An Assessment of the Sources and Magnitudes of Nutrient Inputs Responsible for Degradation of Water Quality in Seven Lakes Located Within the Carleton River Watershed Area of Digby and Yarmouth Counties, Nova Scotia

Prepared for

Nova Scotia Environment

By

M. Brylinsky
Acadia Center for Estuarine Research
Acadia University
Wolfville Nova Scotia

January 2012

SUMMARY

Water quality surveys carried out by Nova Scotia Environment between 2008 and 2010 for a number of lakes located within the Carleton, Meteghan, and Sissaboo River watersheds have shown many of the lakes to be seriously degraded as a result of nutrient overenrichment resulting in the development of extensive algal blooms. In order to better understand the factors responsible for these conditions, a survey to identify the sources and magnitudes of nutrients entering those lakes exhibiting the most serious water quality degradation was carried during June 2011. The lakes surveyed included Nowlans Lake located within the Meteghan watershed, Provost Lake located within the Sissaboo watershed, and Hourglass, Placides, Parr, Ogden and Fanning Lakes all of which are located within the Carleton River watershed.

The results indicate that within the Carleton River watershed, the number and magnitude of nutrient sources is highest within the upper region of the watershed and in close proximity to areas having high concentrations of mink farms. Although in most instances it was not possible to identify specific point source inputs, which would have necessitated travel on private lands, a number of specific areas were noted where high nutrient levels were observed near and downstream of particular properties or areas. In contrast, the lower regions of the Carleton watershed, which has little mink farming activity, had no significant nutrient inputs were identified other than those originating within the upper watershed region.

In the case of Nowlans Lake, the most impacted of all the lakes surveyed, it was possible to identify a number of point sources, all of which are associated with mink farming activities. In contrast, Provost Lake, which has a number of mink farms located nearby, had no surface water inputs and there was little evidence of its water quality being directly impacted by mink farming activities.

Most of the phosphorus was present in the dissolved inorganic form which is not typically found in high concentrations in aquatic ecosystems because of its rapid assimilation by aquatic plants. This suggests that the major source of phosphorus is most likely to be a result of mink farm operations that utilize superphosphate, a substance used to increase the shelf life of mink feed and to reduce the occurrence of kidney stones in mink livestock.

Recommendations are made for further studies to be undertaken with a focus on identifying point sources associated with mink farms located within the region of tributaries having the highest phosphorus levels. Particular attention should be placed on those mink farms that employ superphosphate in their operations.

Table of Contents

List of Figures

List of Tables

Page

An Assessment of the Sources and Magnitudes of Nutrient Inputs Responsible for Degradation of Water Quality in Seven Lakes Located Within the Carleton River Watershed Area of Digby and Yarmouth Counties, Nova Scotia

1. Background

Water quality surveys carried out by the Nova Scotia Environment (NSE) between 2008 and 2010 of ten lakes located in the Carleton, Meteghan, and Sissaboo River watersheds have indicated that water quality is impaired to varying degrees in a number of the lakes surveyed, primarily as a result of high nutrient inputs resulting in the development of high algal concentrations (NSE 2009; 2010; Brylinsky 2010). Of the ten lakes surveyed over the three year period, seven were found to be severely impacted by nutrient over-enrichment in at least one of the three survey years, two were moderately impacted and only one was found not to be impacted in any of the three years. Fig. 1.1 is an overview of the watersheds showing the lakes surveyed.

Those lakes exhibiting the most serious symptoms of nutrient over-enrichment were located within the upper region of the study area and in close proximity to a high concentration of mink farming operations, the activities of which are considered to be the most likely major source of nutrients leading to nutrient over-enrichment of the lakes. As a result, a survey designed to better elucidate the sources of the nutrient inputs to the lakes was carried out during June of 2011. The survey focused on those lakes known from prior water quality surveys to be the most severely degraded and included the following seven lakes: Hourglass, Placides, Parr, Ogden, Fanning, Nowlans and Provost.

2. Approach

The basic approach to identify likely sources of nutrient inputs to each lake was to initially survey by boat the entire shoreline of each lake to identify all potential water inputs to the lake. Particular attention was made to identify shoreline areas exhibiting extensive growth of cattails (*Typha sp*.) or duckweed (*Lemma sp.)* as these species of macrophytes only grow well under conditions of high nutrient concentrations making them excellent indicators of stream inputs or areas of overland run-off having high nutrient levels.

Once identified, each potential nutrient input to the lake was sampled at the point where it entered the lake for phosphorus levels using a field kit. If nutrient levels were found to be high (≥20 µg/L), further sampling was carried out upstream of the input as far as possible by boat or foot until either the source was identified or it became impracticable to travel further upstream. Although this approach clearly indicated the general areas where high nutrients inputs occur, in most cases the exact point source could not be determined because it would have necessitated travel over private property.

The spatial relationship between mink farming operations and sample stations was determined on the basis of the civic addresses of mink farms, provided by the Novas Scotia Department of Agriculture (NSDA), supplemented by Google Earth satellite images and aerial photos of each lake obtained from the Nova Scotia Geomatics Centre.

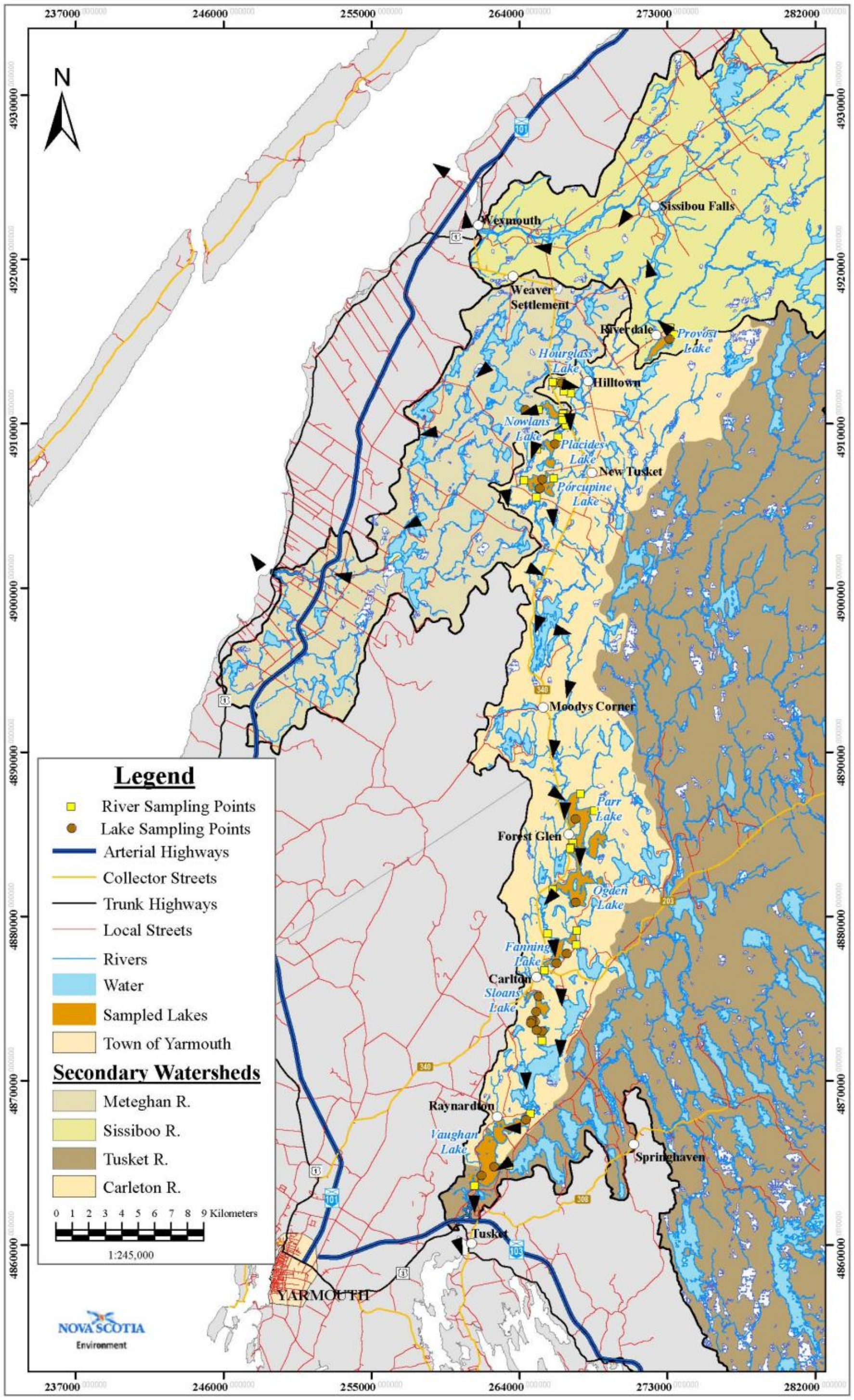

Fig. 1.1 Location of watersheds and lakes surveyed during 2008 to 2010.

3. Methods

Phosphate and total phosphorus nutrient concentrations measured in the field were carried out using a HACH Model DR/2400 field test kit. In addition to nutrient measurements of phosphorus in the field, additional water samples were collected at those sites suspected of having high (≥20 µg/L) levels of phosphorus. These samples were sent to the Environmental Services Laboratory of the QE II Health Science Centre to confirm the high nutrient levels initially identified using the field kit procedure. In addition to phosphate and total phosphorus, these samples were also analyzed for inorganic nitrogen.

When possible, estimates of daily nutrient loading based on measurements of nutrient concentration, current velocity and cross sectional area were also made at each site. Mean current velocities were determined using a Global Flow model FP101 probe. Cross sectional areas were determined based on measurements of water depths at half to one meter intervals across the total width of each site. These measurements were used to construct a diagram of the cross section of each site which was then used to calculate the cross sectional area using an image analysis program.

4. Results

Of the seven lake studied, five are located within the Carleton River watershed. These include Placides, Hourglass, Parr, Ogden and Fanning. The remaining two lakes, Nowlans and Provost, are located within the Meteghan and Sissaboo watersheds, respectively. A summary of the data collected is contained in Appendix I.

4.1 Carleton River Watershed

The upper region of the Carleton River watershed contains an extensive system of lakes and tributaries most of which drain into Placides Lake. The outflow of Placides Lake enters the Wentworth River system which flows into Wentworth Lake. The Carleton River begins as the outflow of Wentworth Lake and passes through Parr, Ogden, and Fanning Lakes.

4.1.1 The Upper Carleton Watershed Region

The upper Carleton River watershed region is a hydrologically complex area containing numerous lakes, streams and wetlands. The lakes and tributaries within this region (Fig.4.1.1.1 and Table 4.1.1.1) were found to have the highest levels of phosphorus within the Carlton watershed, most of which were well above 100 µg/L and in one case exceeded 3,000 µg/L. It also has the highest concentration of mink farms as well as a fish aquaculture operation located along the southwestern shoreline of Hourglass Lake.

The highest total phosphorus level of 3,300 µg/L was measured at Station CMB where Comeaus Mill Brook crosses under Langford Road between Southville and Riverdale. This site was characterized by extensive growths of cattails and duckweeds, particularly along the southwesten side of Langford Road (Fig. 4.1.1.2). Comeaus Mill Brook flows through a wetland area with extensive growth of cattails (Fig. 4.4.4.3) and then into Bill Lake. The outflow of Bill Lake, which passes under Hilltown Road (Station PLAC –H4), had a total phosphorus concentration of 540 µg/L. The much lower total phosphorus concentration relative to Station CMB is likely due to sequestering of phosphorus by the wetland and retention within Bill Lake. The outflow of Bill Lake in turn flows into Simonds Lake. Its outflow (Station PLAC-H3) had a total phosphorus level of 400 µg/L.

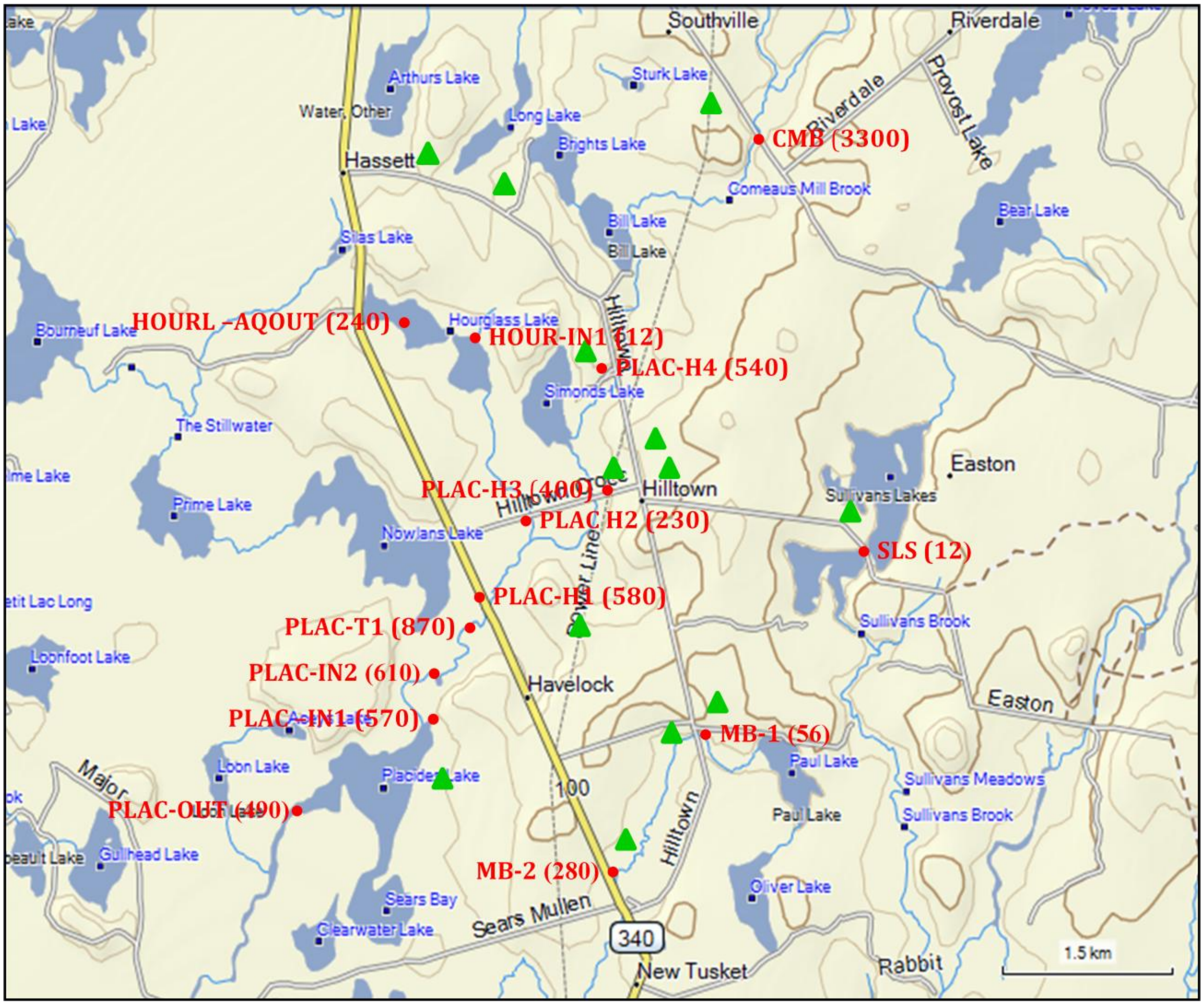

Fig. 4.1.1.1 Location of sample stations (●) and approximate location of mink farms (▲) within the upper Carlton River watershed region (numbers in parenthesis indicate total phosphorus concentration in µg/L).

Table 4.1.1.1 Summary of sample stations and nutrient levels in the upper Carleton River watershed.

Station	Nutrient Concentrations			Site Description
	PO_4 (µg/L)	**TP** (µg/L)	**NOx** (mg/L)	
CMB	3183	3300	1.28	Comeaus Mill Brook culvert flow @ Langford Rd
HOURL-IN1	<10	12	-	Small stream inflow to Hourglass Lake
HOURL-AQOUT	167	240	0.11	Outflow from fish aquaculture operation @ Hourglass Lake
PLAC-H4	481	540	0.40	Outflow from Bill Lake at Hilltown Rd
PLAC-H3	388	400	0.64	Outflow from Simmonds Lake at Hilltown Cross Rd
PLAC-H2	216	230	0.17	Outflow from Hourglass Lake at Hilltown Cross Rd
PLAC-H1	544	580	0.65	Culvert flow at unnamed stream @ Hwy 340
PLAC-T1	698	870	1.25	Overland flow into unnamed stream
PLAC-IN2	575	610	0.67	Unnamed stream flow downstream of overland flow
PLAC-IN1	526	570.	0.69	Inlet flow @ Placides Lake
PLAC-OUT	462	490	0.39	Outflow from Placides Lake
SLS	<5	12	<0.01	Channel between Sullivans Lakes
MB-1	38	56	0.08	Mullen Brook outflow from Paul Lake at Hilltown Rd
MB-2	263	280	1.19	Mullen Brook culvert flow @ Hwy 340

Fig.4.1.1.2. Cattail growth along Langford Road.

Fig.4.1.1.3. Wetland located along west side of Station CMB at Comeaus Mills Brook.

Another nutrient source that eventually enters Placides Lake is the outflow from a land-based smolt aquaculture operation located along the southwestern shoreline of Hourglass Lake (Fig 4.1.1.4). Although a significant outflow could not be measured at the time of the survey, water lying within the outflow channel had a total phosphorus concentration of 240 µg/L. The outflow from Hourglass Lake eventually travels into Placides Lake after it passes under Hilltown Cross Road. The total phosphorus level at this point was 230 µg/L, only slightly lower than the outflow from the aquaculture site. It is unlikely that this level of phosphorus is due entirely to the outflow of the aquaculture operation since it would be expected that some of the phosphorus would be retained within Hourglass Lake. It is more likely that an additional unidentified nutrient input exists within the area between the outflow of Hourglass Lake and Station PLAC-H2.

Fig. 4.1.1.4 Outflow channel of the Hourglass Lake aquaculture facility.

The outflow from Simmonds and Hourglass Lake join each other prior to the stream passing under Hwy 340. At Hwy 340 (Station PLAC-H1) the total phosphorus concentration was 580 µg/L. Below this station total phosphorus levels again increased prior to the stream entering Placides Lake. This increase was due to an area of overland runoff located on the west side of the stream (Station PLAC-T1). This was an area of standing water surrounded by anoxic saturated soils, extensive cattail growth and a strong odour of hydrogen sulphide (Fig. 4.1.1.5). Total phosphorus concentration in the standing water was 870 µg/L.

Fig. 4.1.1.5 Area of overland runoff at Station PLAC-T1

Beyond this point the total phosphorus concentration fell to 610 and 570 µg/L at Stations PLAC-IN2 and PLAC-IN1 respectively, the latter being the input to Placides Lake. There are no other inputs to Placadies Lake. At the output of Placides Lake total phosphorous concentrations fell further to 490 µg//L, a decrease of about 10 percent.

Also located in this region is Mullen Brook, a small stream that originates at Paul Lake and flows into Porcupine Lake. This brook was sampled at two sites, one where it crosses under Hilltown Road and another where it crosses under Hwy 340. Total phosphorus levels were quite low (56 µg/L) at Hilltown Road (Station MB-1), but much higher (280 µg/L) at Hwy 340 (Station MB-2). There are a number of mink farms located in this area.

4.1.2 Wentworth River System

The Wentworth River system begins at the outflow of Placides Lake and extends downstream approximately 14 km where it enters Wentworth Lake. Total phosphorus concentrations were high throughout the River ranging between 320 and 360 µg/L (Fig.4.1.2.1 and Table 4.1.2.1), but lacked any significant variation within the River as it travels downstream indicating that it is unlikely to have any major nutrient inputs, and that it has little ability to sequester the high nutrient load it receives from Placides Lake. Although there are four mink farms located in this area they do not appear to have a significant impact on nutrient levels within the Wentworth River system.

In addition to the Wentworth River, Wentworth Lake has a small stream input at its northern end that originates at Payson Meadow. This brook was sampled at the point where it flows under Cedarwood Lake Road and was found to have a relatively low (18 µg/L) total phosphorus level.

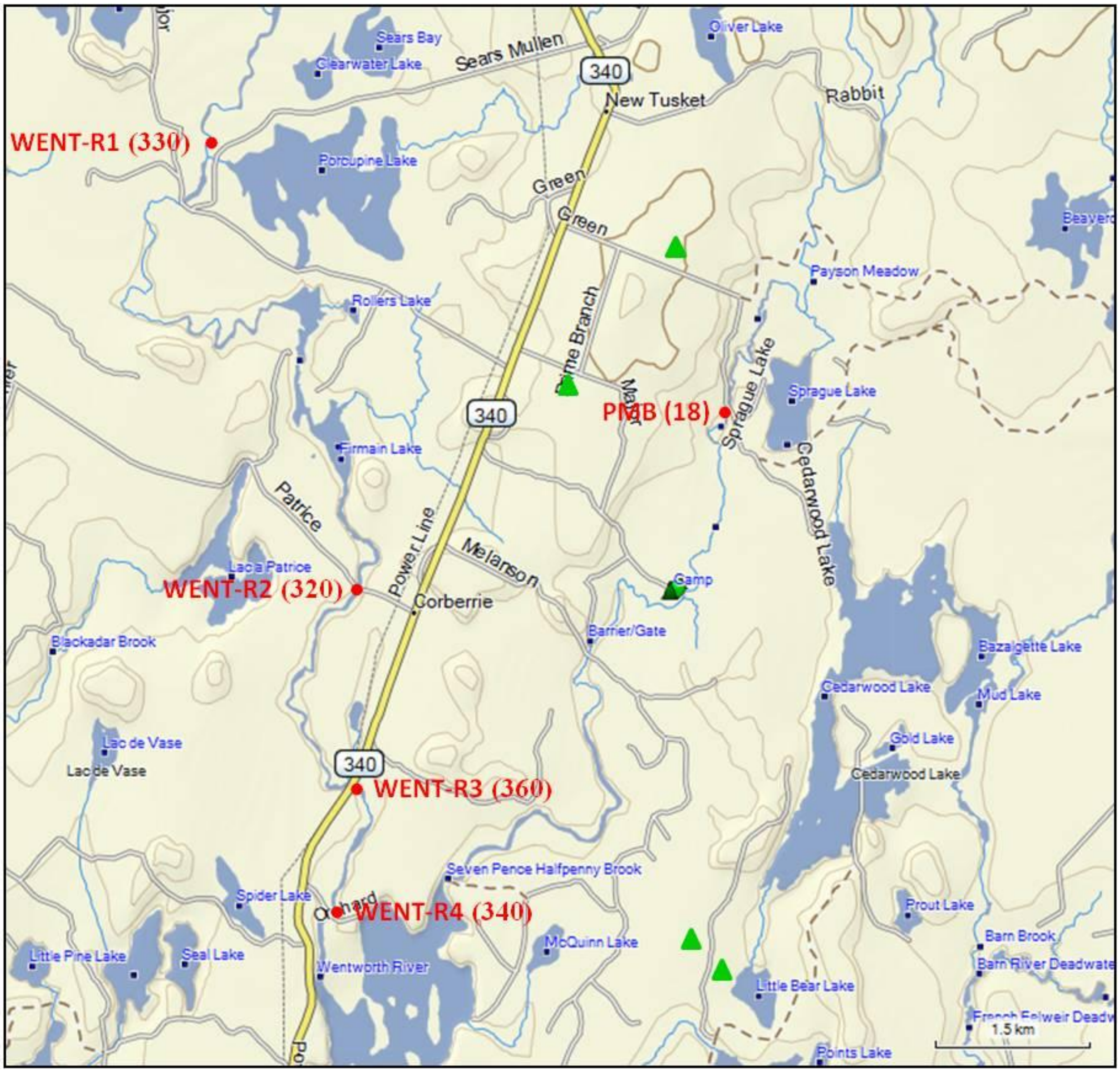

Fig. 4.1.2.1 Location of sample stations (●) and approximate location of mink farms (▲) within the Wentworth River system (numbers in parenthesis indicate total phosphorus concentration in µg/L).

Table 4.1.2.1. Summary of sample stations and nutrient levels in the Wentworth river system

Station	**Nutrient Concentrations**			**Site Description**
	PO_4 (µg/L)	**TP** (µg/L)	**NOx** (mg/L)	
WENT-R1	307	330	0.18	Wentworth River above input from Porcupine Lake
WENT-R2	292	320	0.03	Wentworth River @ Patrice Rd
WENT-R3	312	360	0.06	Wentworth River @ Hwy 340
WENT-R4	304	340	0.06	Wentworth River @ inflow to Wentworth Lake
PMB	5	18	0.01	Payson Meadow Brook culvert flow @ Cedarwood Lake Rd

4.1.3 Upper Carleton River System

The Carleton River system begins at the outflow of Privilege Lake, a small lake that receives the outflow of Wentworth Lake. The total phosphorus concentration at this point (CARLR-1) was 97 µg/L, about four times lower than the total phosphorus concentration at the inlet to Wentworth Lake. This decrease is most likely a result of phosphorus being retained within Wentworth Lake, which is one of the largest lakes in the area. From its origin, the Carleton River travels downstream approximately 11 km where it enters Parr Lake. Unlike the Wentworth River, there is only a small decrease of about 20 percent in total phosphorus by the time it enters Parr Lake (Fig. 4.1.3.1 and Table 4.1.3.1). There are no mink farms in this area and very few tributaries enter this stretch of River.

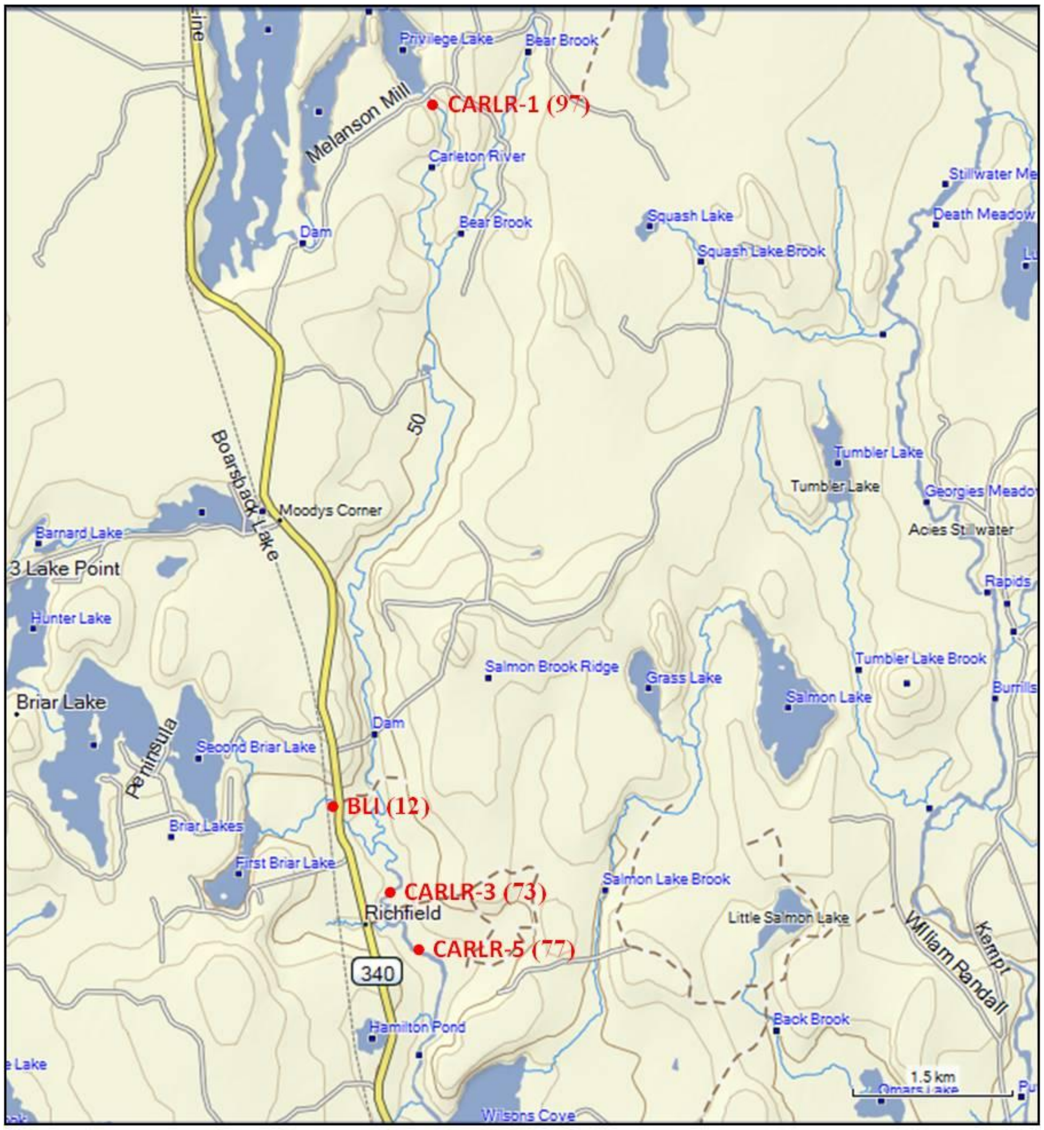

Fig. 4.1.3.1 Location of sample stations (●) within the Upper Carleton River system (numbers in parenthesis indicate total phosphorus concentration in µg/L).

Table 4.1.3.1 Summary of sample stations and nutrient levels in the upper Carleton River system.

Station	Nutrient Concentrations			Site Description
	PO_4 (µg/L)	TP (µg/L)	NOx (mg/L)	
CARLR-1	78	97	0.01	Carleton River at Outlet of Wentworth Lake
BLI	<10	12	-	Inflow to Carleton River form Bear Lake @ Hwy 340
CARLR-3	56	73	0.02	Carleton River above Richfield
CARLR-5	58	77	0.03	Carleton River below Richfield

4.1.4 Parr and Ogden Lake Area

The Carleton River flows into Parr Lake the outlet of which flows through Robichauds Run, a channel connecting Parr to Ogden Lake   Both Parr and Ogden are relatively large lakes. Parr Lake has three inputs, the Carleton River which flows into Parr Lake at Station PARL-IN1 (Fig. 4.1.4.1), and two small streams, Salmon Lake Brook and Tinkhams Mill Brook, both of which were found to have very low total phosphorus levels (Table 4.1.4.1). Ogden Lake, which has no other water inputs other than the input from Parr Lake, exits into the lower Carleton River. Between the inlet of Parr and the outlet of Ogden Lake, the total phosphorus concentration decreased about 50 percent, from 67 to 36 µg/L. This decrease is also likely due to the retention of phosphorus within the lakes, and is indicative of there being no major nutrient inputs to either lake other than that received from the Carleton River.

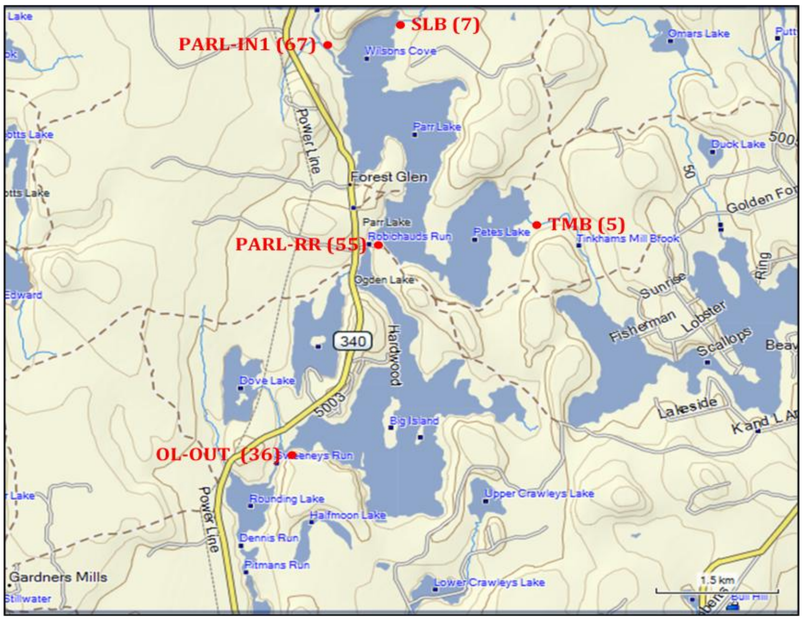

Fig. 4.1.4.1 Location of sample stations (●) within the Parr and Ogden Lake area (numbers in parenthesis indicate total phosphorus concentrations in µg/L).

Table 4.1.4.1 Summary of sample stations and nutrient levels in the Parr and Ogden Lake area.

Station	Nutrient Concentrations			Site Description
	PO_4 (µg/L)	TP (µg/L)	NOx (mg/L)	
PARL-IN1	46	67	0.02	Inflow of Carleton River to Parr Lake
PARL-RR	41	55	0.01	Robichauds Run (channel connecting Parr and Ogden lakes)
OL-OUT	25	36	0.01	Outlet of Ogden Lake to Carleton River
SLB	-	7	-	Outflow from Salmon Lake Brook
TMB	-	5	-	Outflow from Tinkhams Mill Brook

4.1.5 Fanning Lake Area

Fanning Lake receives its major input from the Carleton River. Two smaller inputs are the outflows of Lower Crawleys and Mink Lake, both of which have very low nutrient levels (Fig 4.1.5.1 and Table 4.1.5.1). There are four mink farms located near the lake's western shoreline, but these do not appear to be associated with any tributary flows that may enter the lake. Nutrient levels at the input and output of Fanning Lake are relatively low.

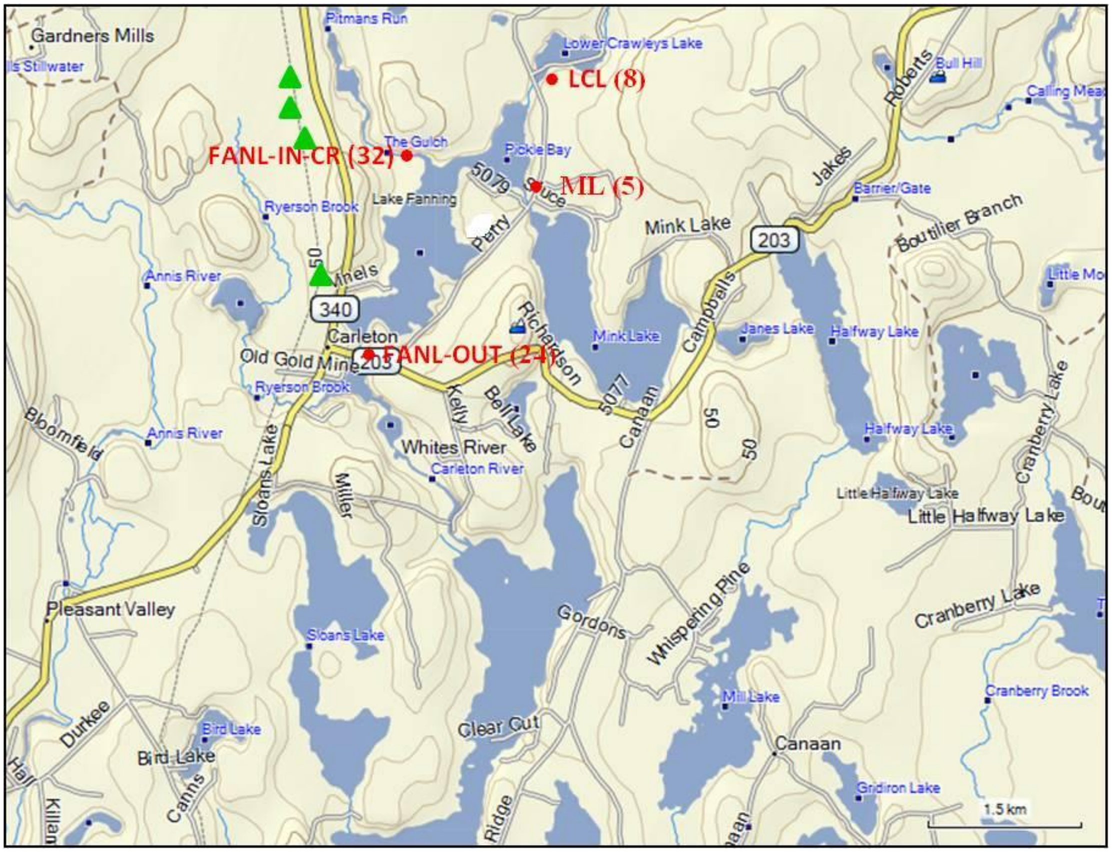

Fig. 4.1.5.1 Location of sample stations (●) and approximate location of mink farms (▲) within the Fanning Lake area (numbers in parenthesis indicate total phosphorus concentrations in µg/L).

Table 4.1.5.1 Summary of sample stations and nutrient levels in the Fanning Lake area

Station	Nutrient Concentrations			Site Description
	PO_4 (µg/L)	**TP** (µg/L)	**NOx** (mg/L)	
FANL-IN-CR	21	32	0.01	Outflow of Carleton River into Fanning Lake
FANL-OUT	24	24	0.01	Outflow of Fanning Lake
LCL	-	8	-	Inflow of Lower Crawleys Lake into Fanning Lake
ML	-	5	-	Inflow of Mink Lake into Fanning Lake

4.1.6 Downstream Nutrient Trends in the Carleton River System

From the preceding description of nutrient levels within the Carleton River watershed it is obvious that there is a dramatic decrease in nutrient levels as the River flows downstream. This decrease is illustrated in Fig. 4.1.6.1 which shows the gradual decrease in both total phosphorus and phosphate at sample stations located within the main stem of the River beginning at Comeaus Mill Brook and ending at the outlet of Fanning Lake. Most of the phosphorus loading to this system originates within the upper region of the watershed in close proximity to the greatest concentration of mink farms. Most of the decrease occurs where the River enters and leaves lakes, the biggest decrease occurring at Wentworth Lake.

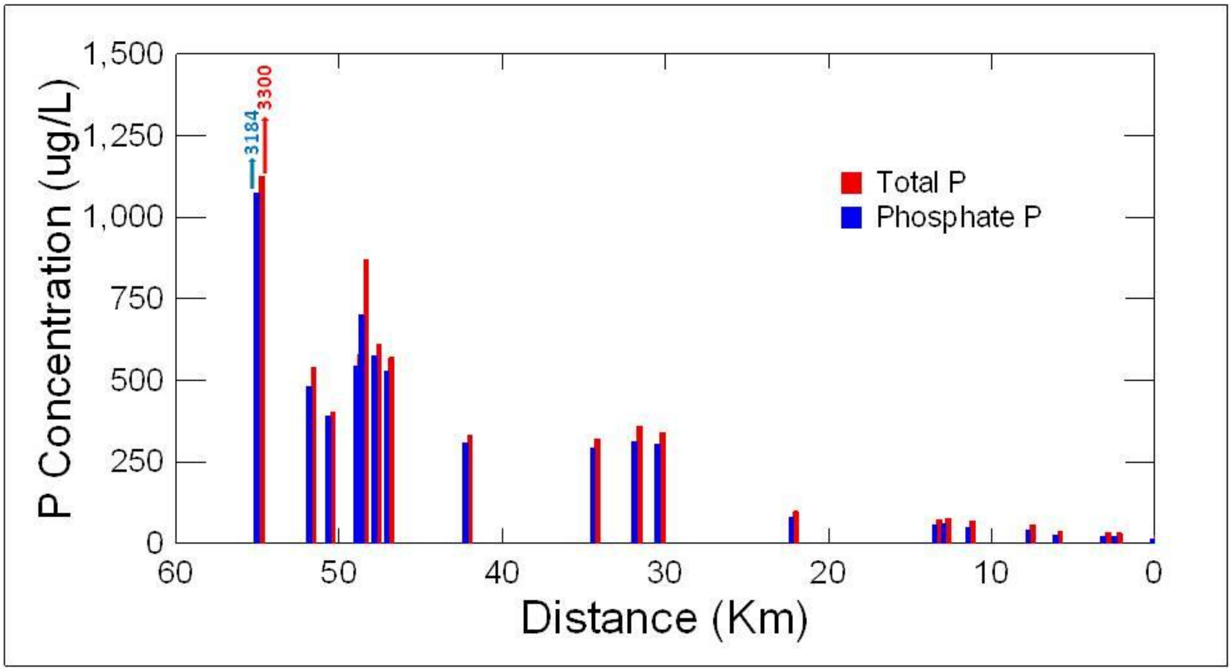

Fig. 4.1.6.1 Variation in total phosphorus and phosphate levels with distance from Fanning Lake.

Also of note is that most of the phosphorus is present in the dissolved as opposed to the particulate form (Fig. 4.1.6.2). This is very unusual since in most natural aquatic ecosystems the level of phosphate is typically present at levels below the limit of analytical detection as a result of its rapid utilization by aquatic plants. The only likely source of dissolved phosphorus input to the Carleton River watershed region is superphosphate[1], a widely utilized chemical among mink farmers that is used to increase the shelf life of mink food as well as reduce the occurrence of kidney stones in mink livestock (Leoschke 1996).

Also obvious is the gradual decrease in phosphate to total phosphorus ratio as water moves downstream, a result of waters low in phosphate entering the River in its lower reaches.

[1] The chemical name for superphosphate is monocalcium phosphate. Its chemical formula is $Ca(H_2PO^4)_2$.

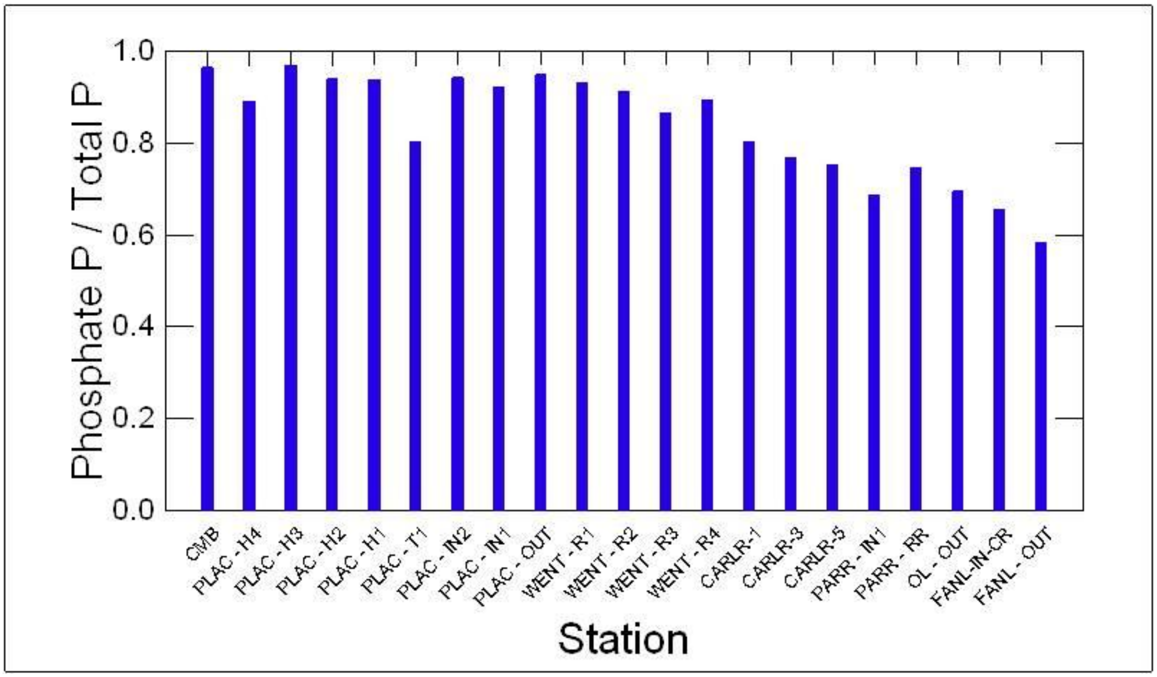

Fig. 4.1.6.2 Ratio of phosphate to total phosphorus for sample stations located within the upper region and main stem of the Carleton River watershed.

Inorganic nitrogen also shows a decreasing trend in concentration from upstream to downstream (Fig. 4.1.6.3). The greater levels within the upper region are most likely a result of the runoff of waste products originating from within mink farms.

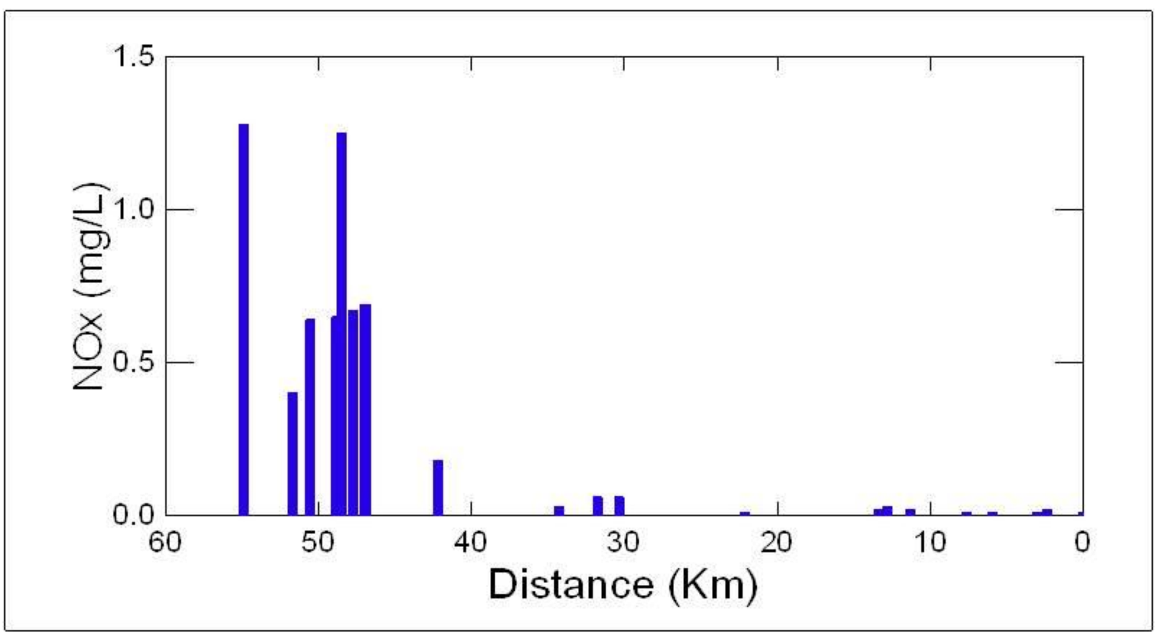

Fig. 4.1.6.3 Variation in inorganic nitrogen levels with distance from Fanning Lake.

4.2 Meteghan River Watershed

Nowlans Lake, a small headwater lake, is the only lake located within the Meteghan River watershed that was evaluated with respect to nutrient inputs. This lake exhibits the most highly degraded water quality of all the lakes surveyed. In addition to six mink farms, a fish meal processing plant is also located within its watershed. Although it is a headwater lake with no well defined stream inputs, flowage from a nearby boggy ravine located along its eastern shoreline enters the lake after flowing through a culvert located under Hwy 340. The ravine is saturated with water and has a heavy growth of cattails indicating that it receives an inflow of high nutrient water. Total phosphorus values measured in this area were among the highest observed during the survey and ranged between 7,100 and 32,000 µg/L (Fig. 4.2.1 and Table 4.2.1). The nutrients appear to originate from a number of mink farms located just north of and above the ravine. At Station NOWL-IN5, a small stream located at the head of the ravine, it was possible to measure a flow rate into the bog of 5,424 L/day and a total phosphorus concentration of 32,000 µg/l which results in a phosphorus loading of 173.5 kg/day. This stream appeared to originate from a mink farm building located approximately 150 metres above this outflow (Fig.4.2.2)

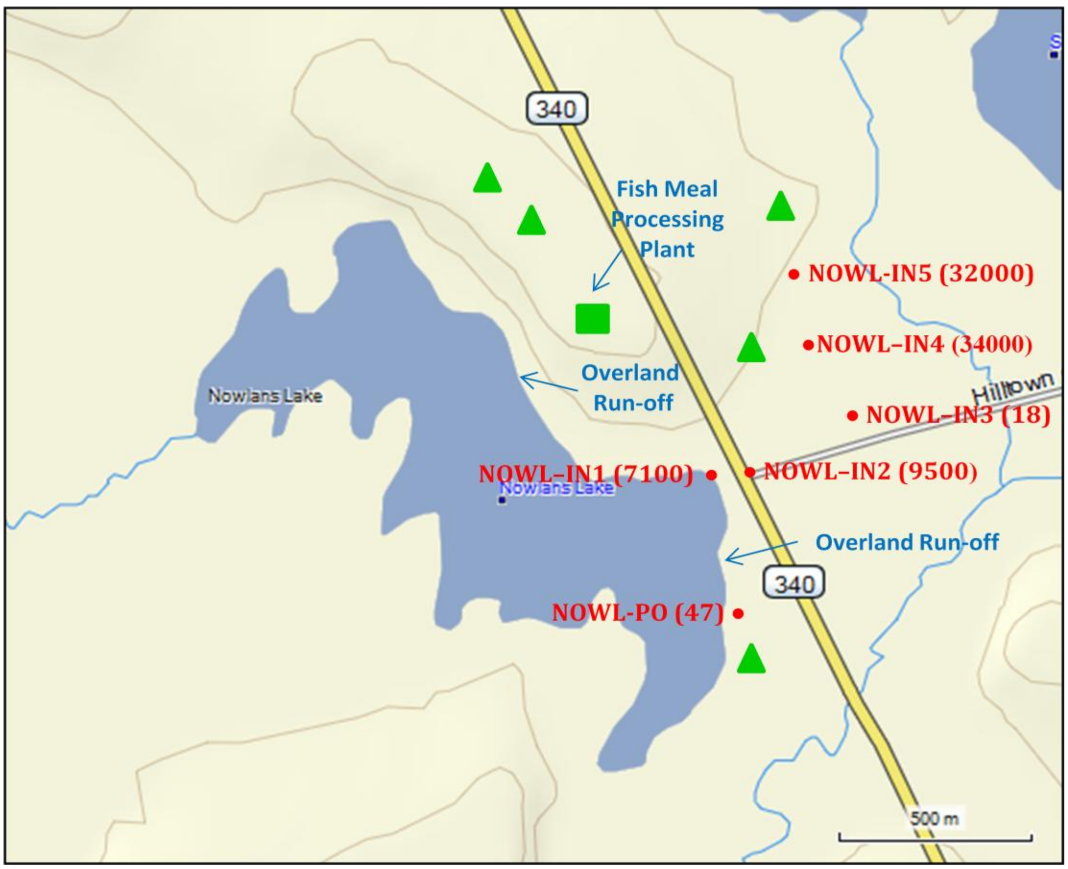

Fig. 4.2.1 Location of sample stations (●) and approximate location of mink farms (▲) within the Nowlans Lake watershed (numbers in parenthesis indicate total phosphorus concentration in µg/L).

Table 4.2.1 Summary of sample stations and nutrient levels in Nowlans Lake watershed.

Station	**Nutrient Concentrations**			**Site Description**
	PO_4 (µg/L)	**TP** (µg/L)	**NOx** (mg/L)	
NOWL-IN1	6790	7100	0.58	Standing water along shoreline of Nowlans lake
NOWL-IN2	9200	9500	0.19	Standing water beneath culvert @ Hwy 340
NOWL-IN3	-	18	-	Sanding water above east side of ravine
NOWL-IN4	34000	34000	1.37	Standing water within ravine
NOWL-IN5	3100	32000	-	Flow from small stream located at top of ravine
NOWL-PO	23	47	3.31	Flow from discharge pipe into Nowlans Lake

Fig. 4.2.2 Mink farm building located above boggy ravine.

There was also an inflow to the lake from a plastic pipe observed at Station NOWL-PO (Fig.4.2.3). This inflow had a flow rate of 13,248 L/day and a total phosphorus concentration of 0.047 µg/l resulting in a phosphorus loading 0.622 kg/day. The discharge of the pipe appeared to originate from a mink farm operation located just above the lake's shoreline.

Fig. 4.2.3 Pipe outflow along the lower eastern shoreline of Nowlans Lake.

Also observed were two areas along the lake's shoreline that appear to be sites where overland flow periodically enters the lake, although at the time of the survey no flow was observed. In both cases extensive cattail growth was observed along the lake's shoreline. One was located along the lower western shoreline just north of where the pipe outflow was located and just below a mink farm building (Fig. 4.2.4). The other was located along the upper eastern shoreline just southwest of the fish meal processing plant (Fig. 4.2.5).

Fig. 4.2.4 Area of overland flow along lower eastern shoreline of Nowlans Lake

Fig. 4.2.5 Area of overland flow along upper eastern shoreline of Nowlans Lake

4.3 Sissaboo River Watershed

Provost Lake, a small headwater lake, was the only lake surveyed within the Sissaboo River watershed. Its water quality is the least impacted of all the lakes surveyed. It has no significant surface water inputs and is most likely spring fed. The total phosphorus concentration at the lake's output was relatively low (Fig. 4.3.1). The only potential nutrient sources to the lake observed during the shoreline survey were a number of cottage properties having extensive lawn areas and the droppings of large numbers of roosting seagulls on the lake's water surface and along its shoreline. The latter may be due to the presence of several mink farms located nearby to the west of the Lake.

Although it has a number of mink farms located within its watershed, these do not appear to have any significant impact on the lake.

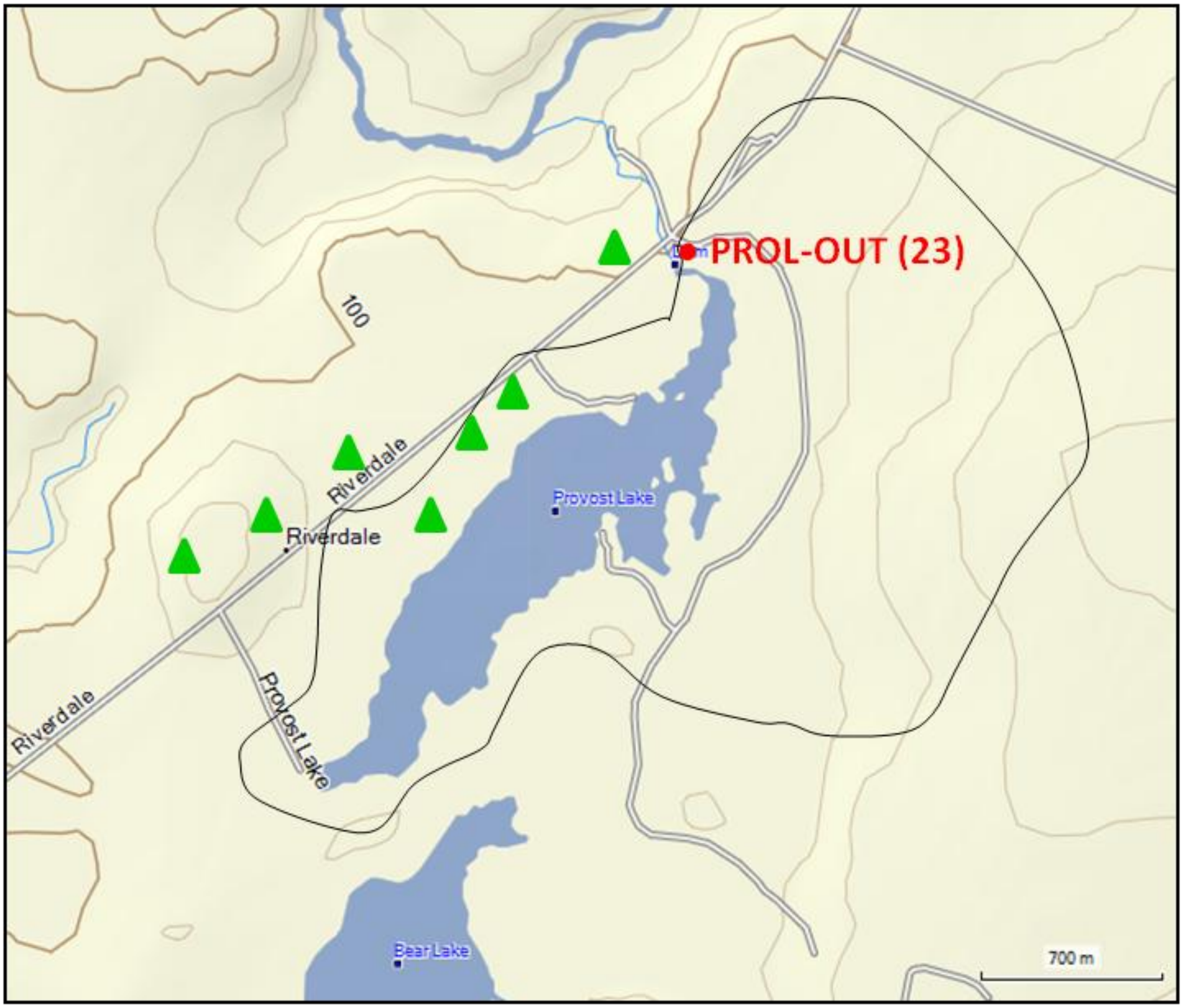

Fig. 4.3.1 Location of sample stations (●) and approximate location of mink farms (▲) within the Provost Lake watershed (numbers in parenthesis indicate total phosphorus concentration in µg/L).

4.4. Phosphorus Loadings

Of the 39 stations sampled, daily phosphorus loading rates were measured at 18. Those stations for which loading rates were not measured had either insufficient flow for a measurement of current velocity to be made, or the site was too deep to traverse and water depth measurements for determination of surface area could not be made.

The highest phosphorus loadings were within the upper region of the Carleton Watershed. Loadings measured below the outlet of Wentworth Lake were much lower.

Table 4.4.1 Summary of total phosphorus loadings.

STATION	TP (µg/L)	Current Velocity (m/sec)	Surface Area (m^2)	Width (m)	Maximum Depth (m)	P Load (Kg/day)
CMB	3300	1.49	2.6	6.0	0.7	1034.4
PLAC-H1	580	1.76	1.1	4.5	0.5	94.0
PLAC-H2	230	0.65	1.1	7.0	0.3	14.0
PLAC-H3	400	0.56	2.1	6.0	0.5	41.4
PLAC-H4	540	0.68	6.7	10.0	1.2	213.2
PLAC-IN1	570	0.1	12.5	10.0	1.5	615.6
PLAC-OUT	490	0.7	8.5	15.0	0.8	25.2
MB-1	56	0.6	1.8	5.0	0.4	5.2
MB-2	280	1.2	1.6	3.5	0.5	46.2
WENT-R1	330	2.0	6.0	10.0	1.0	338.1
PMB	18	3.1	0.2	1.5	0.2	1.1
PARR-IN1	67	0.7	10.0	10.0	1.0	40.5
PARR-RR	55	0.4	27.0	15.0	1.6	1.5
FANL-IN-CR	33	4.4	5.3	20.0	0.4	6.8
ML	5	1.3	2.4	8.5	0.8	1.2
LCL	8	0.7	1.8	5.0	0.6	0.9
NOWL-PO	23	-	-	-	-	0.6
NOWL-IN5	3100	-	-	-	-	173.5

5. Discussion

Although this survey was able to determine the watershed regions where high levels of phosphorus input occur, with few exceptions it has not identified the point sources responsible for these high levels. This proved difficult since most of the sources appear to be either located within the upper reaches of tributaries not accessible by boat and mostly in areas of boggy wetlands that were difficult or unsafe to traverse by foot, or were located on private property and were not accessed due to trespass issues. However, it is clear that the origin of the high phosphorus inputs are closely associated with the area of high mink farm activities. Within the Carleton River watershed this is largely the region around Hilltown and Havelock. Below this region there was little evidence of any significant phosphorus inputs to either the Wentworth or Carleton River or to the lakes surveyed below these rivers. Much of the phosphorus originating within the upper region appears to be entrained within Wentworth Lake, but levels are sufficiently high at its outlet to account for the observed degradation of water quality in Parr, Ogden and Fanning Lakes.

Although it is expected that some of the phosphorus leading to the deterioration of water quality of the lakes is due to runoff associated with cleaning operations and/or the storage of mink manure, the high ratio of phosphate to total phosphorus suggests that the major source of phosphorus is more likely to be due to mink farm operations that utilize superphosphate. If this is the case, it is highly likely that a great reduction in phosphorus loading to the lakes could be accomplished by simply reducing, eliminating or better controlling this practice. It should be noted, however, that the typical remediation methodologies for reducing nutrient inputs to watercourses, such as diverting outflows into natural or constructed wetlands and settling ponds, may not work well if the nutrient concentrations are very high and largely in the dissolved as opposed to the particulate form. Although wetlands are considered to be nutrient sinks, they do have limits with respect to how much they can assimilate and unless quite extensive in area can easily become nutrient saturated under conditions of high nutrient loads. Settling ponds are only effective if the nutrients are in the particulate form and will not significantly reduce nutrient outputs if they are in the dissolved form.

6. Recommendations for Further Study

Prior to this survey, during November 2010, NSE inspectors, with the assistance of Environment Canada and NSDA personnel, carried out inspections of 21 mink farm operations located within the Carleton watershed area to determine potential sources of nutrients that may enter watercourses and lead to the deterioration of water quality that had been documented in the water quality surveys (NSE 2011). An additional 11 sites were also inspected by NSE personnel prior to the November 2011 inspections. Of the 32 sites inspected, 10 were found to have activities that could lead to nutrient runoff into water courses. Further surveys of this type should be carried out focusing on identifying the specific point sources leading to the high phosphorus levels found in this survey. Particular attention should be paid to those mink farm operations known to use superphosphate. It may also prove useful to inspect mink farming operations that appear to have little impact on water quality, such as those located within the watershed of Provost Lake, to determine if there is anything unique about the methodologies they employ which could minimize their potential impact on water quality.

7. References

Brylinsky, M. 2011. Water quality survey of ten lakes in the Carleton River watershed area of Digby and Yarmouth Counties, Nova Scotia. Report prepared for Nova Scotia Department Environment. 78p.

Leoschke, W.L. 1996. Phosphoric acid in modern mink and fox nutrition. Applied Science Reports, Animal Production Review, VIth International Congress of Fur Animal Production. Warsaw. 28:.77-78.

NSE. 2009 A water quality survey of nine lakes in the Carleton River watershed area, Yarmouth County, Nova Scotia. 16p.

NSE. 2010. A water quality survey of ten lakes in the Carleton River watershed area, Yarmouth and Digby Counties, Nova Scotia. 26p.

NSDOE. 2011. 2010 mink farm inspection report: Carleton River watershed. Report prepared by Nova Scotia Environmental Monitoring and Compliance Division, Yarmouth District. 11p.

8. APPENDIX I

Data Summary

Appendix I. Data Summary

Watershed	Station	Date	Location		Cond-uctivity (µSi/cm)	Phosphorus (mg/L)		Nitrogen (mg/L)		TP Loading (Kg/day)
			Easting	Northing		TP	PO4	NOX	NH4	
Carleton	CMB	06/14/11	269670	4913941	129.2	3.300	3.184	1.28	3.79	1034.4
Carleton	HOUR-AQOUT	06/05/11	266191	4912468	103.9	0.240	0.167	0.11	0.21	-
Carleton	HOUR - IN1	06/05/11	266940	4912354	146.2	0.012	<10	-	-	-
Carleton	PLAC - H4	06/12/11	268260	4911962	112.6	0.540	0.481	0.40	0.19	213.2
Carleton	PLAC - H3	06/07/11	267977	4910961	119.9	0.400	0.388	0.64	0.04	41.4
Carleton	PLAC - H2	06/07/11	267419	4910847	120.8	0.230	0.216	0.17	0.02	14.0
Carleton	PLAC - H1	06/07/11	266961	4910007	118.6	0.580	0.544	0.65	0.04	94.0
Carleton	PLAC - T1	06/07/11	266695	4909883	148.3	0.870	0.698	1.25	0.56	-
Carleton	PLAC - IN2	06/07/11	266528	4909564	128.9	0.610	0.575	0.67	0.07	-
Carleton	PLAC - IN1	06/07/11	266280	4909224	126.1	0.570	0.526	0.69	0.07	615.6
Carleton	PLAC - OUT	06/07/11	265001	4908398	115.5	0.490	0.465	0.34	0.09	25.2
Carleton	MB - 1	06/14/11	268907	4908970	71.2	0.056	0.038	0.08	0.06	5.2
Carleton	MB - 2	06/14/11	268150	4907561	92.3	0.280	0.263	1.19	0.63	46.2
Carleton	SLS	06/14/11	270563	4910434	84.5	0.012	0.005	<0.01	0.03	-
Carleton	WENT - R1	06/14/11	263822	4806191	86.5	0.330	0.307	0.18	0.10	338.1
Carleton	WENT - R2	06/12/11	265533	4902416	109.8	0.320	0.292	0.03	0.11	-
Carleton	WENT - R3	06/12/11	265153	4900527	110.8	0.360	0.312	0.06	0.16	-
Carleton	WENT - R4	06/12/11	265153	4899259	109.5	0.340	0.304	0.06	0.18	-
Carleton	BL	06/12/11	265896	4890024	83.2	0.012	0.010	-	-	-
Carleton	PMB	06/14/11	269437	4904005	69.1	0.018	0.005	<0.01	0.03	1.1
Carleton	CARLR-1	06/12/11	266991	4896572	94.8	0.097	0.078	<0.01	0.06	-
Carleton	CARLR-3	06/12/11	266349	4888976	95.7	0.073	0.056	0.02	0.03	-
Carleton	CARLR-5	06/12/11	265707	4878965	94.5	0.077	0.058	0.03	0.04	-
Carleton	PARR - IN1	06/13/11	266565	4887202	96.2	0.067	0.046	0.02	0.05	40.5
Carleton	PARR - RR	06/13/11	267156	4884365	94.5	0.055	0.041	<0.01	0.05	1.5
Carleton	SLB	06/13/11	267669	4887467	87.5	0.007	-	-	-	-
Carleton	TMB	06/13/11	269284	4884671	87.5	0.005	-	-	-	-
Carleton	OL - OUT	06/13/11	267510	4882710	94.2	0.036	0.025	<0.01	0.04	-
Carleton	FANL-IN-CR	06/14/11	266295	4878649	90.5	0.032	0.021	0.02	0.04	6.8
Carleton	FANL - OUT	06/14/11	265551	4876729	91	0.024	0.014	<0.01	0.03	-
Carleton	LCL	06/14/11	267551	4879313	82.8	0.008	0.005	<0.01	0.02	0.9
Carleton	ML	06/14/11	267495	4878194	96.5	0.005	0.005	<0.01	0.02	1.2
Meteghan	NOWL - IN1	06/05/11	266616	4910647	370.5	7.100	6.790	0.58	1.03	-
Meteghan	NOWL - IN2	06/05/11	266682	4910710	352.1	9.500	9.200	0.19	1.70	-
Meteghan	NOWL - IN3	06/05/11	266837	4910772	316.6	0.015	0.010	-	-	-
Meteghan	NOWL - IN4	06/05/11	266690	4910811	480	34.000	34.000	1.37	7.89	-
Meteghan	NOWL-IN5	06/05/11	266831	4911205	510	32.000	30.000	-	-	173.5
Meteghan	NOWL - PO	06/05/11	266595	4910180	220	0.047	0.023	3.31	0.01	0.6
Sissaboo	PROV - OUT	06/06/11	273120	4915214	81.3	0.023	0.005	<0.01	0.03	-