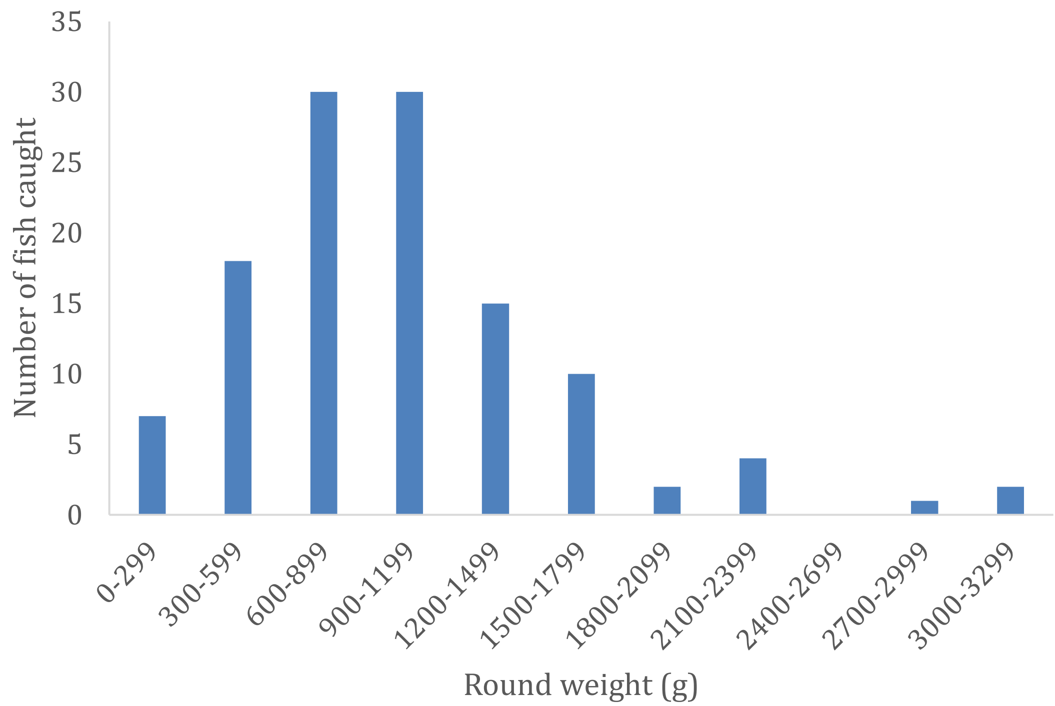



**Figure 28.** Round weight (g) distribution of 119 northern pike caught in Lake Laurentian in 2022 using the broad-sale monitoring protocol.

***Small Fish Survey***

Five species of fish have been identified in Lake Laurentian between 2022 and 2023, making it the most diverse lake in the watershed (Table 2), but in 2023 the minnow trap surveys produced surprisingly few fish in Lake Laurentian. Only a total of 48 yellow perch were collected in 30 traps. The catch per unit of effort for minnow traps was only 1.6 yellow perch per day. Even though Lake Laurentian had the most sampling effort with 30 pairs of minnow traps, it still had the lowest total catch of all three lakes. Prior to the pike introduction in 1996, the urban lake survey conducted in 1991 had revealed that the lake was dominated by abundant brook stickleback and fathead minnows (Poulin et al. 1991). In 1995, the community appears to have then dramatically changed with super abundant yellow perch and only a single white sucker noted (CFEU, unpublished data). Further changes occurred after 1996, when 100 northern pike trapped from nearby Bethel Lake were transported to Lake Laurentian to expand Sudbury's urban fisheries and promote fishing in the conservation area (Gunn, Pers. comm. 2023). This introduction of northern pike into Lake Laurentian would explain the decline of the formerly dominant prey fish species. For example, in an experiment of the effects of pike introduction on lakes in northwestern Ontario, researchers showed over a 99% decrease in minnow populations within 2 years (Elser et al. 1998). Northern pike are a piscivorous fish, meaning they prey on other fish (Elser et al. 1998).

Minnow trapping yielded 75 fish on Perch Lake in 2023. The CPUE on Perch Lake is only slightly higher than Lake Laurentian with 7.4 yellow perch and 0.1 golden shiner per unit of effort for the minnow traps. In addition, a sweep of the D-ring net for invertebrate sampling caught 3 emerald shiners, one of which was brought back to the lab for positive identification. Angling and gill net efforts however confirmed that northern pike had also made their way into Perch Lake presumably entering through the drainage channel during high water levels. In less than 2 hours of angling 6 northern pike were caught and 1 more was caught in a short set (approximately 3 hours) gill net, suggesting that they might be quite abundant in this new lake. The emerald and golden shiners found in Perch Lake are some of the most widely sold baitfish (Ontario 2018d), therefore the introduction of these species into the Lake Laurentian Watershed could be explained by release of live fish due to angling (Gunn. Pers. comm. 2023). Bait shops near Sudbury confirmed that they most commonly sell shiners (golden, common, Simcoe, and emerald), chubs, dace, and suckers as bait fish (Sudbury Bait Suppliers. Pers. Comm. 2023). As per the Ontario website, northern redbelly dace, Iowa darter, common shiner, emerald shiner, golden shiner, lake chub, fathead minnow, brook stickleback, white sucker and many more species are all permitted baitfish. Although all these baitfish are legal in most lakes in Ontario (there are some exceptions), it is always important to check guidelines and protocols regarding safe baitfish practices to mitigate risks to the environment.

Minnow trapping in Little Laurentian Lake indicated that this little lake only supports 2 species of small fish (northern redbelly dace and Iowa darters) but the dace were in very high abundance (CPUE of 111.6/trap night). The northern redbelly dace typically occurs in boggy lakes, creeks and ponds, often correlated with presence of beavers (Alberta Government, 2012). Northern redbelly dace primarily use~~s~~ the littoral zone of lakes and tend to remain in shallow water in order to avoid predation by piscivores (Dupuch et al. 2009). Little Laurentian Lake is very shallow and the presence of piscivores is unlikely, which makes it the perfect environment for northern redbelly dace to thrive.

The Lake Laurentian Watershed makes up around 1/6 of the larger Ramsey Lake Watershed. Ramsey Lake is known to support many more species of fish than the LLW itself with occurrences of 16 known species to date including the brown bullhead (*Ameriurus rebulosus*), burbot (*Lota lota*), northern pike, pumpkinseed (*Lepomis gibbosus*), rock bass (*Ambloplites rupestris)*, smallmouth bass (*Micropterus dolomieu*), walleye (*Sander vitreus*), white sucker, yellow perch and many forage fish such as blacknose shiner (*Notropis heterolepis*), central mudminnow (*Umbra limi*), common shiner (*Luxilus cornutus*), creek chub (*Semotilus atromaculatus*), fathead minnow (*Pimephales promelas*), golden shiner, and Iowa darter (Coady and Gunn, 2022). Ramsey Lake is a large lake with a surface area of 795.2 ha and with a maximum depth of around 20.5 meters (Coady and Gunn, 2022). In contrast, Lake Laurentian has less than 1/5 of the surface area and only 3.8 m maximum depth. Little Laurentian Lake and Perch Lake are even smaller and much shallower. The species richness in Lake Laurentian, Perch Lake and Little Laurentian Lake may appear relatively low at 5, 4, and 2 respectively. However, it is unlikely that the LLW is capable of supporting a much higher diversity of fish due to limited habitat, particularly the shallow depth.

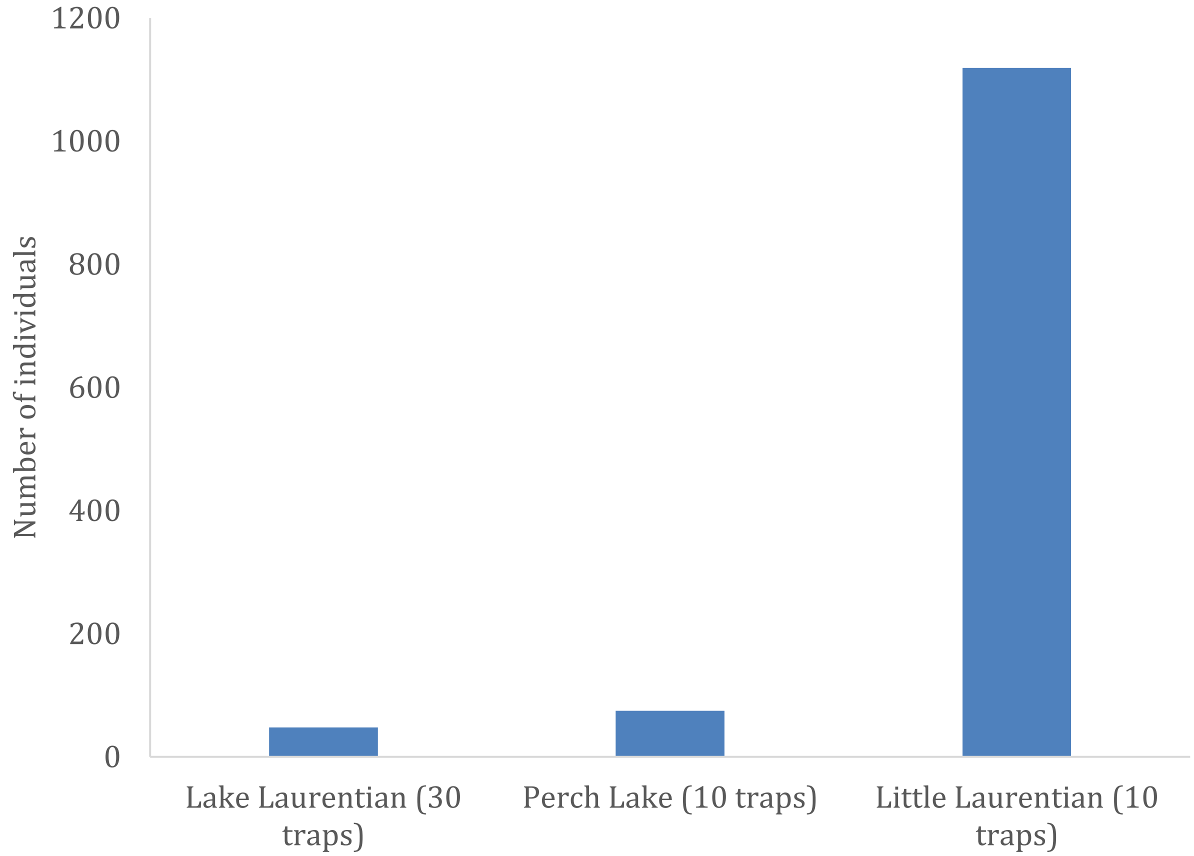
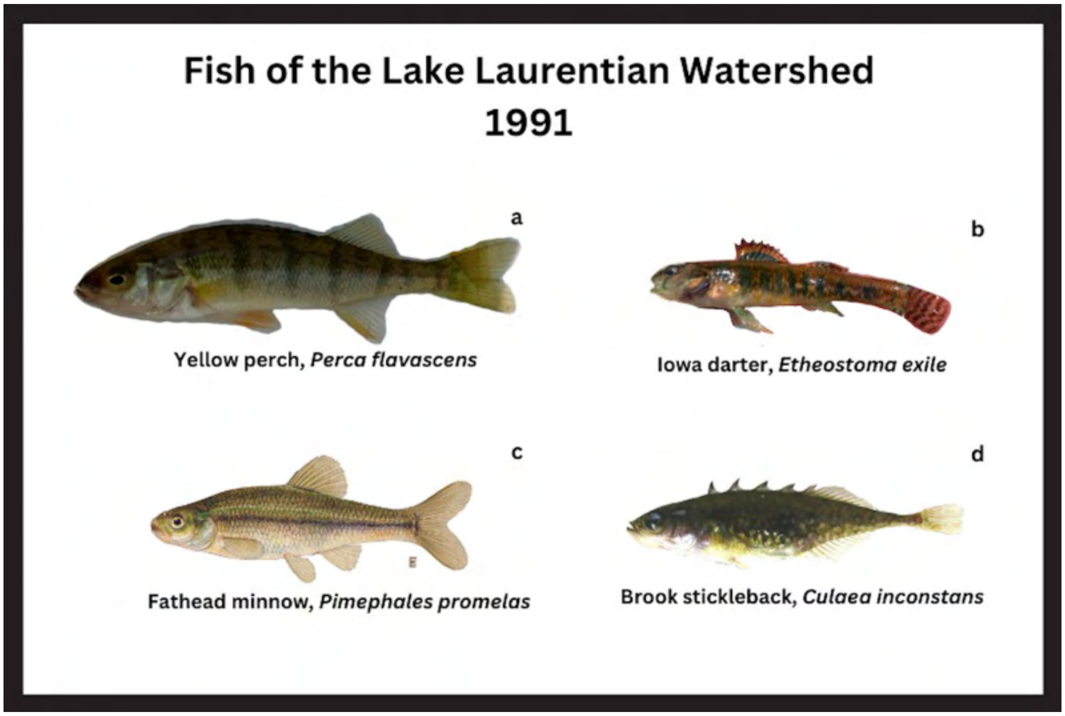



**Figure 29.** Bar chart comparing number of fish captured by minnow traps in Lake Laurentian, Perch Lake and Little Laurentian Lake. Number of traps is indicated to demonstrate catch per unit effort (CPUE).



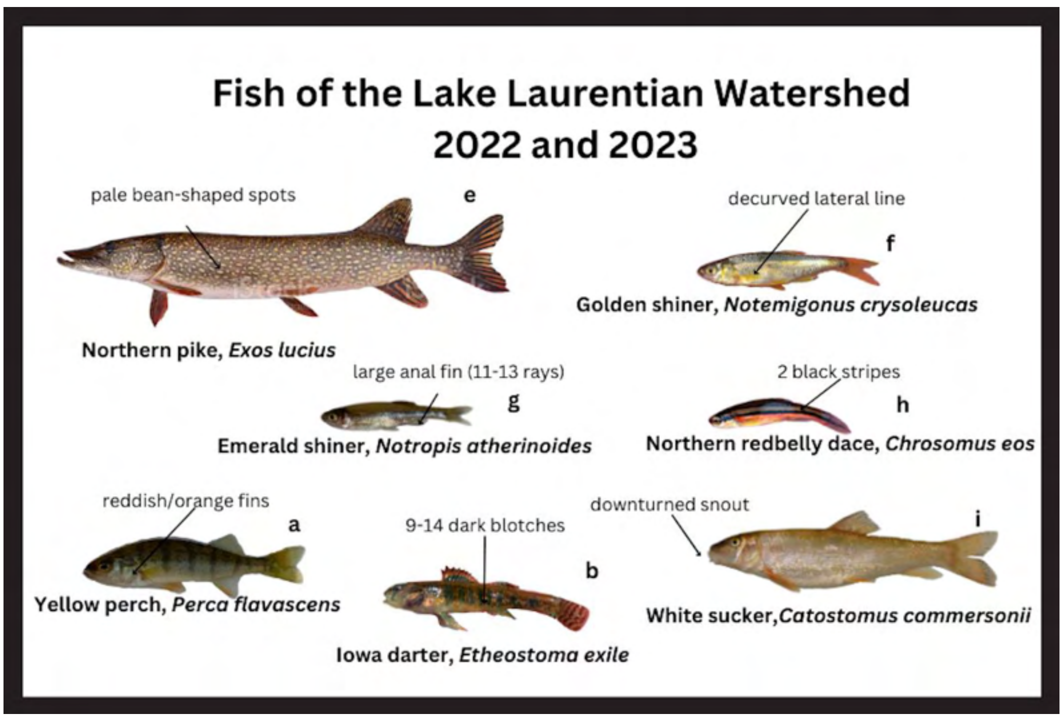




**Figure 30.** Change in fish community composition over time in the Lake Laurentian Watershed. Some distinguishing features in the current species are included.

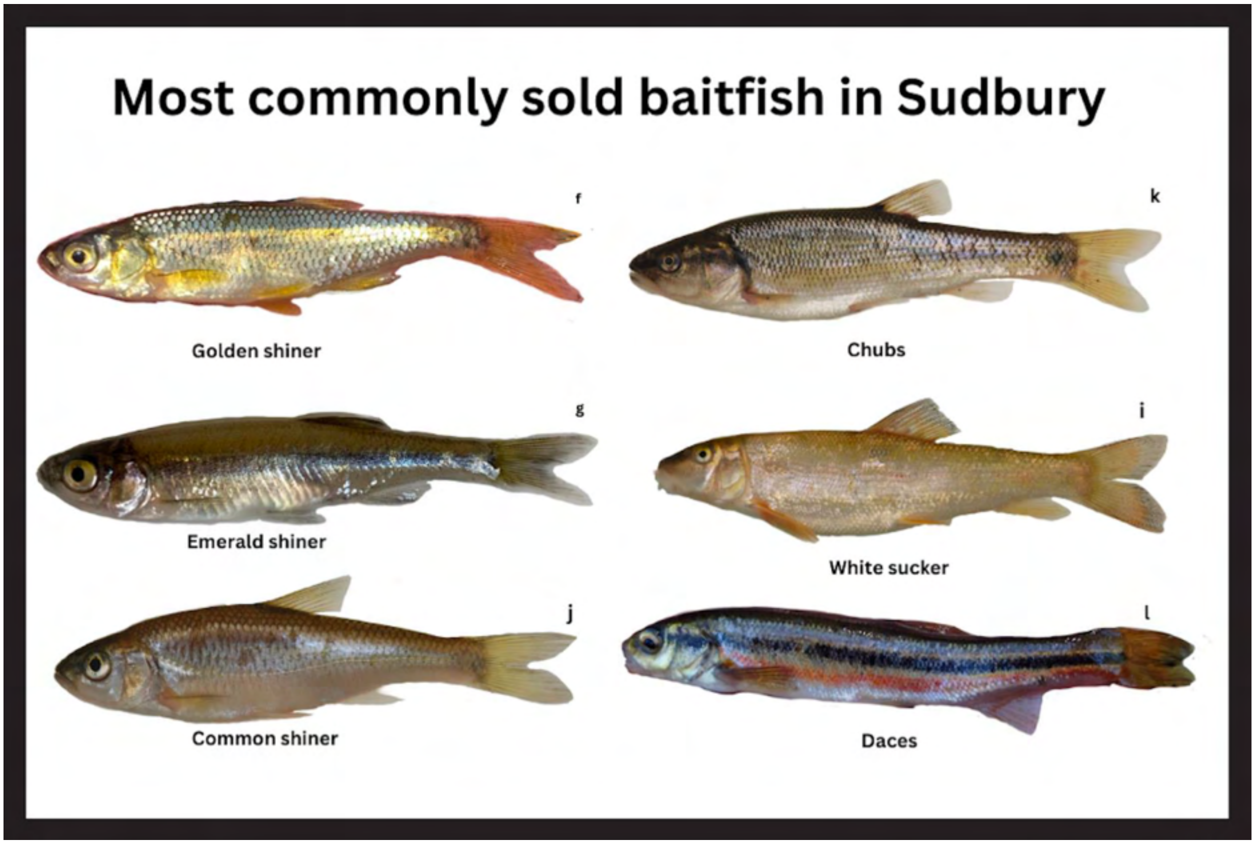



**Figure 31.** Most commonly sold baitfish species in Sudbury according to the bait shops in the area.

**Table 2.** Changes in fish community composition in Lake Laurentian and Perch Lake from 1980 – 2023. Sampling methods include minnow traps (MT), crayfish traps (CT), plexiglass traps (PT), trap nets (TN), gill nets (GN), D-nets (DN), angling (AN), and the standardized NORDIC and broad-scale monitoring (BsM) sampling methods.

| Lake | Lake Laurentian | | | | | Perch Lake | | | Little Laurentian |
|---|---|---|---|---|---|---|---|---|---|
| Year | 1980[1] | 1991[2] | 2006[3] | 2022[4] | 2023[5] | 1980[1] | 1991[2] | 2023[5] | 2023[5] |
| Sampling Methods<br>Species | MT | MT, PT, TN | NORDIC | BsM | MT, CT AN | MT | MT, PT, TN | MT, CT, AN, GN, DN | MT, CT |
| Brook Stickleback | | 7,062 | | | | | 296 | | |
| Emerald Shiner | | | | 11 | | | | 3 | |
| Fathead Minnow | | 5,646 | | | | | 21,352 | | |
| Golden Shiner | | | | 46 | 1 | | | 1 | |
| Iowa Darter | | 37 | | | | | 104 | | 3 |
| Northern Pike | | | 18 | 119 | 1 | | | 7 | |
| Northern Redbelly Dace | | | | | | | | | 1,308 |
| White Sucker | | | | 1 | | | | | |
| Yellow Perch | | 633 | 658 | 79 | 52 | | | 121 | |
| Species Richness | 0 | 4 | 2 | 5 | 3 | 0 | 3 | 4 | 2 |
| Total Catch | 0 | 13,378 | 676 | 256 | 54 | 0 | 21,752 | 132 | 1,311 |

1 Bubelis et al. 1980., 2 Poulin et al. 1991., 3 CFEU unpublished data. 2006., 4 CFEU, unpublished data., 5 Newly generated

### *Crayfish of the Lake Laurentian Watershed*

There were no crayfish captured in any of the three lakes. *Orconectes rusticus* as well as native crayfish species such as *Orconectes virilis* and *Cambarus robustus* prefer lakes, rivers and ponds that have clay, silt or gravel bottoms with rocks and logs that they can hide underneath (Ontario, 2018e). All three of the lakes had a relatively soft bottom with very little rocky habitat or logs that crayfish are usually associated with. The lack of suitable habitat of these three lakes likely explains their absence. In a 1995 practice survey completed by the CFEU, there were also no crayfish found in Lake Laurentian (Cooperative Freshwater Ecology Unit, unpublished data).

### *Benthic invertebrates of the Lake Laurentian Watershed*

Amphipods and mayflies were most abundant along the shores of Lake Laurentian. Relatively few mayflies and amphipods were observed in Perch Lake and both invertebrates were absent in Little Laurentian Lake. Throughout sampling on Lake Laurentian we observed a total of 91 mayflies; most abundant were *Stenonema* but there was also presence of *Stenacron* and *Ephemerellidae*. Forty-seven *Hyalella* were captured on Lake Laurentian using the D-net kick sweeping method. Amphipods and mayflies are indicators of lake health. Absence in the past could have been due to acidity and metal contamination (Gunn et al. 1991; Ocon and Capitulo, 2004). The presence of *Hyalella* in Lake Laurentian indicates improving water quality in the watershed (Watson, 1992; Gunn and Keller, 1995). On Perch Lake we captured a total of 60 mayflies (*Stenenoma*) and 25 amphipods (*Hyalella*). Little Laurentian Lake yielded no amphipods or mayflies but there were multiple incidental captures of other invertebrates such as; damselfly nymphs, leeches, dragonfly nymphs (Suborder *Anisoptera*) and caddisflies (Order *Trichoptera*).

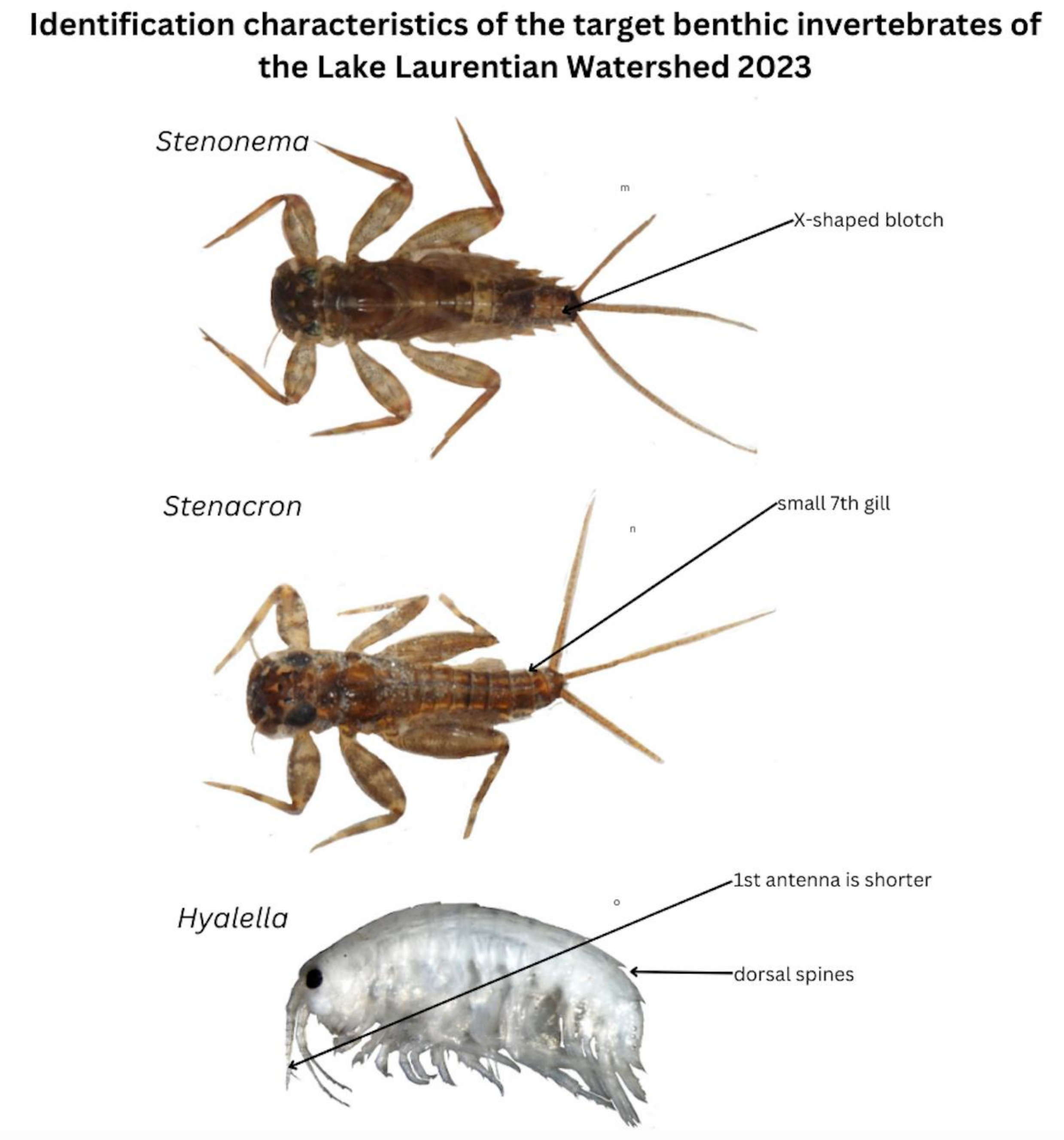



**Figure 32.** Identification characteristics of the target benthic invertebrates in the Lake Laurentian Watershed in 2023.

### *Birds of the Lake Laurentian Watershed*

All three of the lakes supported a great diversity of avian species. Commonly observed species included the Canada goose (*Branta canadensis)*, the mallard (*Anas platyrhynchos*), red-winged blackbird (*Agelaius phoeniceus)*, red-eyed vireo (*Vireo olivaceus)*, sandhill crane (*Grus canadensis*), great blue heron (*Ardea herodias*), and many others. The shoreline habitat provided waterfowl species with suitable nesting and feeding grounds. Using the Merlin app on a smartphone, the songs of song sparrows (*Melospiza melodia*), common yellowthroat (*Geothlypis trichas*), killdeer (*Charadrius vociferus*) and american crows (*Corvus brachyrhynchos*) were recorded. List 3 in the appendix has all bird call and sighting observations.

### *Herpetofauna of the Lake Laurentian Watershed*

The LLW supports a healthy diversity of herpetofauna. Observations of 3 turtle species, 2 snake species and 5 amphibian species occurred throughout our fish assessments. A surprising result was the abundance of midland painted turtles (*Chrysemys picta marginata*) in the LLW. Although the number of occurrences was not noted, we estimate that over 30 individual painted turtles were observed per day at each of the three lakes. Other reptile observations included blanding turtle (*Emydoidea blandingii*), common snapping turtle (*Chelydra serpentina*), northern watersnake (*Nerodia sipedon sipdeon*) and eastern garter snake (*Thamnophis sirtalis sirtalis*). Amphibians such as the green frog (*Lithobates clamitans*), american bullfrog (*Lithobates catesbeianus*), mink frog (*Lithobates septentrionalis*), spring peeper (*Pseudacris crucifer*) and american toad (*Anaxyrus americanus*) were identified by visual and auditory characteristics.

### *Mammals of the Lake Laurentian Watershed*

Mammals spotted in and around the lakes included beaver (*Castor canadensis*), muskrat (*Ondatra zibethicus*), eastern chipmunk (*Tamias striatus*) and red squirrel (*Sciurus vulgaris)*. Around the lake, we also observed raccoon (*Procyon lotor*) and red fox (*Vulpes vulpes*) prints, as well as black bear (*Ursus americanus*) feces. Conservation area users have also recently reported observing black bears, coyotes (*Canis latrans*) and moose (*Alces alces*) in the watershed (Pers. comm. 2023). Beaver houses and dams were observed on all three lakes and their presence seemed to be abundant. Perch Lake had 2 active beaver houses on the north side of the lake and a beaver was observed swimming between the two beaver houses. Lake Laurentian and Little Laurentian Lake are separated by a beaver dam on the north-east side of Little Laurentian Lake. Beavers can be considered one of the most prominent mammals in a watershed. They occupy most lakes and provide essential ecosystem services such as maintaining water. The beaver has had a historic role in the LLW by increasing and maintaining the water level. Beaver dams are also known to be effective at removing heavy metals, sediment, and pollutants by filtering the water through the mud, sticks and vegetation of the dams (Holzer et al. 2019). The beaver dams are even potentially reducing the road salt impact on the lake by acting as a barrier between road salt runoff in streams and the lakes.

***Zooplankton of the Lake Laurentian Watershed***

Very limited data are available to assess changes in zooplankton species in the LLW. Lake Laurentian has only been sampled for zooplankton three times (in 1990, 2003 and 2018) over the course of 80 years. The limited data suggest that the zooplankton communities are quite similar in terms of acid-tolerant versus acid-resistant species ratios and have not changed much over time (W. Keller pers. Comm). The apparent appearance and disappearance of certain species might simply be due to the fact that only single annual samples were collected. Table 3 below shows the comparison of species from 1990-2018.

**Table 3.** Zooplankton community composition in Lake Laurentian in 1990, 2003, and 2018.

| Species name | 1990 | 2003 | 2018 |
|---|---|---|---|
| *Bosmina sp.* | X | X | X |
| *Ceriodaphnia sp.* | | X | X |
| *Daphnia pulex* | * | | |
| *Daphnia retrocurva* | * | | X |
| *Diaphanosoma birgei* | X | * | X |
| *Epischura lacustris* | | | X |
| *Holopedium glacialis* | X | * | X |
| *Leptodiatomus minutus* | X | * | |
| *Mesocyclops edax* | X | | X |
| *Skistodiaptomus oregonensis* | * | X | X |
| *Tropocyclops extensus* | | X | X |
| Species Richness (SR) | 8 | 7 | 9 |

*=only one individual detected; X= species present

***Water Quality of the Lake Laurentian Watershed***

Conductivity is a measure of the ability of water to pass an electrical current. Inorganic chemicals such as dissolved salts are good conductors, therefore conductivity increases as salinity increases (Government of the Northwest Territories, n.d). In our study water conductivity results showed a high correlation between the lake's proximity to the highway and high salinity. The highest result was the Little Laurentian Wetland with a conductivity of 1939 µS which is nearly 4 times higher than the Perch Lake outlet stream. The conductivity results show a rise in conductivity in the last few decades but they have not reached dangerous levels for aquatic life (see Table 1 in appendix).

Although Lake Laurentian currently seems to have relatively stable water chemistry, it is important to note that circumstances such as droughts or dam damage could result in the return of toxic metal concentrations. In the 1980s, the Conservation Authority proposed the drainage of the lake to replace the dam (Hall, 1983; Keller, 1984). They anticipated that oxidative decomposition would allow the nutrients that remained in the sediments to be released for uptake by aquatic vegetation once the area was reflooded (Hall, 1983; Keller, 1984). At the time it appears that Laurentian University faculty did not agree with the removal of the dam and argued that it would harm the wildlife due to the release of toxic metals stored in the sediments (Hall, 1983; Keller, 1984). Despite the disagreement the Conservation Area went ahead with draining the dam in 1982 and began refilling in the winter of 1982 (Keller, 1984). A sampling program used this opportunity to study the biological and chemical changes that would result from this event. It was determined that pH of the lake had been significantly reduced from 6.5-6.8 to 4.6, conductivity increased from 49 to 232 µS, concentrations of Cu, Ni and $SO4_4$ significantly increased and other metals including Al, Fe, Mn and Zn also increased. It is important to note that INCO was on strike during most of the period between 1982 and 1983 meaning there was a halt in smelting processes and atmospheric inputs of metals, therefore the rise of toxic metals in the water can be assumed to have come almost entirely from the sediments (Keller, 1984). This study confirmed that draining the lake as a water management technique did more harm than good in Lake Laurentian (Hall, 1983). In today's view of climate change and drought it is therefore important to maintain current water levels in Lake Laurentian to prevent remobilization of acid and metal pollutants.

**Figure 33.** Images of the west shore of University Bay (Lake Laurentian) in May (above) and August (below) 1982, showing the beginning and final stages of lake draining. Images from Hall, 1983.

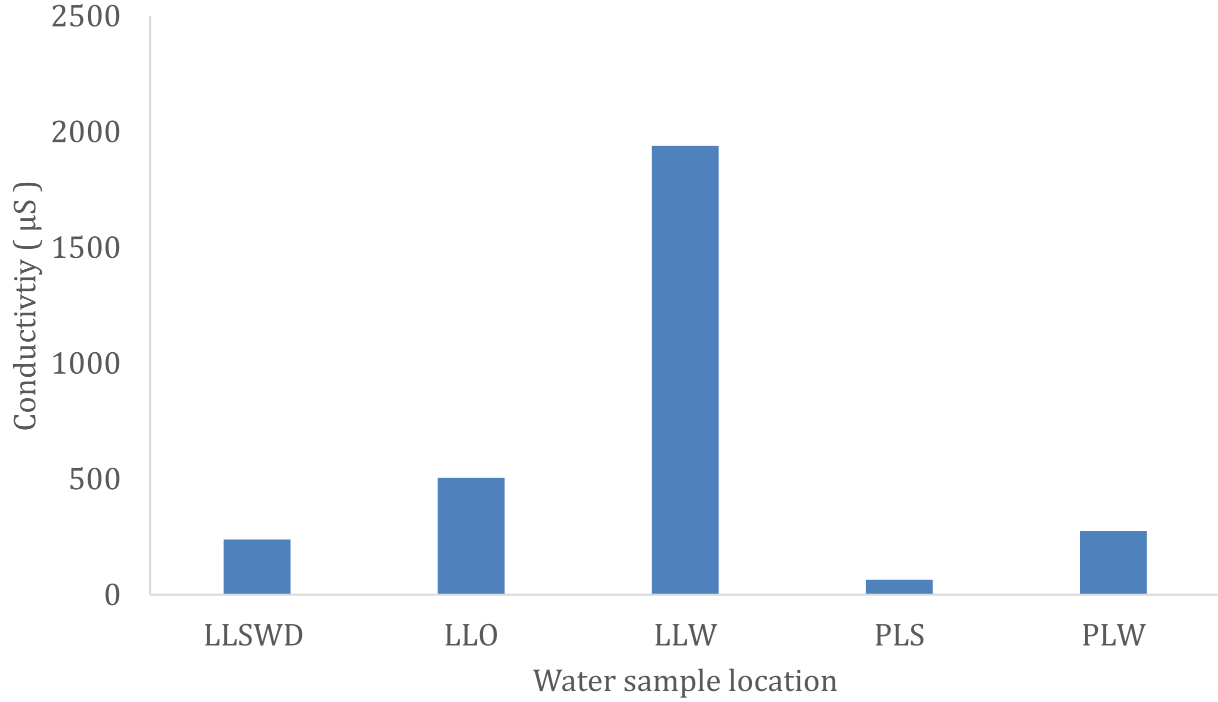



**Figure 34.** Conductivity (µS) of water samples from 5 locations within the Lake Laurentian Watershed boundary. Acronyms: LLSWD, Lake Laurentian watershed Drainage; LLO, Little Laurentian Outlet; LLW, Little Laurentian Wetland; PLS, Perch Lake Stream; PLW, Perch Lake Wetland. (See map below [Figure 35] for sample locations)

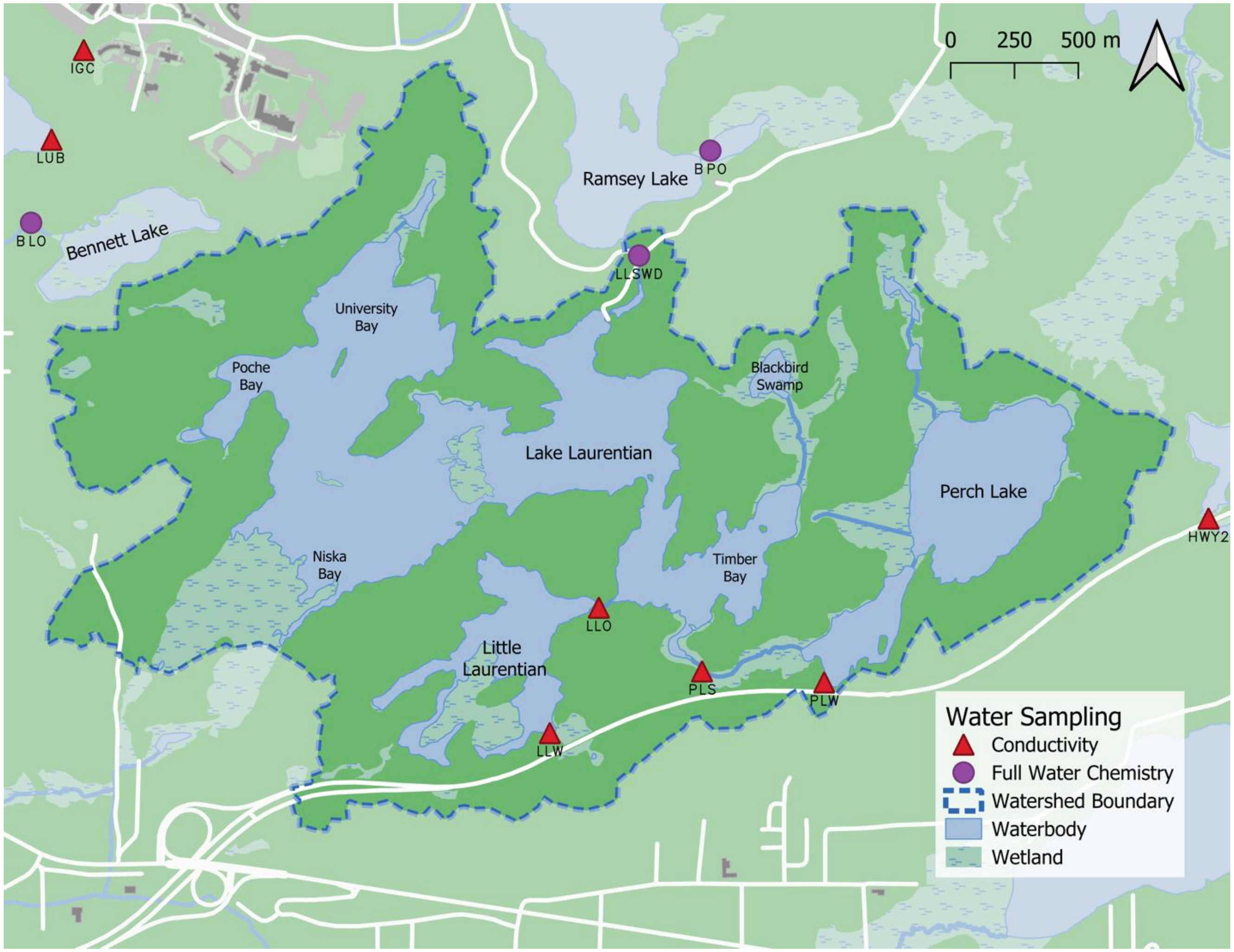



**Figure 35.** Map of all water sampling sites within the Lake Laurentian Watershed with sampling purpose denoted by different coloured circles. The dotted blue line represents the boundary of the watershed. Acronyms: LLSWD, Lake Laurentian watershed Drainage; LLO, Little Laurentian Outlet; LLW, Little Laurentian Wetland; PLS, Perch Lake Stream; PLW, Perch Lake Wetland.

**LU Experimental Wetlands within the Lake Laurentian Watershed**

Within the LLW lie 2 experimental wetlands located on the northwest side of Lake Laurentian (Figure 2). These experimental sites are relevant because they are in part of the LLW area shared between Laurentian University and the LLCA. Atmospherically deposited metals are retained in wetlands through ionic exchange with the organic matter (Szkokan-Emilson 2014) and past studies have shown these experimental wetland sites exhibit high levels of stored metals that are released after drought events (Szkokan-Emilson 2014). Research teams at Laurentian, Nipissing, Lakehead and McMaster Universities are attempting to solve this climate change issue by experimenting with ways of restoring sphagnum moss in degraded wetlands in the Sudbury area. Sphagnum mosses have high water-holding capacity and are essential in flood control, carbon sequestration, water quality and restoring ecosystem services. However, the natural recovery of sensitive sphagnum is a slow process, therefore transplants or other methods may be needed to help accelerate this process.

**Figure 36.** Sphagnum mosses. Top image *Sphagnum divinum* (left) and *Sphagnum subg. Acutifolia* (right), middle image *Sphagnum fuscum*, bottom image *Sphagnum squarrosum* (Images by A.Lepage).

**Conclusion**

The Lake Laurentian Watershed has undergone significant changes in the last 80 years. Combined surface water area increased by almost 4-fold (3.7) through dam construction and beaver activity. The number of fish species in the watershed has increased from 0 to 7, including establishing a healthy recreational northern pike fishery. Water quality made significant improvements in terms of metal contamination, allowing sensitive benthic invertebrate species (e.g. *Hyalella azteca*) to return to the watershed. Although overall water quality of the watershed has improved, increasing trends of sodium, chloride, and conductivity, although not yet at concerning levels, demonstrate the influence of road salt use and should continue to be monitored.

Overall pollution control efforts and good collaborative efforts among community, university, government and industry partners, has allow the LLW watershed area to make steady progress towards recovery. Revitalizing the peatlands and forest to increase their carbon capture potential is now one of the most important goals for the future, but ongoing protection of these lands and waters is also essential for biodiversity to continue to flourish and to provide future generations with clean water and healthy recreational opportunities, now and forever.

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**Image Sources**

**a)** Image by E.Wright

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**Appendix A – Lists, Tables, and Figures**

**List 1. Complete list of all waterfowl, herpetofauna, mammals and invertebrates observed on/in Perch Lake and Lake Laurentian in 1980. (Source; Bubelis et al.1980)**

*Flora*
Trees: cherry birch, white birch, red maple, red oak, jack pine, red pine, poplar, willow
Shrubs, bushes and flowers; arrowhead, aster, blueberry, bunchberry, clover, dock, dogbane, duckweed, red elderberry, fireweed, goldenrod, honeysuckle, field horsetail, iris, jewelweed, sheep laurel, leatherleaf, raspberry, sweet gale, fragrant waterlily, wintergreen, yarrow
Ferns and mosses: bracken fern, haircap moss, pohlia moss, sphagnum moss
Grasses and sedges: bluejoint grass, broad leaved cattail, joe-pye-weed, rattlesnake grass, rough bedstraw

*Fauna*
Reptiles: eastern garter snake, midland painted turtle
Amphibian: bullfrog, green frog, leopard frog, wood frog, salamander
Birds: American goldfinch, belter kingfisher, blackbird, bronzed grackle, cedar waxwing, common loon, eastern kingbird, great blue heron, herring gull, killdeer, mallard, myrtle warbler, raven, redwing blackbird, robin, ruffed grouse, slate-colored junco, song sparrow: spotted sandpiper, tree swallow, turkey vulture, white throated sparrow, woodcock, yellow-shafter flicker
Mammals: beaver, moose, muskrat, red fox, unidentified

*Invertebrates*
Insecta: ant, aphid, backswimmer, bumblebee, caddisfly, click beetle, cockroach, crawling water beetle, damselfly, dobsonfly, dragonfly, grasshopper, horsefly, ladybug, mayfly, midge, milkweed butterfly, mosquito, moth fly, predaceous diving beetle, red admiral, spider, tent caterpillar, tent caterpillar, tiger beetle, tiger swallowtail, water boatman, water scavenger beetle, water scorpion, water strider, whirligig beetle
Arachnida: common water mite, fishing spider, wolf spider
Crustacea: Cyclops, Daphnia
Hiriudinea: leech
Trematoda: fluke

**List 2. Dominant aquatic plants in the Lake Laurentian Watershed in 2023**
American water lily, common cottongrass, eagle fern, northern blue flag, northern St-John's wort, leatherleaf, pickerelweed, sheep laurel

**List 3. Observed vertebrate species in the Lake Laurentian Watershed 2023. Observations were made during the field surveys. The iNaturalist app and field guides were used to confirm identification of species.**

*Herpetofauna:* American bullfrog, American toad, blanding's turtle, common snapping turtle, eastern garter snake, green frog, midland painted turtle, mink frog, northern water snake, spring peeper

*Birds*: American bittern, American crow, American redstart, American robin, alder flycatcher, black-and-white warbler, broad-wing hawk, Canada goose, common grackle, common raven, common yellowthroat, chest-nut sided warbler, hermit thrush, house wren, indigo bunting, mallard duck, Nashville warbler, killdeer, ovenbird, pine warbler, pine warbler, red-breasted nuthatch, red-eyed vireo, red-winged blackbird, rose-breasted grosbeak, song sparrow, tree swallow, white-throated sparrow, yellow-bellied sapsucker, yellow warbler

*Mammals*: black bear, beaver, coyote, eastern chipmunk, muskrat, moose, red squirrel

*Fish*: emerald shiner, golden shiner, Iowa darter, northern pike, redbelly dace, white sucker, yellow perch

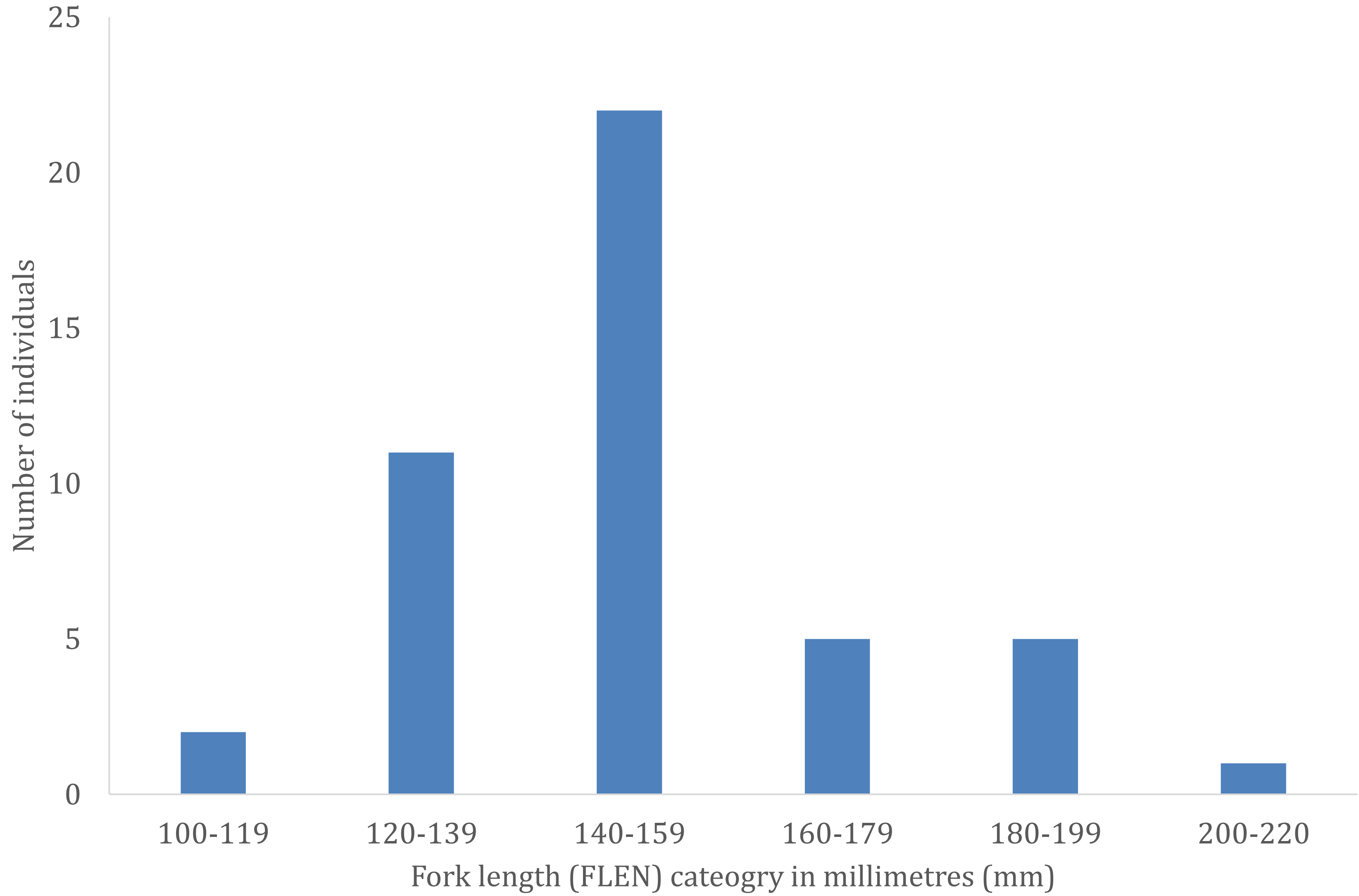



**Figure A1.** Fork length distribution of 46 yellow perch caught in Lake Laurentian using the broad-scale monitoring protocol in 2022.

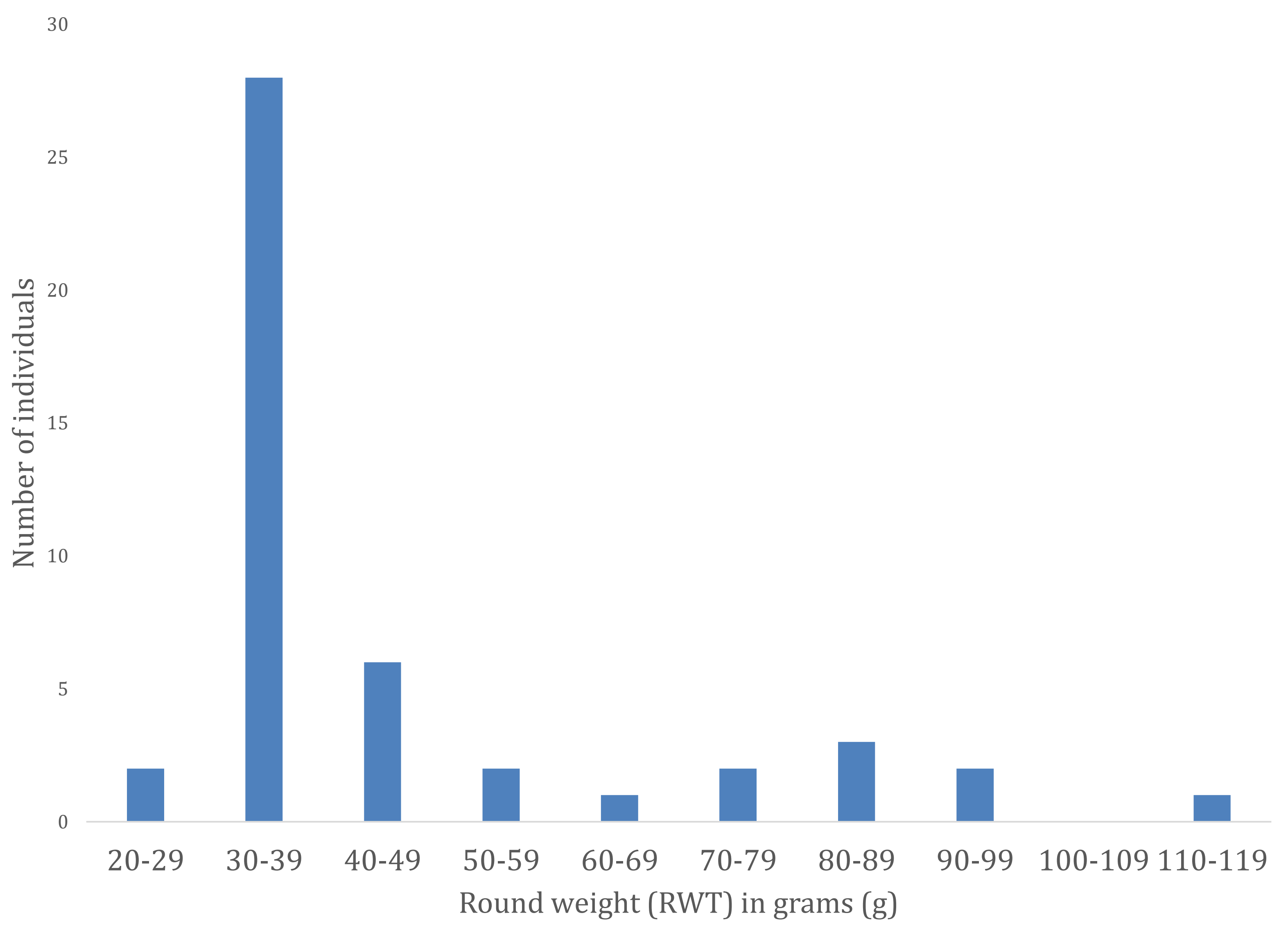



**Figure A2.** Frequency of round weight class (RWT) distribution 46 yellow perch caught in Lake Laurentian using the broad-scale monitoring protocol in 2022.

## Appendix B - Photos taken during field work

#1. Iowa darter (*Etheostoma exile*) caught in minnow trap in Little Laurentian Lake on June 20th, 2023. Image by E.Wright

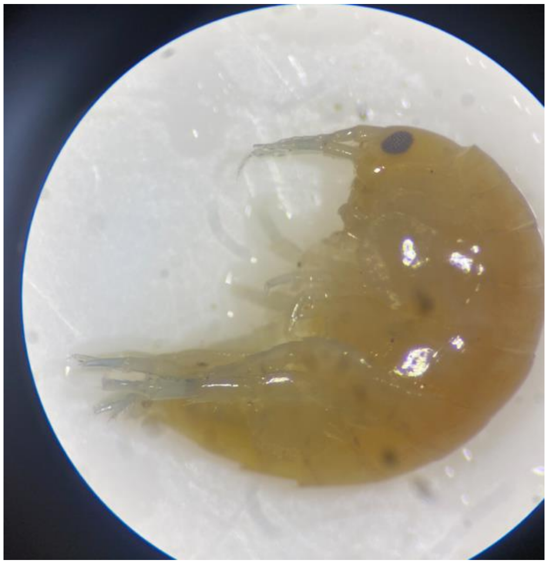
#2. Emerald shiner (*Notropis atherinoides*) caught in D-net in Perch Lake on June 12, 2023. Image by E.Wright

#3. Midland painted turtle (*Chrysemys picta marginata*) caught on Lake Laurentian on June 7th, 2023. Image by E.Wright

#4. Golden shiner (*Notemigonus crysoleucas*) caught in minnow trap in Perch Lake on June 14th, 2023. Image by E.Wright

#5. Northern pike (*Esox lucius*) caught by angling on Lake Laurentian on June 16th, 2023. Image by E.Wright

*#6. Ephemerelliae* collected by flipping rocks on the shore of Lake Laurentian on June 12th, 2023. Image by E.Wright



*#7. Hyalella azteca* collected while netting for amphipods in Lake Laurentian on June 12th, 2023. Image by E.Wright

#8. Collection of *Stenonema* collected on Lake Laurentian on June 12, 2023. Image by E.Wright

#9. Green frog (*Lithobates clamitans*) tadpole incidentally captured on Little Laurentian Lake on June 20th, 2023. Image by E.Wright

#10. Deceased juvenile northern water snake (*Nerodia sipedon sipdeon*) caught in minnow trap on Little Laurentian Lake. Image by E. Wright

#11. Yellow perch (*Perca flavescens*) caught in minnow traps in Perch Lake. Image by E.Wright

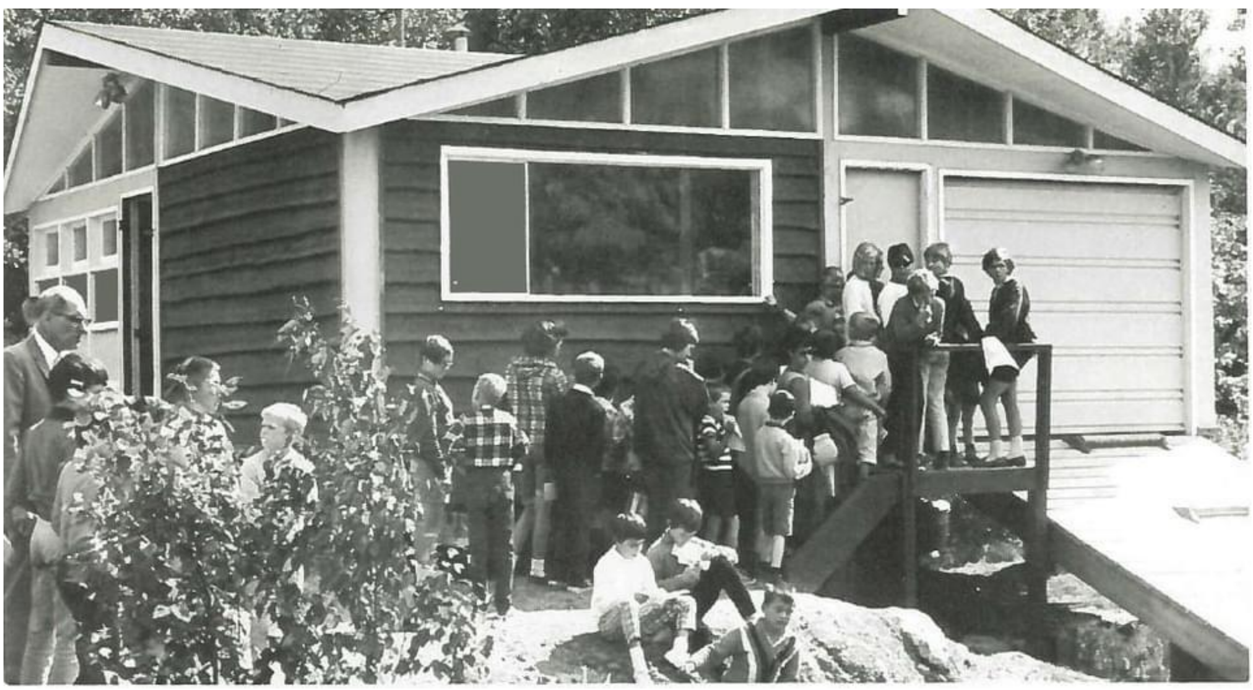
#12. Vertical diving beetle captured in minnow trap in Little Laurentian Lake on June 20th, 2023. Image by E. Wright

#13. Deceased golden shiner found on shore of Lake Laurentian on June 19th, 2023. Image by E.Wright

#14. Aquatic field technician Emma Wright with a northern pike caught by angling in Perch Lake on July 27th, 2023. Image by A.Lepage

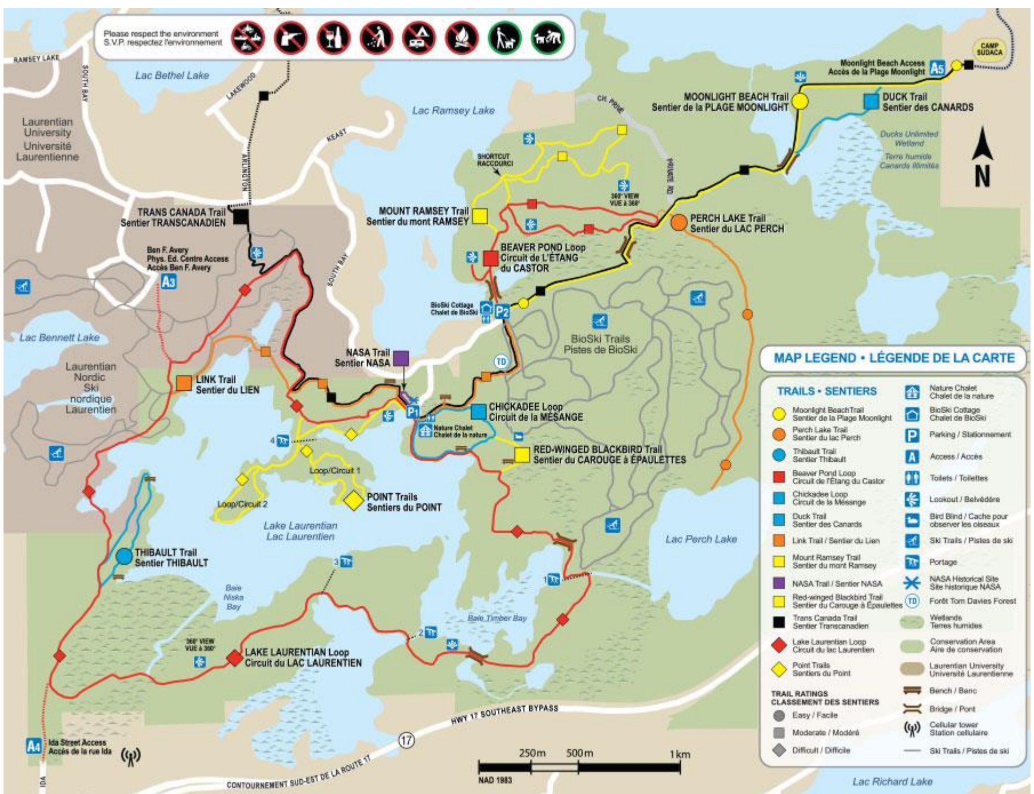
#15. Project biologist Adam Lepage with a northern pike caught by angling in Perch Lake on July 27th, 2023. Image by E.Wright

#16. Beaver dam located between Little Laurentian Lake and Lake Laurentian. Image by A.Lepage



#17. Celebration of the official opening of the Lake Laurentian Conservation Area Nature Centre on August 22, 1967. Image from Conservation Sudbury

#18. Lake Laurentian Conservation Area 1970 (left) and 2023 (right), highlighting the improvements in tree cover on the ridge. Image from Conservation Sudbury




#19. Map of hiking, biking, skiing trails. Image from Conservation Sudbury