A WATER QUALITY SURVEY

OF

NINE LAKES IN THE CARLETON RIVER WATERSHED AREA

YARMOUTH COUNTY, NOVA SCOTIA

Prepared by

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ABSTRACT

A water quality investigation was undertaken on nine lakes in the vicinity of the Carleton River Watershed in Yarmouth County to address concerns related to recently reported impaired conditions. Turbid, green conditions, including floating or suspended algal masses were reported in Lake Fanning during the summer of 2007. The intent of the current investigation was to provide a snapshot of water quality in the lakes during late summer conditions, assess status compared to existing benchmarks (such as standards or guidelines derived in support of recreational or other water uses), and provide a comparison to other lakes in Nova Scotia. A cursory shoreline survey was also undertaken of each lake to identify any obvious activities that may be impacting lake water quality in the immediate watershed. This investigation could be used to identify additional assessment needs and possible management approaches to improve water quality in the future.

A sampling program was set up to determine chemical water quality at mid lake locations of each of the nine lakes, as well as determining algal abundance, speciation, and toxins concentrations at shoreline areas. Sampling occurred opportunistically by reallocating existing Lake Survey Program resources to focus on these lakes which were of particular concern. Lakes were sampled during the late summer/early fall period to capture the worst case scenario of water quality conditions for the year – since algal populations tend to peak under high temperature and high light conditions.

Results from the current study suggest that water quality in the 9 lakes during the summer varied considerably among lakes, ranging from near pristine to highly impacted. Three lakes (Nowlans, Placides, Hourglass) were very productive, with nutrient, chlorophyll a concentrations, and Secchi disk transparency indicating eutrophic conditions due, at least in part, to nutrient inputs from human activities in one or more of the watersheds. Five lakes (Provost, Porcupine, Parr, Ogden, and Fanning) were moderately productive having mesotrophic conditions. One lake (Vaughan) appeared near pristine with low productivity and oligotrophic conditions.

Water quality generally met Recreational Water Quality Guidelines. However, recreational guidelines were exceeded in one instance (Nowlans Lake) when cyanobacteria cell counts were greater than 100,000. Concurrent samples however, indicated no significant levels of cyanobacteria toxins, with concentrations generally below or near laboratory detection limits. Lake shoreline surveys identified three large nutrient sources which could potentially be stimulating algal production in these lakes. These potential sources were mink farms and a mink food processing facility on Nowlans Lake and an aquaculture operation on Hourglass Lake. Otherwise, shoreline and watershed surveys to identify pollutant sources noted only a few small farms, limited commercial or industrial land use, and clustered residential development. No in-depth assessment of nutrient or pollutant sources from these activities or land uses was undertaken, since this was beyond the scope of the current investigation and available resources.

Recommendations include more in-depth study to determine the most significant nutrient sources, to set priorities for mitigation of sources as appropriate, and to establish a watershed protection planning process with appropriate stakeholders.

ACKNOWLEDGEMENTS

The water quality sampling program was jointly undertaken by Halifax Central Office staff from Nova Scotia Environment (NSE) and Nova Scotia Department of Fisheries and Aquaculture (NSDFA). Yarmouth Regional Office staff and members of Tusket River Environmental Protection Association (TREPA) contributed to lake selection, assessment of watershed influences, and local knowledge within the project area.

Data entry and management was provided by Anthony Heggelin, NSDFA who created an electronic database of water quality information. Cindy Starratt, Charlie Williams, Carmella Robertson and Alan Tattrie (NSE) also contributed significantly to data processing, analysis, mapping, and report production.

Special thanks to Jason LeBlanc and Anthony Heggelin for undertaking both the bulk of the field efforts and data processing and mapping efforts without whose help this study would not have been possible.

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We appreciate the efforts of all who were involved and in any way contributed to this endeavour.

BACKGROUND & INTRODUCTION

During the period of August to October of 2008 a water quality monitoring program was undertaken on the selected lakes of concern in, or adjoining, the Carleton River watershed. This program was initiated in response to recent concerns brought forward by local residents relating to perceived impaired water quality. Background information leading to this initiative is outlined in the following text.

In the summer of 2007 turbid, green water conditions, including algal masses were reported in Lake Fanning. This resulted in follow up water quality sampling, which identified a cyanobacteria (blue green algae) bloom, and subsequent temporary posting of the lake as unsafe for recreational use and as a drinking water supply for a YMCA camp located on its shoreline. The following year similar conditions existed and additional lakes in the area were also reported as having turbid, green waters with surface scums – indicative of algal blooms. Local community groups had suggested that mink farms in the area might be impacting lakes in the area and the cause of such blooms. NSE Regional staff investigated to determine if any point source discharges were present and possibly impacting these lakes. The provincial Department of Agriculture is assessing farm practices on area farms to ensure best practices are used and water resources in the area are not impacted. The agricultural assessment is ongoing and separate from this investigation.

The purpose of the current study was to determine the status of water quality in the lakes of concern, particularly in terms of nutrient concentrations and trophic status, and to assess trends relative to any baseline water quality previously established. Additionally, the status of algal populations was estimated base on cyanobacteria abundance, speciation, and toxin concentrations at shoreline areas. Water quality was compared to existing benchmarks including OECD trophic categories, historic water quality, and Health Canada Guidelines for Canadian Recreational Water Quality.

This study was not intended to be a comprehensive water quality assessment, but rather to provide an indication of current lake water quality and algal populations, and a comparison to water quality conditions measured in previous studies. This information could serve as the basis for subsequent discussions about actions or management which could be implemented to improve water quality in these watersheds.

STUDY AREA

The Carleton River watershed is located in south-western Nova Scotia, lying northeast of Yarmouth and is tributary to the Tusket River. The Carleton River is in the Southern Upland region of the province, draining approximately 200 km^2 of watershed, and contains nearly 100 lakes, 7 of which are included in the survey. These lakes, listed in drainage order, are as follows; 1) Hourglass (a headwater lake), 2)Placides, 3)Porcupine, 4)Parr, 5)Ogden, 6)Fanning and Vaughan. Two additional lakes from neighbouring watersheds are also included: 1) Nowlans Lake, a headwater lake in the Meteghan River system, and 2) Provost Lake a headwater lake in the Sissaboo River system. The study area, including the three major watersheds and lakes of concern are shown on Figure 1A,

Appendix A. Land use in these watersheds is mixed, consisting largely of forested land, limited agricultural use, and generally sparsely populated rural residential land use. Wetlands are interspersed throughout the area, imparting colour to adjoining surface waters through dissolved organic substances. This area of Nova Scotia is exposed to acidifying emissions from the northeastern US and eastern Canada, and subsequently 'acid rain' conditions. This situation, in conjunction with poorly buffered soils, results in acidified surface waters with low pH values.

METHODS

During August-October of 2008, a sampling program was undertaken in the study area lakes whereby physical and chemical characteristics of water quality were investigated, primarily to determine nutrient levels and associated trophic state[1]. On one or two occasions per lake, sampling was performed to determine late summer water chemistry and algal population status. Water temperature and dissolved oxygen profiles were determined in the field using a model 57 YSI meter while transparency or clarity was determined using a standard 20 cm Secchi disk. Water samples were taken at both a shoreline location and at a mid-lake location (generally at the deepest spot on the lake). These samples were collected at the lake surface (i.e. 0.5 meter depth) and at depth using a 2 litre Van Dorn type water sampler and placed in new clean 500 ml polyethylene bottles and further rinsed with lake water. Shoreline samples were expected to reflect conditions where recreational water use might occur – and followed standard protocols to assess blue green algae (cyanobacteria) in swimming areas (Recreational Water Quality Guidelines – Health Canada 2007 (in press)}. Mid-lake samples were expected to reflect overall lake condition and were used for comparison to generally accepted OECD trophic state indicators and any historic water quality data. Procedures followed standard protocols derived for the Nova Scotia Lake Survey Program and standard approaches for characterizing lakes in northern temperate climates.

Sampling methods for assessing lake condition followed standard protocols established for the NS Lake Survey program administered by NSE and NSDOFA, and Health Canada's Recreational Water Quality Guidelines in order to provide consistent results for comparison purposes.

Sampling stations are shown on outline or bathymetric maps for each lake as presented on Figures 2 to 10, Appendix A.

Nutrient and chlorophyll a concentrations were determined in samples taken at a depth of 0.5 m below the surface (hereafter referred to as surface samples) at all lake stations. In addition, a sample was collected at a mid-depth (thermocline) and at 1 m above the bottom (hereafter referred to as bottom samples) to assess any water quality differences over depth. Secchi disk transparency was also determined at mid lake stations for each of the study lakes. Metal and major ion concentrations were also determined from all samples taken at mid-lake stations in the study lakes.

[1]Trophic state refers to the level of biological productivity in a waterbody.

Cyanobacteria samples were collected at shoreline locations on all lakes and at mid-lake locations on selected lakes to determine algal population density, speciation, and cell counts, and to assess spatial variation.

All samples were kept cool and in the dark prior to lab analysis. Subsequently, samples were shipped to the lab such that analysis was performed within 24 hours of collection, as per APHA standard protocols.

Chemical analysis was performed at the Environmental Chemistry Laboratory of the Queen Elizabeth II Health Science Center (QE II) where analytical procedures were undertaken in accordance with established protocols outlined in "Standard Methods for the Examination of Water and Waste Water" (APHA Latest Edition). Algal analysis was performed at ALS Laboratory in Winnipeg, where analytical procedures were undertaken in accordance with established protocols such that comparison with Health Canada's Guidelines for Canadian Recreational Water Quality was possible.

Cursory shoreline and watershed surveys were undertaken to identify large pollutant sources and activities which may impact lake water quality. This investigation was performed by boat on the lakes, on foot in suspect areas, and from road vehicle in more remote areas of the watershed. Visual observations were noted in field reports.

RESULTS AND DISCUSSION

The chemical water quality characteristics or parameters which were measured during this study can be divided into three broad categories. These include parameters necessary to determine trophic state (i.e. nutrients, chlorophyll, transparency), major ions and metals. Trophic state was given primary consideration due to the nature of the expressed concerns as well as potential impacts from local land uses. Major ions and metals were included in order to provide quality assurance of the data set, to fully characterize water quality, and to facilitate further assessment if required. Chemical data are presented in Table 2, in Appendix C.

Physical characteristics, as outlined in the previous section, were investigated in terms of water temperature and dissolved oxygen profiles for all mid-lake stations. Physical data are presented in Table 3, in Appendix C.

Limited historic water quality data existed for several study lakes. These data were used for comparison of water quality changes over time and are presented in Table 4, Appendix C.

The biological water quality parameters measured during this study were related to algal populations and primary production in the lake. Blue green algae (cyanobacteria) populations were identified in terms of genus and /or species for major groups in the lake at time of sampling, and were quantified both in general terms (small / medium/ large amount) and numerically (cell count / ml of sample). Blue green algae toxin levels were also measured in terms of concentrations of Microcystin LR in collected samples. Algal data are presented in Table 5 in Appendix D.

Lake shoreline surveys identified only three potentially large nutrient sources which could be stimulating algal production in these lakes. These potential sources were mink farms and a mink food processing facility on Nowlans Lake and an aquaculture operation on Hourglass Lake. Otherwise, shoreline and watershed surveys to identify pollutant sources noted only a few small farms, limited commercial or industrial land use, and clustered residential development. No in-depth assessment of nutrient or pollutant sources from these activities or land uses was undertaken, since this was beyond the scope of the current investigation and available resources.

Results from each of the main areas of investigation (trophic state, temperature and dissolved oxygen, blue green algae, major ions and metals, and shoreline survey) are discussed below.

LAKE CONDITIONS

Trophic State

Trophic state refers to the level of biological productivity within a lake gauged over a range of very unproductive (oligotrophic) conditions to very productive (eutrophic) conditions. Conditions midway between these two extremes are termed mesotrophic. A progression from very unproductive to very productive conditions typifies the natural lake aging process and is termed eutrophication. This process, which involves the lake basin gradually infilling with silt and organic matter, takes thousands of years to complete and eventually causes the lake to evolve back to dry land. Manmade influences that contribute additional nutrients, organic matter and sediment to a lake can greatly accelerate this process and cause the lake to infill at a much faster rate. This accelerated process is termed cultural eutrophication.

Three key indicators of trophic state have been established. They are generally recognized as being chlorophyll a, nutrient concentrations (typically total phosphorus or nitrogen), and transparency as determined by a Secchi disk.

Chlorophyll a concentration has been shown to correlate well with levels of algal biomass (Nicholls and Dillon 1978). Additionally, strong correlations between chlorophyll a, total nutrient concentration and transparency have been shown, based on mean annual or mean ice-free season concentrations (Dillon and Rigler 1974, Vollenweider and Kerekes 1980, Clark and Hutchison 1992).

Total nutrient concentrations represent the chemical response of a lake to eutrophication while chlorophyll a concentrations represent the biological response, and transparency represents the physical response. Together these water quality parameters provide an excellent indication of trophic state when monitored over a full growing season and taken in the context of the lake as a whole.

However, due to both time and resource constraints mean annual or ice-free season concentrations could not be determined for this study. As a surrogate, nutrient, chlorophyll, and transparency values were determined during the end of summer period when associated peak water temperatures for the year are expected. This period was chosen to represent the "worst case scenario" situation, where algal production and chlorophyll concentrations should be at peak values for the year.

These water quality parameters are addressed in the following text - where 2008 data and historic water quality are compared to established values for trophic state categories (OECD 1982) as shown in Table 2 below and as presented in Figures 10, 11, and 12, Appendix B.

Table 1

PROPOSED BOUNDARY VALUES FOR TROPHIC CATEGORIES (OECD 1982)
(fixed boundary system)

Trophic Category	**(P)**	**(chl)**	**(max chl)**	**(Sec)**	**(min sec)**
	mg/m^3 (ug/l) *			**Meters**	
Ultra-oligotrophic	**< 4.0**	**<1.0**	**<2.5**	**>12.0**	**>6.0**
Oligotrophic	**<10.0**	**<2.5**	**<8.0**	**>6.0**	**>3.0**
Mesotrophic	**10 - 35**	**2.5 - 8**	**8 - 25**	**6 - 3**	**3 - 1.5**
Eutrophic	**35 -100**	**8 - 25**	**25 - 75**	**3 - 1.5**	**1.5 - 0.7**
Hypertrophic	**>100**	**>25**	**>75**	**<1.5**	**<0.7**

(P) annual mean in-lake total phosphorus concentration
(chl) annual mean chlorophyll a concentration
(max chl) annual maximum chlorophyll a
(sec) annual mean Secchi disk transparency
(min sec) annual minimum Secchi disk transparency
* Note: mg/m^3 and ug/l are equivalent units = parts per billion

Nutrients

Nutrients investigated in this study include two forms of phosphorus – ortho phosphorus and total phosphorus (Total P), and three species of nitrogen - nitrate + nitrite, ammonia, and total nitrogen (Total N). Results for these parameters are found in Table 2, Appendix C.

Total nutrient concentrations (i.e. both organic and inorganic species, as in Total P and Total N) are considered to be the best chemical indicators of trophic state (OECD 1982, Clark & Hutchison 1992) and therefore, are of primary interest to this investigation. Ratios of Total N to Total P concentrations can be used to determine which nutrient is in shortest supply and therefore is the limiting nutrient for plant growth in any given lake. It has been shown that if the Total N/Total P ratio is greater than 17:1 phosphorus is limiting; less than 17:1 nitrogen is limiting (OECD 1982). In the study area lakes, 4 lakes appear to be nitrogen limited (Nowlans, Hourglass, Placides, and Parr) and phosphorus appears limiting in the remaining 5 lakes (Provost, Porcupine, Ogden, Fanning, and Vaughan). Calculated ratios are shown in Table 2.

Phosphorus is generally in shortest supply in natural lakes, and therefore is typically the limiting nutrient controlling biological production. Low TN to TP ratios in some study lakes suggest significant inputs of phosphorus to these lake systems.

Total P concentrations during the 2008 sampling period for all sample locations ranged from a minimum of 5 ug/l at the surface of the mid-lake station of Vaughan Lake on September 5th to a maximum of 5200 ug/l at a depth of 7 meters at the mid-lake station of Placides Lake on August 14th.

Total P concentrations from samples taken at mid-lake stations of study lakes ranged from 5 ug/l at Vaughans Lake to 740 ug/l at Placides Lake. Nutrient levels in the 9 lakes during the summer of 2008 varied considerably among lakes, ranging from near pristine to highly impacted. Three lakes (Nowlans, Placides, Hourglass) were very productive, with nutrient, concentrations indicating eutrophic or hyper-eutrophic conditions. Five lakes (Provost, Ogden, Parr, Porcupine, and Fanning) were moderately productive having mesotrophic conditions. One lake (Vaughan) appeared near pristine with low productivity and oligotrophic conditions. These results are shown in Figure 10A, Appendix B. Placides Lake Total P values were exceptionally high – nearly twice the value found in Nowlans Lake (400 ug/l) – suggesting a likely significant nutrient source in the immediate watershed.

Total P concentrations from samples taken at mid-lake stations of study lakes during the summer of 2008 are compared to those taken in previous surveys as well as established trophic categories, and are presented in Figure 10B, Appendix B.

The Total P values shown in Figure 10B indicate that study area lakes nutrient values have changed greatly in some lakes and very little in others. The apparent trend is increasing Total P concentrations in all lakes which had historic data. Two lakes (Nowlans and Hourglass) had significant increases in Total P levels, showing increases from 6 to 400 ug/l and from 12 to 69 ug/l respectively.

Nowlans lake was observed to be turbid green during all visits during the sampling period. A mink farm was observed near the lake and up-gradient in the watershed. Diffuse overland runoff from the site was observed and was assessed as a potential nutrient source. Samples were taken at three shoreline locations on Nowlans Lake on August 28th. One sample was taken at a boat launch (SL1), one near the diffuse flow from the farm (SL2), and one down wind of the farm (SL3), as indicated in Figure 2, Appendix A. Total P at these locations were 350, 340, and 460 ug/l at the three sites respectively, and are presented in Table 2 and Figure 10 C. These results indicate very high concentrations of Total P with the highest value located in the lake location down wind of the suspect nutrient source.

Chlorophyll

Primary productivity can be defined for the purpose of this study as being the extent of microscopic plant life or algal production in the water column as a result of available nutrients. The most commonly accepted indicator to quantify this primary productivity or algal biomass is obtained by measuring the chlorophyll a concentration in representative water samples. Chlorophyll a concentrations have been shown to correlate extremely well with algal biomass (Nicholls and Dillon 1978). Therefore, an increase in Chlorophyll a concentrations indicate an associated and proportional increase in algal biomass or density.

As in the case of nutrients, algal population growth can vary significantly, over time and space. Therefore, the sampling protocol was designed to address this natural variability as much as possible.

Chlorophyll concentrations recorded at the mid-lake stations are most representative of a lake as a whole and are presented in Figure 11A. Chlorophyll values ranged from 3.9 ug/l in Vaughan Lake on September 5th to 67 ug/l in Nowlans Lake on August 14th. When compared with the OECD eutrophication tables (Table 2), current chlorophyll values indicate that study area lakes fall into a range of trophic categories from a very unproductive, oligotrophic state to the very productive hyper-eutrophic state. Headwater lakes higher in the watershed tended to be more productive (Nowlans – eutrophic) (Provost, Hourglass, and Placides – mid mesotrophic) with other lakes progressively less productive as they flowed downstream to oligotrophic Vaughan Lake at the bottom of the watershed, as indicated in Figure11A.

No chlorophyll data is available from previous surveys. Therefore no comparisons were possible.

Shoreline samples were also analysed for chlorophyll to assess spatial differences within each lake. Chlorophyll values were roughly comparable between mid-lake and shoreline sampling locations, as indicated in Table 2. Chlorophyll concentrations ranged from a minimum of 1.9 ug/l at the shoreline station of Porcupine Lake on August 28th to a maximum of 84 ug/l at the shoreline station of Nowlans Lake on October 15th.

Three shoreline samples were taken on Nowlans Lake to assess chlorophyll concentrations in varying proximity to a potential nutrient source (farm runoff). Results indicate that chlorophyll concentrations progressively increased from shoreline station #1 at the north end of the lake (boat launch), to station #2 (nearest the farm), and further increasing to station #3 at the southern end of the lake (down wind from farm), as indicated in Figure 11B, confirming the Total P results.

Transparency

Transparency, as determined by a Secchi disk depth, is considered a good indicator of productivity and trophic state when suspended sediment and highly coloured waters are not present to bias results (OECD 1982). During this study, mid-lake surface samples, which are representative of overall lake conditions, exhibited a range of colour values from 16 True Colour Units (TCU) in Nowlans Lake to 68 TCU in Placides Lake, both on August 14th , with an overall mean for all lakes of 40 TCU. These colour values are not considered high and are about average for Nova Scotia lakes which are usually less than 45 TCU (see following section on Colour page 8). Secchi measurements were not taken during or immediately following any major rain event. At least 24 hours following any significant rain event was used as a requirement of any given sampling date. Given these conditions, Secchi depth transparency is considered to be an appropriate indicator of algal production and therefore trophic state.

Secchi depths ranged from a minimum of 0.85 meters at the mid-lake stations of Nowlans Lake on August 14th to a maximum of 3.0 meters on Vaughan Lake on September 5th. The Secchi disk values reported appear to be directly related to chlorophyll concentrations at the respective sampling locations. Transparency values recorded at mid-lake stations of all lakes are presented in Figure 12A and compared to OECD trophic categories. When compared with the OECD eutrophication tables (Table 1), current transparency values indicate that study area lakes falls into a range of trophic categories from a very unproductive oligotrophic state (Vaughan and Porcupine lakes) to the very productive eutrophic state (Nowlans Lake, Hourglass, and Placides lakes) (see Figure 12 A, Appendix B.

Figure 12B presents transparency as a time series from the mid 1980s to 2008 for 6 study lakes. Generally, the transparency data indicate that 2008 values were significantly lower than values from the 1980s. There appeared to be a generally increasing trend in lake transparency relative to the position in the watershed, That is, transparency increased in the series of lakes as one progressed downstream in the watershed.

In summary, the primary indicators of trophic state, chlorophyll a, total phosphorus, and transparency suggest that study area lakes ranged from very unproductive oligotrophic conditions to very productive hyper-eutrophic conditions during this study. The majority of lakes were relatively unproductive and nutrient poor with low algal growth, and associated high transparency. Several lakes were nutrient rich, and biologically very productive with respect to algal growth, with associated low transparency due to the significant algal populations present.

Nowlans Lake had the lowest transparency of all lakes in the study. This is consistent with the other trophic state indicators – having highest chlorophyll and second highest Total P in the study lakes.

Temperature:

Temperature profiles were recorded for the entire water column on each lake at a mid-lake station. From this data it was determined whether thermal stratification existed at that time. This information, in association with dissolved oxygen concentrations, was primarily used to interpret analytical results.

All lakes stratified to some degree with exception of the two shallowest lakes (Provost and Parr) which were isothermal (approximately 21 degrees C top to bottom). The remaining and deeper lakes were observed to be thermally stratified during the sampling period.

Dissolved Oxygen:

Dissolved oxygen profiles were recorded concurrently with water temperature at all mid-lake stations. As indicated above, dissolved oxygen concentrations were primarily used in interpreting analytical results but were additionally used to determine probability of nutrient reintroduction from bottom sediments.

Minimum concentrations of dissolved oxygen were recorded as approximately 0.5 mg/l at the bottom of the mid-lake station on Vaughan and Ogden lakes on September 5th and August 15th , respectively. These were the deepest lakes studied with 15 meter (Vaughan) and 18 meter (Ogden) depths.

In summary, temperature and dissolved oxygen profiles indicated significant thermal stratification in all but the shallowest lakes during the late summer of 2008. Dissolved oxygen concentrations approached 0 mg/l in bottom waters of deeper lakes. Therefore, the reintroduction of nutrients from the bottom sediments as a result of hypolimnetic oxygen depletions is likely to occur in those deeper lakes.

Blue Green Algae (Cyanobacteria):

Blue green algae concentrations ranged from 48 cells /ml in Vaughan Lake on August 27th to 104,000 cells /ml in Nowlans Lake on August 28th. All lakes had low levels of blue green algae with the exception of Nowlans Lake. The next highest concentration was found in Fanning Lake with 5160 cells /ml on October 15th. Results for all lakes are presented in Table 5, Appendix D and Figure 13 A, Appendix B.

Water quality met Recreational Water Quality Guidelines on all lakes and on all sampling dates except one. Recreational guidelines were exceeded in one instance (Nowlans Lake) when cyanobacteria cell counts were greater than 100,000 / ml on August 28th. Concurrent samples however, indicated no significant levels of cyanobacteria toxins, with concentrations generally below or near laboratory detection limits. Microcystin toxin results for all lakes are presented in Table 5, Appendix D and Figure 13 C, Appendix B.

Recreational water quality indicators (microcystin toxin level and cyanobacteria cell count) may show differing results, as in the case of Nowlans Lake. The former indicator measures algal toxins already present in water and the latter indicator measures the potential for toxin release to water from algae. Microcystin toxin concentration is a more reliable indicator, since it is a direct measure of toxicity to humans. Nevertheless, cyanobacteria cell count can be a valuable indicator as well, since it is a measure of the potential for toxin release from those cells. Toxin levels can increase in a lake with an algal population crash and associated toxin release from these algal cells. Therefore, it might be prudent to take a conservative approach and favour the cell count indicator.

Blue green algae cell counts were determined at three shoreline locations (SL1, SL2, And SL3) on Nowlans Lake as described previously, as well as at a mid-lake location. Values at the shoreline locations sampled on August 28th were 104,000, 78,800, and 95,600 cells/ml, respectively, and are presented in Figure 13 B. The mid-lake location sampled on August 14th had a count of 24,352 cells / ml and is also presented in Figure 13 B, Appendix D. Shoreline locations of lakes typically have higher blue green algae cell counts than mid-;lake locations, due to effects of wind and waves concentrating algal biomass along shorelines. This was reflected in algal cell counts determined in this study as well.

Major Ions

Ions are both negatively and positively charged particles which are found dissolved in water. These include substances which may be considered to be nutrients and metals, but for the purpose of this study refer to all other common substances found in solution.

A list of these water quality parameters and associated results are found in Table 2 (Appendix C). Concentrations of these parameters are presented for 2008, with summary statistics calculated (i.e. minimum, maximum, and mean values). No further analysis or interpretation of these parameters are provided at this time.

However, a brief explanation follows of each parameter, its environmental significance, and typical values expected in natural surface waters in Nova Scotia.

pH:

The pH of a solution refers to the hydrogen ion concentration or the relative acidic/basic nature of the solution expressed on a scale of 0 to 14, with a neutral pH at 7.

In natural aquatic systems, the pH usually results from the geology and geochemistry of the rocks and soils of the watershed or drainage basin. For surface waters, the pH range of interest is typically 4 to 11 (CCME 1987).

Alkalinity:

Alkalinity refers to the capacity of a solution to neutralize acid and in natural waters is primarily the result of carbonate and bicarbonate ions. Because of the predominant effect of carbonate, alkalinity is expressed in equivalent amounts of calcium carbonate ($CaCO3$). Concentrations of carbonate and bicarbonate in surface waters result in large part from the natural weathering of rock in the watershed. Greater concentrations are found, and therefore, higher alkalinity exists where sedimentary or metamorphic bedrock is present.

In natural surface waters alkalinity varies greatly. In Nova Scotia concentrations are generally less than 50 mg/l unless limestone deposits are in close proximity. In such cases concentrations can more than double. Conversely, in areas of non-carbonate bedrock, alkalinities below detectable limits are common.

Conductivity:

Conductivity refers to the ability of a substance to conduct an electric current. In an aqueous solution this measurement is dependent upon the total concentration of dissolved substances and the solution's temperature.

The conductivity of natural fresh waters varies greatly and may range from less than 20 umhos/cm in dilute waters to over several hundred or more in waters influenced by limestone or salt deposits.

Colour:

The true colour of water refers to the colour resulting from substances which are totally dissolved in the solution. It is not to be mistaken for apparent colour resulting from suspended or colloidal matter. The colour in natural waters are primarily due to coloured organic substances, known as humic substances, resulting from the decay or aqueous extraction of vegetation. The presence of metals such as iron, manganese, and copper which are weathered from rock can also contribute to colour, but this situation predominates in groundwater.

Natural surface waters in Nova Scotia may range in colour from less than detectable limits, in many cases, to over 100 True Colour Units (TCU), in a very limited number of cases where bog lakes are encountered. Average colour values are usually less than 45 TCU.

Turbidity:

Turbidity measurements provide an approximation for concentrations of suspended material such as clay, sand, silt, finely divided organic and inorganic matter, plankton and other microorganisms in water.

Total Organic Carbon:

Total organic carbon (TOC) refers to the total of suspended and dissolved organic constituents of water. Elevated levels of TOC are primarily indicative of naturally occurring organic matter such as humic substances but also can reflect high algal concentrations. Levels of organic carbon in surface waters vary widely, ranging from non-detectable in newly risen rivers supplied by limestone springs to greater than 100 mg/l in peaty swamp waters (Croll 1972).

Hardness:

Hardness is a traditional measure of the capacity of water to react with soap and is expressed in terms of mg/l of $CaCO_3$.

In fresh water the principal hardness-causing ions are calcium and magnesium which naturally leach from rock and soils. Soft water is considered to have a value of 0 to 60 mg/l, medium hard 60 to 120 mg/l, hard 120 to 180 mg/l, and very hard 180 mg/l and above (Health and Welfare Canada 1980).

Natural fresh waters in Nova Scotia are almost invariably soft, if not in close proximity to limestone or salt deposits.

Sodium:

Sodium is a non-toxic metal which is abundant, widely distributed in nature, and present to some extent in all natural waters. The principal sources of sodium are from the weathering of igneous rock and salt deposits, as well as the leaching of soils. Deicing salt used on highways can also significantly contribute to overall sodium levels in nearby watercourses. Concentrations in pristine surface waters vary greatly, ranging from less than 1 mg/l to over 300 mg/l, depending upon amount of rainfall and evaporation, and geologic formations present. Typical undisturbed lakes in Nova Scotia however would have sodium concentrations generally less than 50 mg/l.

Potassium:

Potassium is a widely distributed non-toxic element which is essential to plant and animal nutrition. The primary natural source is from the weathering of rock. Although potassium may be found in many rocks, those with significant amounts (e.g. granite) are resistant to weathering. Commercial chemical fertilizers contain substantial concentrations of this element and may be a significant cultural source from the watershed.

Concentrations of potassium in natural surface waters seldom reach 20 mg/l and are generally less than 10 mg/l (CCME 1987).

Calcium:

Calcium is one of the most abundant cations (positively charged ions) found in surface or groundwaters. It is readily soluble in water and enters the aquatic environment through the weathering of rocks, especially limestone, and from the soil, through seepage and run-off. Calcium salts, along with those of magnesium, are primarily responsible for the hardness of water. This element is considered to be essential for nearly all living organisms.

The concentrations of calcium in natural fresh waters vary according to the proximity of calcium-rich geological formations. Typical concentrations are less than 15 mg/l, whereas waters close to carbonate rocks may have concentrations in the range of 30-100 mg/l. (CCME 1987)

Magnesium:

Magnesium is the eighth most abundant natural element in the earth's crust and is a common constituent of natural water (CCME 1987). The principal sources of magnesium are ferromagnesium minerals in igneous rocks and magnesium carbonates in sedimentary rocks. Along with calcium, it is one of the main contributors to water hardness, and is also considered to be an essential element for all living organisms.

Water in watersheds with magnesium-containing rock may have magnesium in the concentration range of 1 to 100 mg/l.

Sulphate:

Sulphate is widely distributed and is an ionic component of all natural waters. It may be leached from most sedimentary rocks, including shales, with the most appreciable contributions from such sulphate deposits as gypsum and anhydrite. Acid rain can also contribute to sulphate concentrations in surface waters.

Concentrations normally vary from 10 to 80 mg/l in naturally occurring surface waters (CCME 1987).

Chloride:

Chloride is widely distributed in the environment, generally as sodium chloride, potassium chloride, and calcium chloride (CCME 1987). The weathering and leaching of sedimentary rocks and soils and the dissolution of salt deposits release chlorides to water (Mc Neely et al. 1979). In natural waters, chlorides are present in low concentrations, commonly less than 50 mg/l. Deicing salts applied to highways can contribute significantly to chloride concentrations where extensive urbanization has occurred.

Silica:

Silicon is a stable, relatively light chemical element that does not occur free in nature, but combines with oxygen and other elements to form oxides of silicates (CCME 1987). The term "silica" refers to silicon in natural waters, and is usually represented by the hydrated form of the oxide. Silica is present in most rocks, but many are resistant to chemical weathering. Although relatively unreactive chemically, silicon is considered an essential micronutrient to some algal species, most notably the diatoms. Therefore, silicon concentrations in freshwaters are significantly influenced by diatom cycling.

Most natural waters contain less than 5 mg/l of silica, although a range of 1 to 30 mg/l is not uncommon. Typical surface waters have a silica concentration of 3 to 4 mg/l (McNeely et al. 1979).

Metals

Dissolved metals which were investigated during this study are listed, along with results, in Table 2. (Appendix A). As with major ions, concentrations of specific metals are presented, with summary statistics calculated (i.e. minimum, maximum, and mean values). No further analysis or interpretation of these parameters is provided at this time.

WATERSHED / SHORELINE SURVEY

Lake shoreline surveys identified three large nutrient sources which could potentially be stimulating algal production in the study lakes. These potential sources were mink farms and a mink food processing facility on Nowlans Lake and an aquaculture operation on Hourglass Lake. Otherwise, shoreline and watershed surveys to identify pollutant sources noted only a few small farms, limited commercial or industrial land use, and clustered residential development. No in-depth assessment of nutrient or pollutant sources from these activities or land uses was undertaken, since this was beyond the scope of the current investigation and available resources.

CONCLUSIONS

Based on the results of this study, it can be concluded that the 9 lakes surveyed fall into a range of trophic categories from a very unproductive, oligotrophic state to the very productive hyper-eutrophic state. Headwater lakes higher in the watershed tended to be more productive (Nowlans – eutrophic) (Provost, Hourglass, and Placides – mesotrophic to eutrophic) with other lakes progressively less productive as they flowed downstream (Parr- high mesotrophic) (Porcupine, Ogden, and Fanning – low mesotrophic) (Vaughan – Oligotrophic).

The headwaters lakes (Nowlans, Provost, and Hourglass) tended to be more productive, which suggests significant nutrient sources in their immediate watersheds. Typically, headwater lakes are lower in nutrients and productivity than lakes lower in the same watershed, when only natural nutrient sources and processes are at play.

Rough comparisons of nutrient related water quality parameters between the mid 1980s and 2008 indicate an overall increasing trend and somewhat deteriorating conditions. Several large nutrient sources were identified in the study area which may be major contributors to the observed increase in nutrients, high chlorophyll levels, and decrease in transparency observed in some lakes.

Reintroduction of nutrients from bottom sediments to the water column as a result of hypolimnetic oxygen depletions may occur due to the fairly strong thermal stratification observed.

The algal assessment indicated that cyanobacteria populations were generally low in all lakes tested, with the exception of Nowlans Lake, and to a lesser extent Fanning lake, which had indications of high algal populations or bloom conditions (high cell counts and turbid green coloration) but little or no toxin production.

Recreational use guidelines (< 100,000 cell count) were exceeded on Nowlans Lake on one sampling date. Concurrent samples however, indicated no significant levels of cyanobacteria toxins, with concentrations generally below or near laboratory detection limits. Toxin guideline levels for recreational use were not exceeded at any time in any lake.

The two recreational water use guidelines did not support the same conclusion regarding safe use for swimming in Nowlans Lake. It might be prudent to take a conservative approach and consider water quality in that lake as unsuitable for recreational water use based on the cell count indicator. Toxin levels could increase in the lake with an algal population crash and associated toxin release from algal cells. Blue green algae cell counts (approx 5200) and microcystin toxin levels (below detection limits of 0.2 ug/l) in Fanning Lake did not exceed the recreational use guidelines, indicating safe conditions for this use.

It should be noted that due to the limitations of this survey, peak blue green algae populations may not have been fully captured. Very high nutrient concentrations in some lakes suggest that algal blooms may continue to be a concern in these watersheds.

The cursory lake shoreline surveys identified several large nutrient sources which could potentially be stimulating the observed algal production in some of the study area lakes. Other unidentified point and non-point pollutant sources may be contributing to deteriorating water quality of lakes in the study area.

RECOMMENDATIONS

Study area lakes appear to be sensitive to nutrient inputs as demonstrated by significant recurring algal blooms in several lakes. Although the geological setting of the area contributes to the natural background levels of nutrients in these lakes, human related nutrient sources are likely contributing more significantly in certain watersheds and impacting lake water quality.

In order to improve water quality in study area lakes and to ensure that desired water uses are not compromised, known nutrient sources should be reduced where possible, and efforts should be made to identify additional sources.

Watershed best management practices should be implemented in order to minimize the export of phosphorus from the watershed to promote low nutrient and high transparency in-lake conditions. Development in the watershed (e.g. forestry, farming, residential, etc.) can be accommodated without negative impacts to water quality as long as it is undertaken in an environmentally acceptable manner. Buffer strips, erosion control measures, good livestock manure management, and suitable sewage disposal systems, are examples of appropriate practices which must be implemented if the water resources are to continue to provide the expected uses to area residents.

It would also be advisable to further investigate and assess nutrient and /or pollutant sources in the watershed through a more intensive and comprehensive shoreline/watershed survey.

An assessment of tributary streams to impacted lakes would allow the relative contributions of nutrients to be determined from each sub-watershed and upstream source. Based on these analyses sub-watersheds with the greatest need for management to reduce nutrient sources could be identified and prioritized.

Where activities in the watershed are identified as having negative impacts on lakes or tributary streams and expected water uses, regulators should work with property owners, industry, and other stakeholders to employ appropriate management actions to mitigate impacts and reduce effects.

Large suspect contributors of nutrients to the lakes should be further investigated and where appropriate and possible, discharges reduced or eliminated. This should include the mink farms and a mink food processing facility on Nowlans Lake and the aquaculture operation on Hourglass Lake. Placides Lake watershed should also be further investigated for significant nutrient sources due to the very high nutrient levels found in the lake water chemistry.

Community or watershed groups, such as TREPA, could act as lead to form a watershed protection plan with stakeholders. Through that process water resource issues could be addressed and desired water uses protected in the watershed.

Nowlans Lake and /or Fanning Lake could serve as a starting point to work with stakeholders in forming and implementing a watershed protection plan.

It would be prudent to refrain from body contact recreation (eg swimming) in Nowlans Lake as a precautionary measure, since recreational use guidelines were exceeded. Although Nowlans Lake is not known to be used as a drinking water supply, it would be advisable to refrain from using lake water for this purpose as well, to avoid possible health effects from algal toxins.

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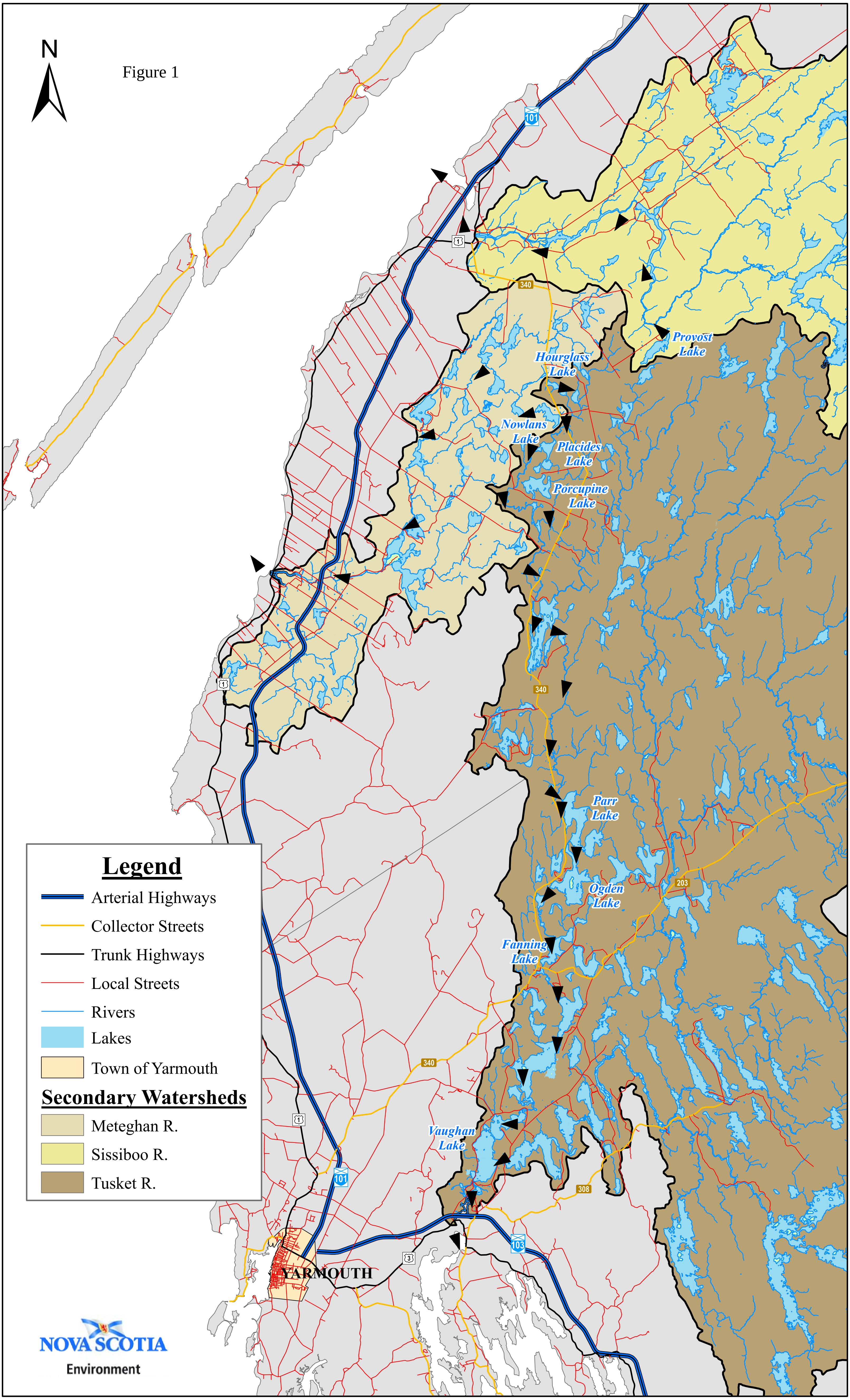
APPENDIX A



N
Figure 1
Provost Lake
Hourglass Lake
Nowlans Lake
Placides Lake
Porcupine Lake
Parr Lake
Ogden Lake
Fanning Lake
Vaughan Lake
YARMOUTH
101
1
340
203
308
103
3
Legend
Arterial Highways
Collector Streets
Trunk Highways
Local Streets
Rivers
Lakes
Town of Yarmouth
Secondary Watersheds
Meteghan R.
Sissiboo R.
Tusket R.
NOVA SCOTIA
Environment

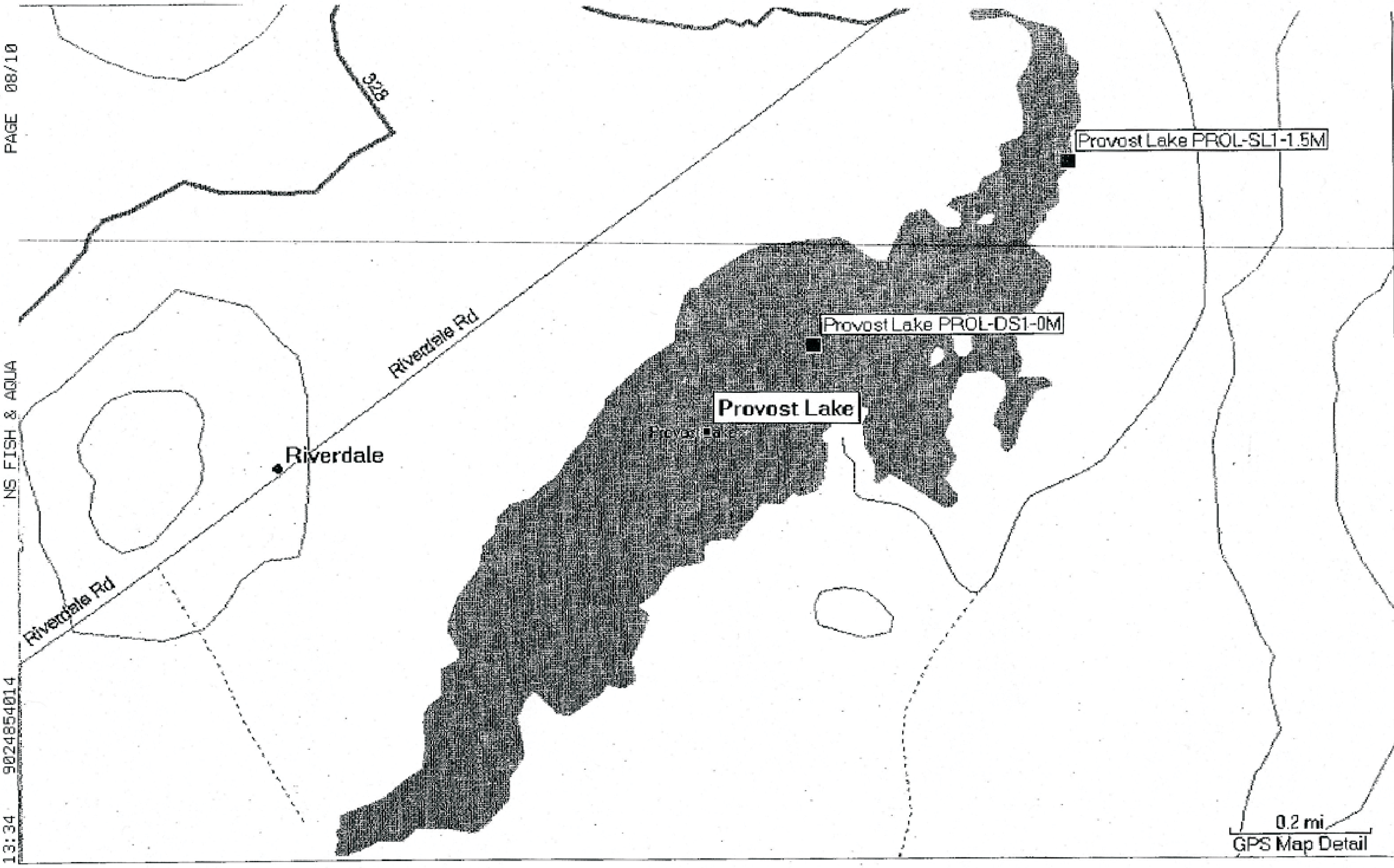
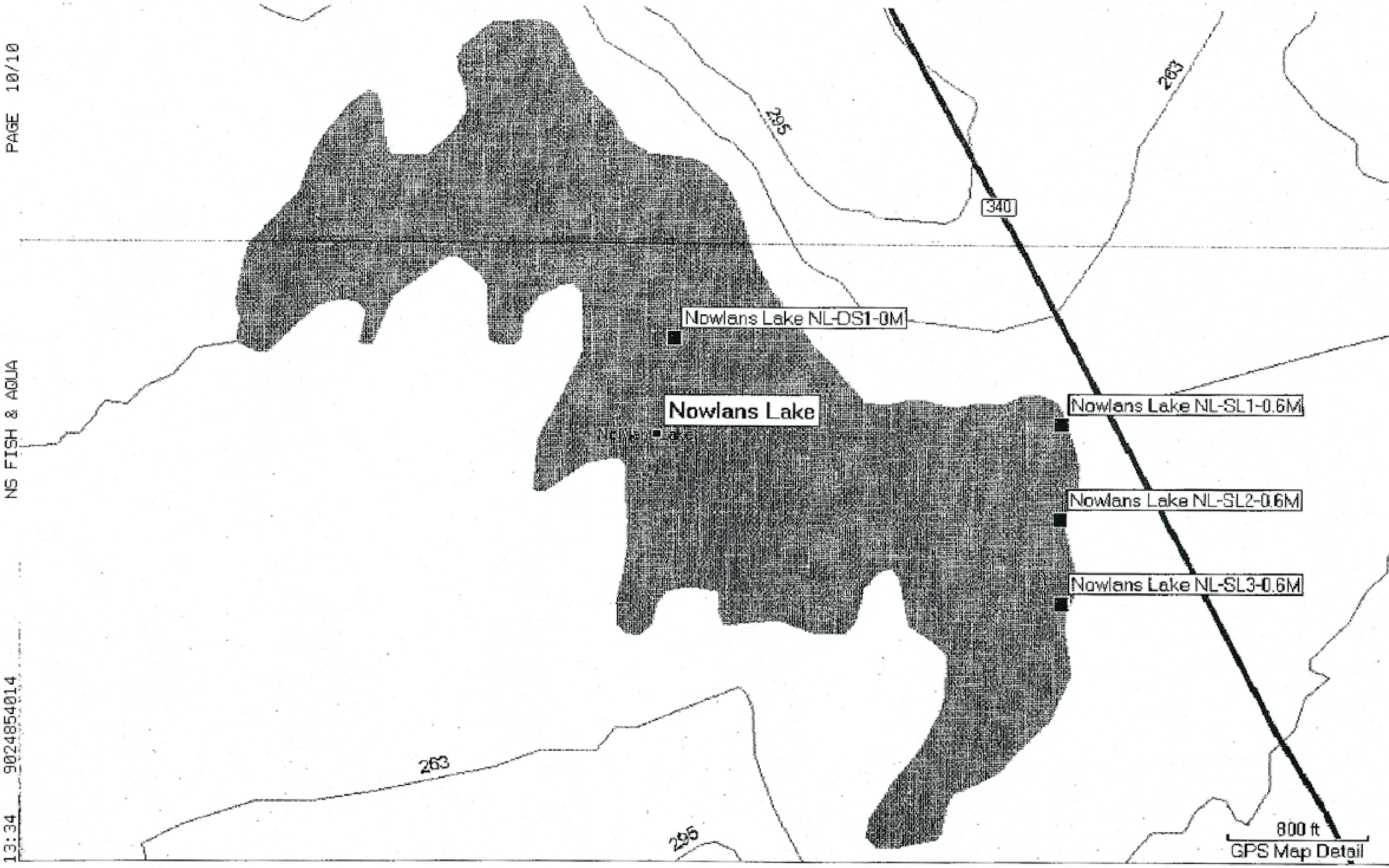

328
Provost Lake PROL-SL1-1.5M
Provost Lake PROL-DS1-0M
Riverdale Rd
Provost Lake
Riverdale
Riverdale Rd
0.2 mi.
GPS Map Detail

Figure 2



Nowlans Lake NL-DS1-0M
Nowlans Lake
Nowlans Lake NL-SL1-0.6M
Nowlans Lake NL-SL2-0.6M
Nowlans Lake NL-SL3-0.6M
340
295
263
263
295
800 ft
GPS Map Detail

Figure 3

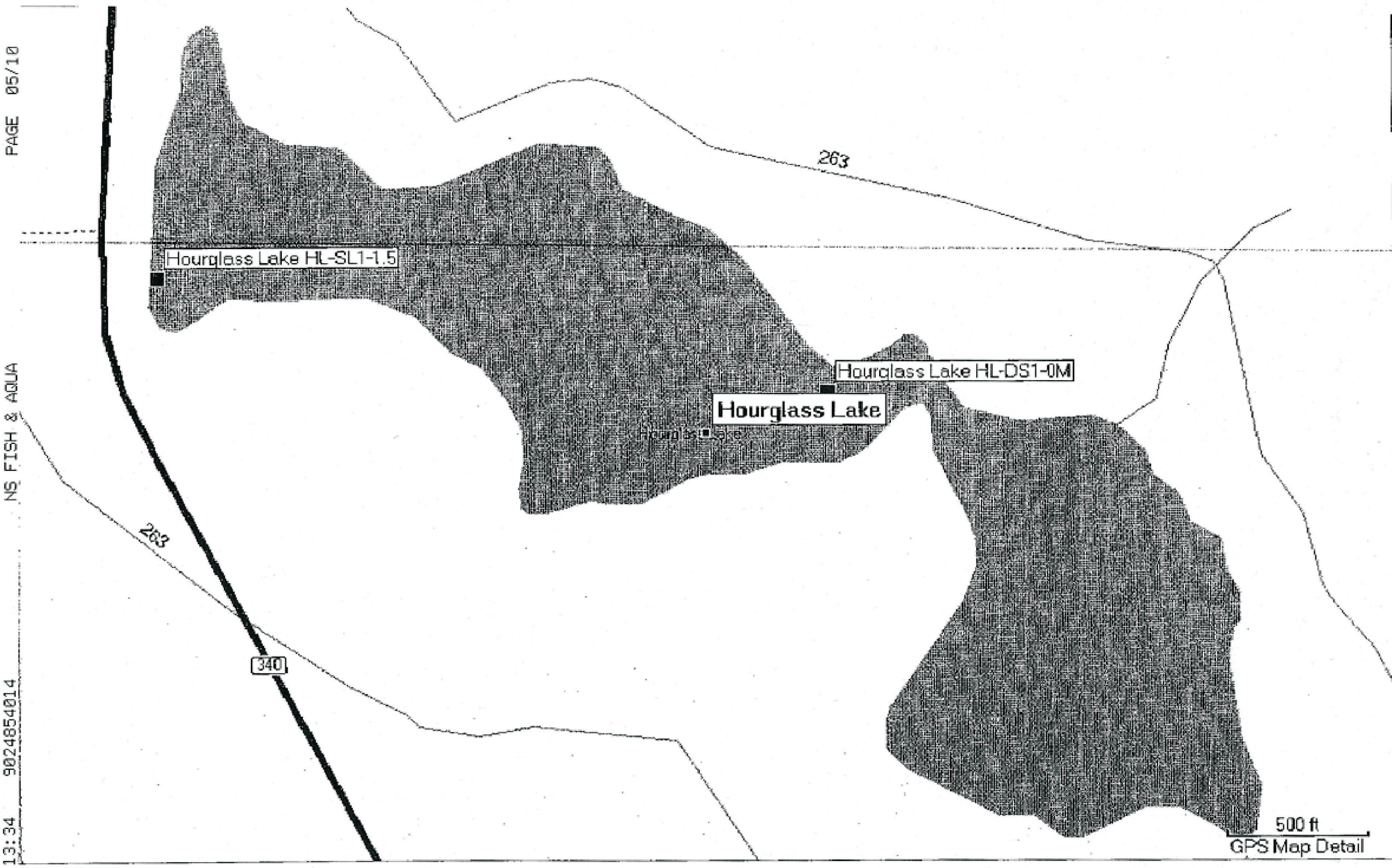

263
Hourglass Lake HL-SL1-1.5
Hourglass Lake HL-DS1-0M
Hourglass Lake
263
340
500 ft
GPS Map Detail

Figure 4

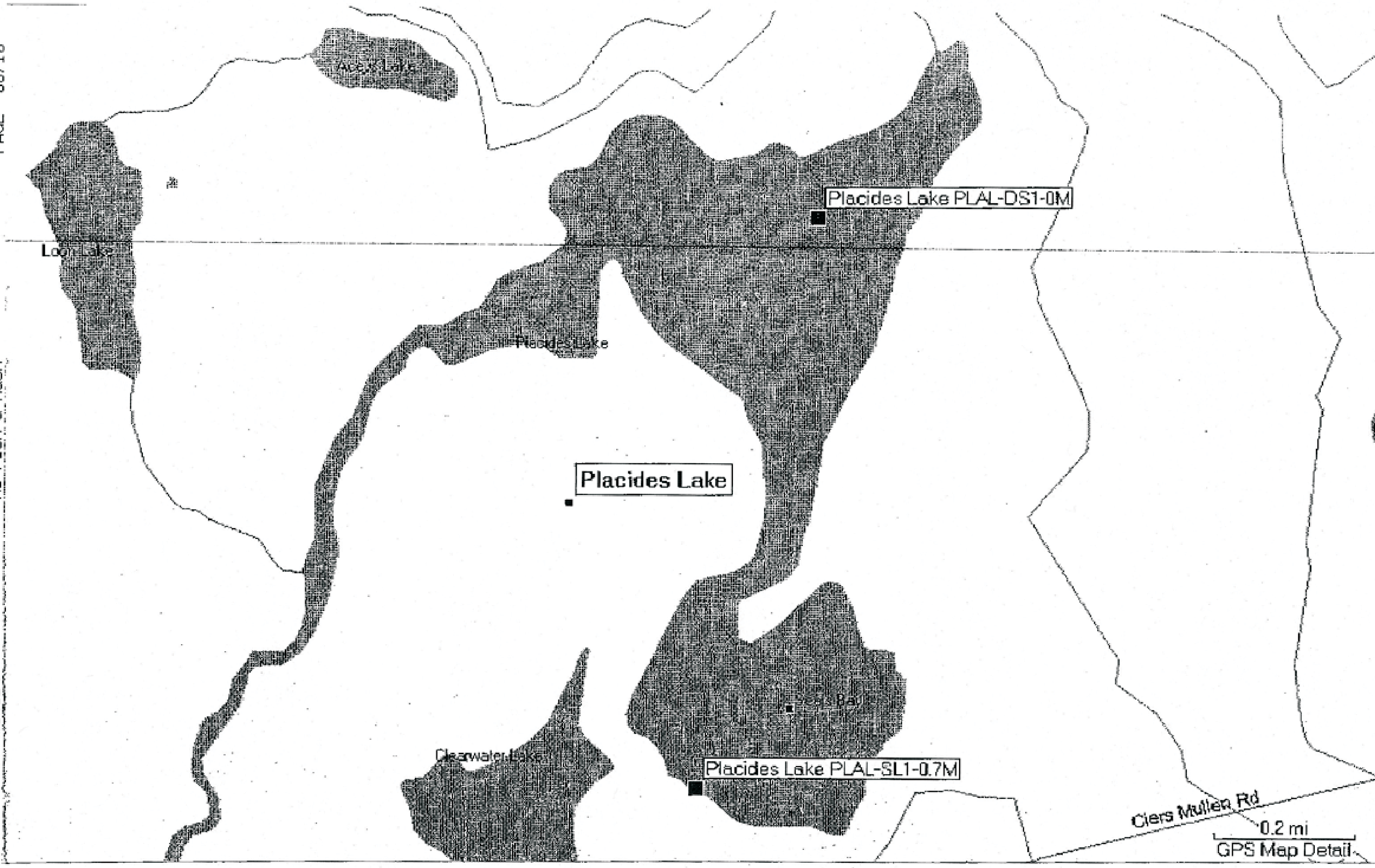

Placides Lake PLAL-DS1-0M
Placides Lake
Placides Lake
Clearwater Lake
Placides Lake PLAL-SL1-0.7M
Ciers Mullen Rd
0.2 mi
GPS Map Detail

Figure 5

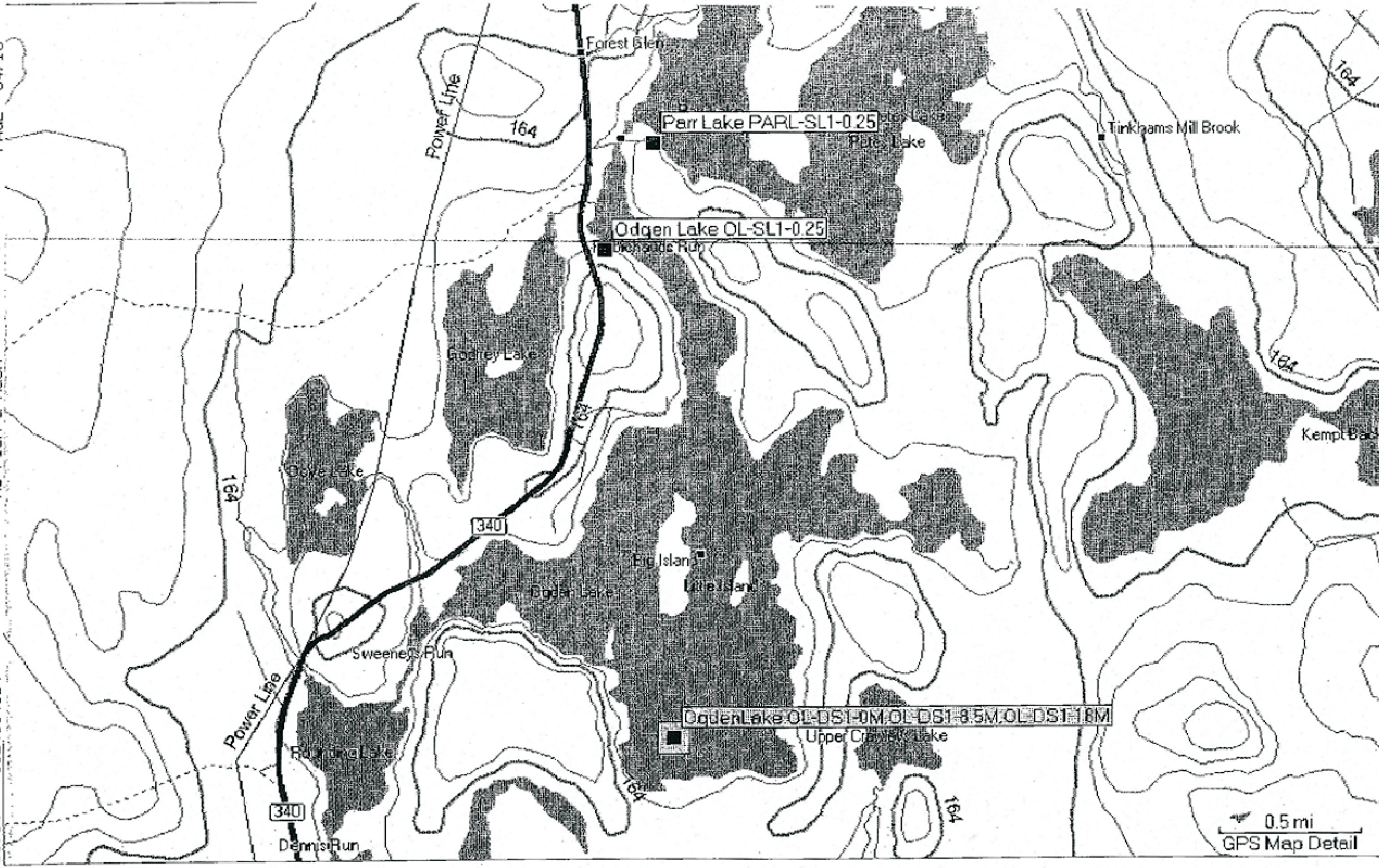
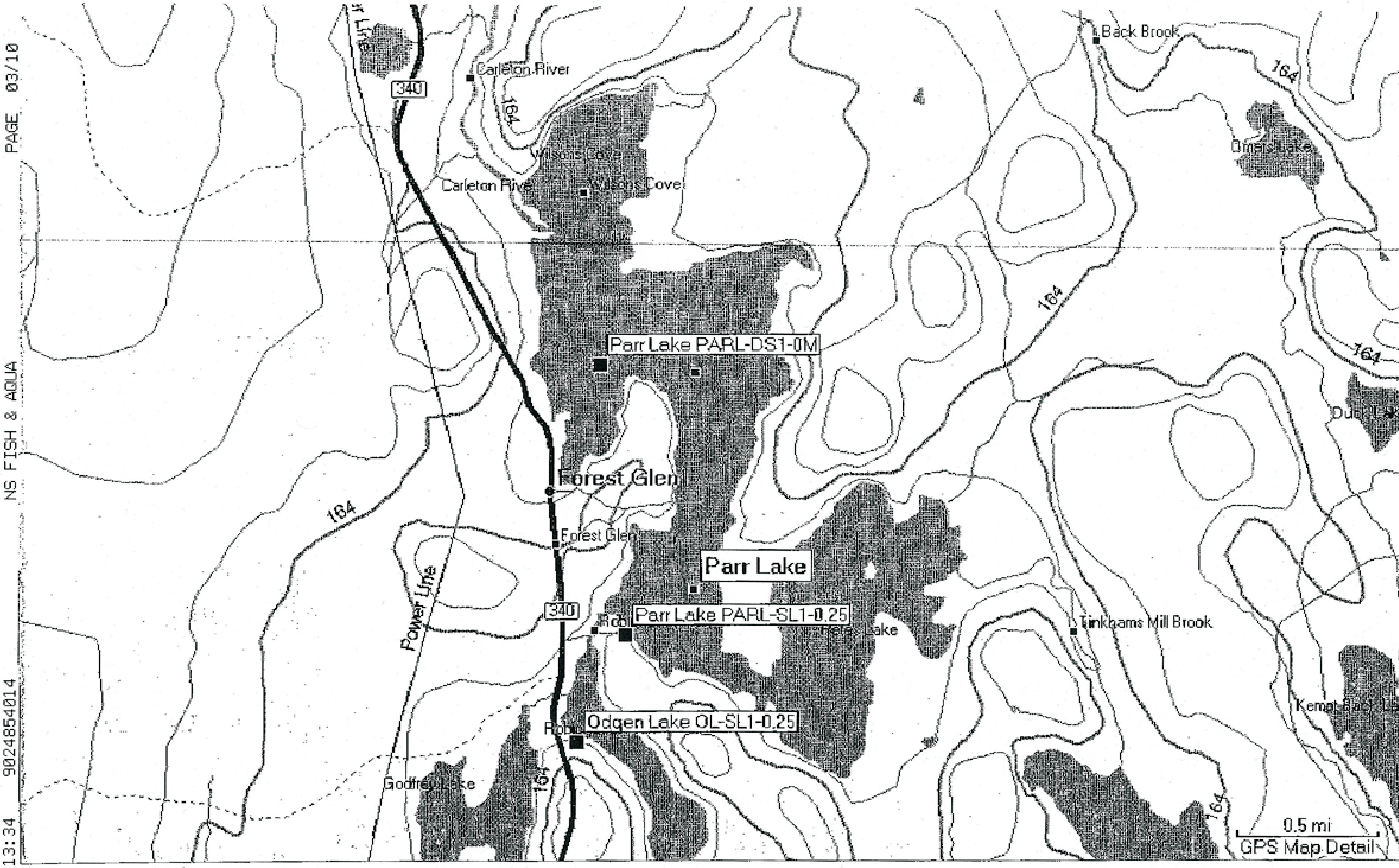
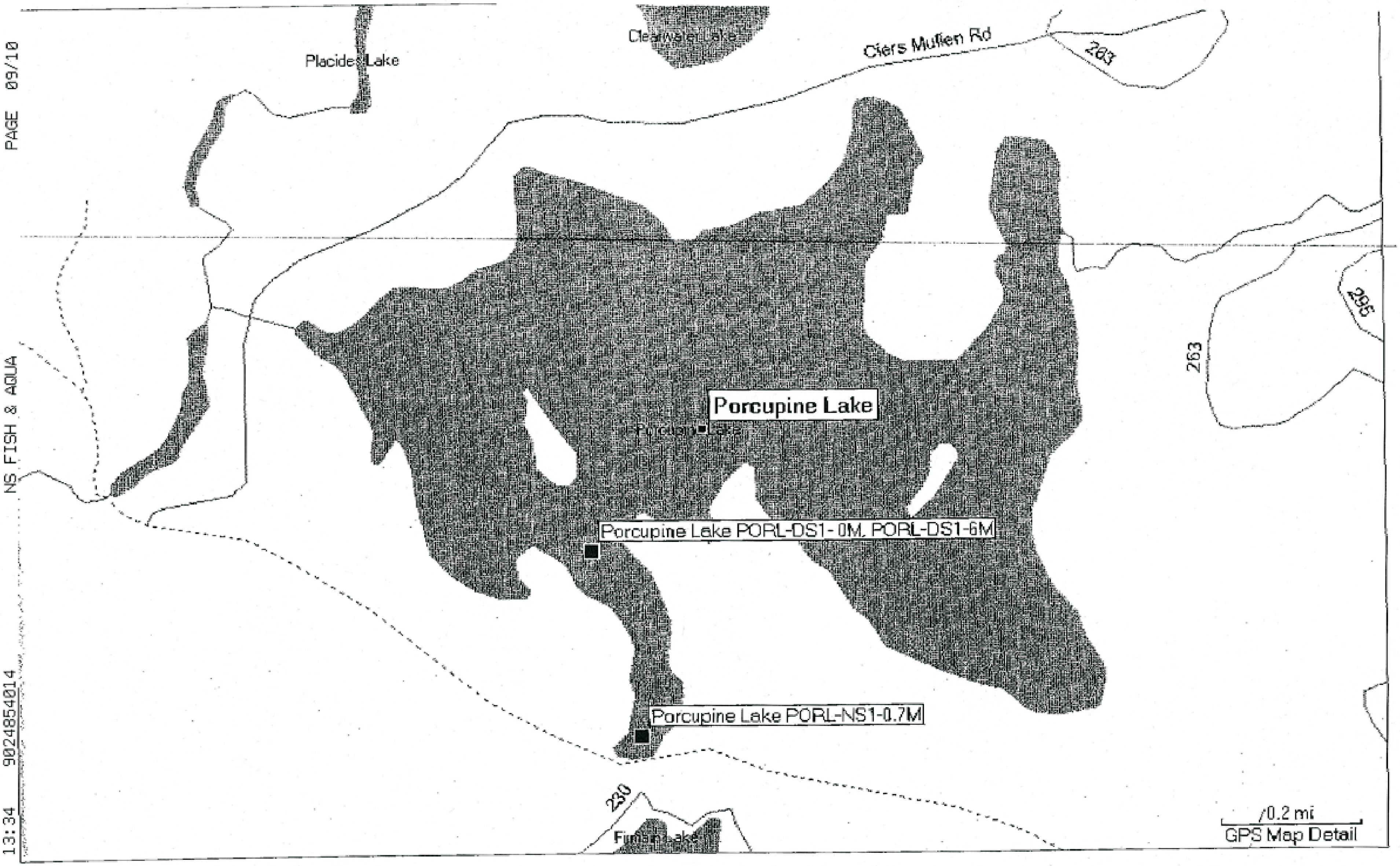

Forest Glen
Power Line
164
Parr Lake PARL-SL1-0.25
Peter Lake
Tinkhams Mill Brook
Odgen Lake OL-SL1-0.25
Godfrey Lake
Kempt Back
Cove Lake
340
Big Island
Little Island
Ogden Lake
Sweeneys Run
OgdenLake OL-DS1-0M,OL-DS1-8.5M,OL-DS1-18M
Upper Crawley Lake
Power Line
Rounding Lake
0.5 mi
GPS Map Detail
Dennis Run

Figure 6



Back Brook
Carleton River
340
164
Wilsons Cove
Carleton River
Wilsons Cove
Omers Lake
Parr Lake PARL-DS1-0M
Forest Glen
Forest Glen
Parr Lake
Power Line
340
Parr Lake PARL-SL1-0.25
Tinkhams Mill Brook
Odgen Lake OL-SL1-0.25
Godfrey Lake
0.5 mi
GPS Map Detail

Figure 7



Placide Lake
Clearwater Lake
Ciers Mullen Rd
263
295
263
Porcupine Lake
Porcupine Lake PORL-DS1-0M, PORL-DS1-6M
Porcupine Lake PORL-NS1-0.7M
230
0.2 mi
GPS Map Detail

Figure 8

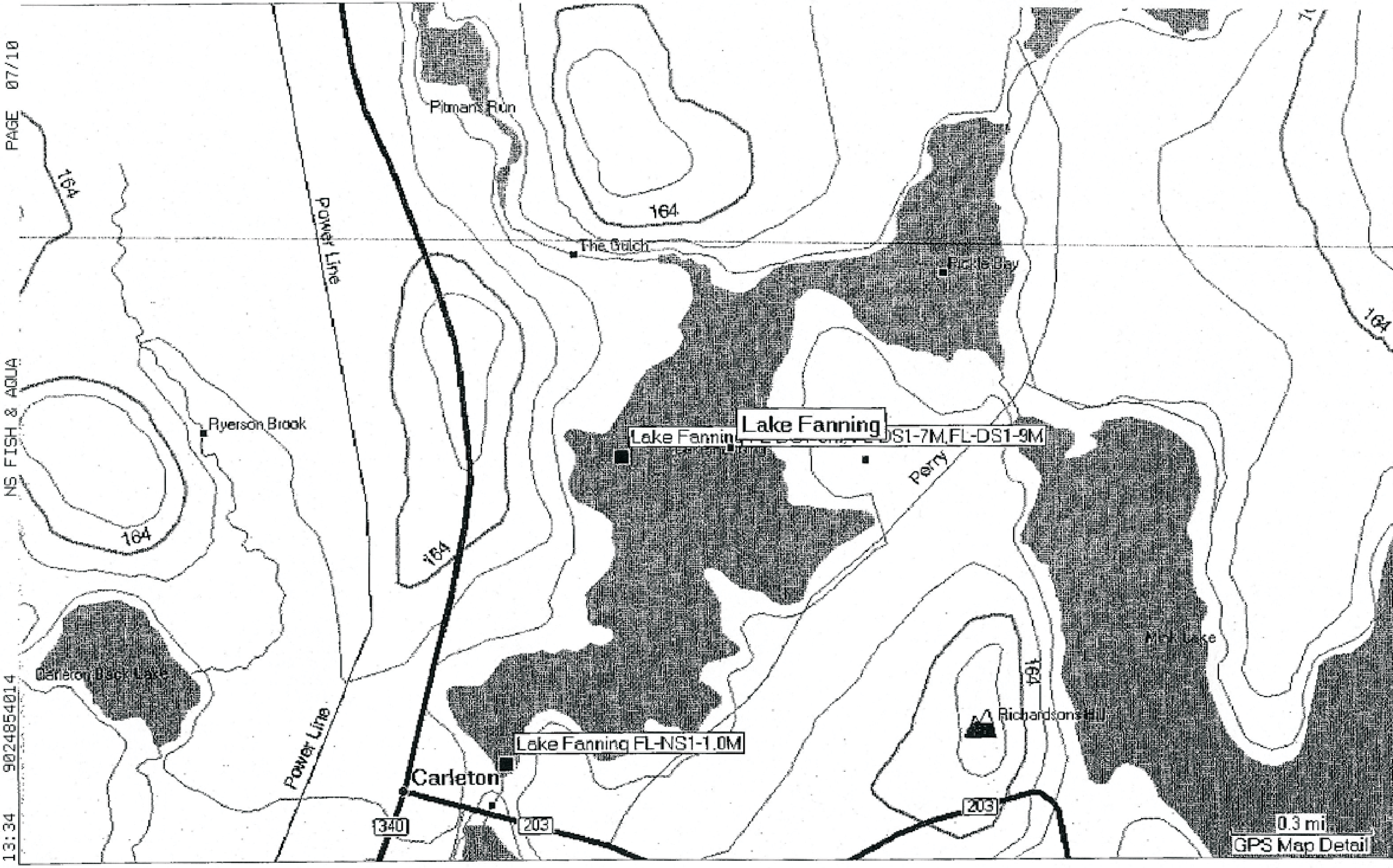

Pitmans Run
164
The Gulch
Pickle Bay
Power Line
Ryerson Brook
Lake Fanning
DS1-7M,FL-DS1-9M
Perry
Mink Lake
Carleton Back Lake
Richardsons Hill
Power Line
Lake Fanning FL-NS1-1.0M
Carleton
340
203
203
0.3 mi
GPS Map Detail

Figure 9


Raynardton
Canaan
Lake Vaughn VL-DS1-0M,VL-DS1-9.5M,VL-DS1-14M
Raynardton
Lake Vaughn
Tusket River
Tusket River
The Narrows
Gavelton
Lake Vaughn VL-SL1-0.25M
Power Line
Power Line
Lake Vaughn
Mikes
Gavel
Canaan
0.5 mi
GPS Map Detail

Figure 10

APPENDIX B

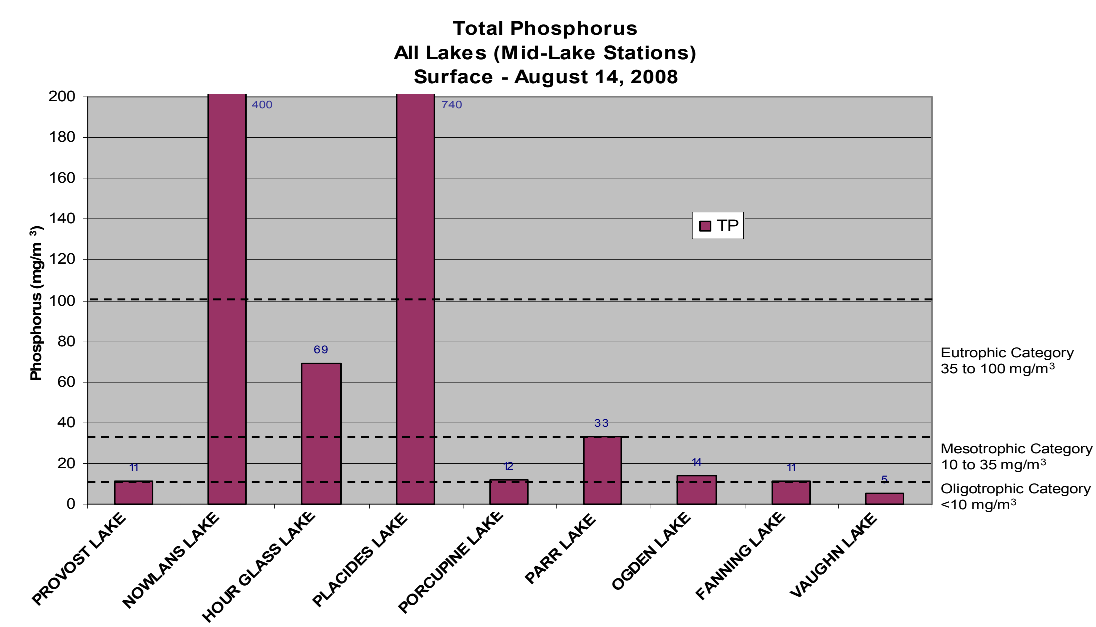


Figure 10 A

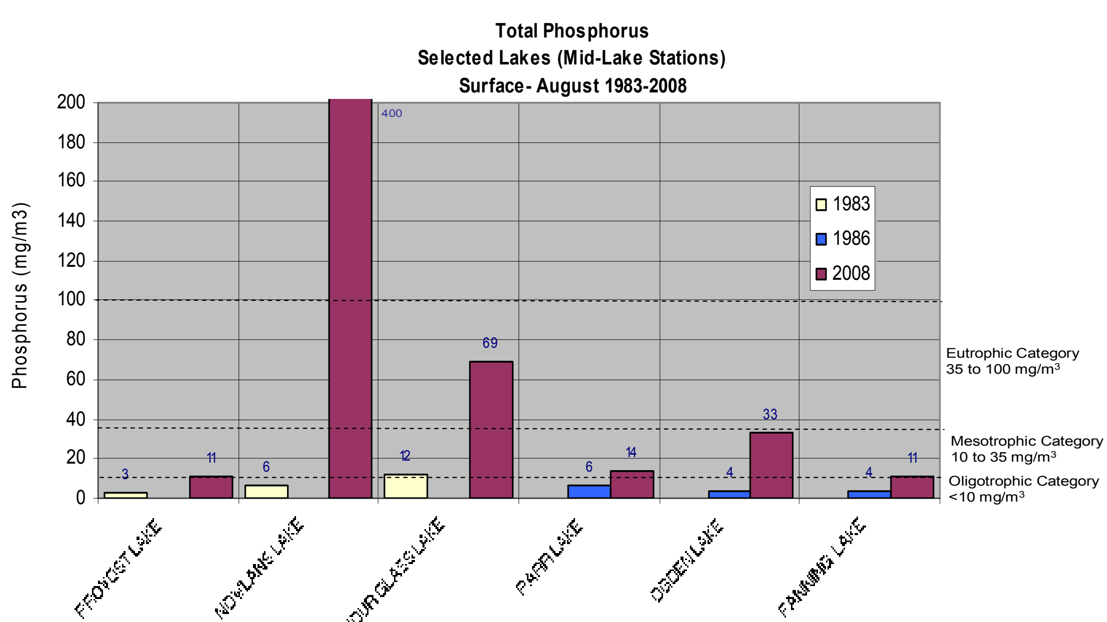


Figure 10 B

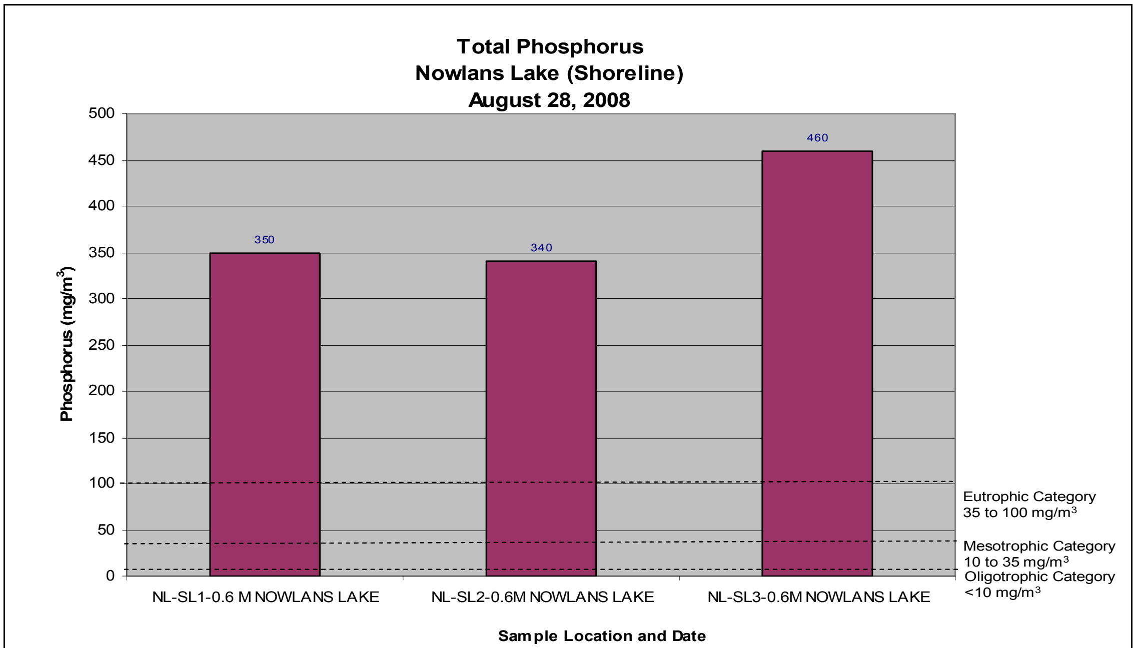


Figure 10 C

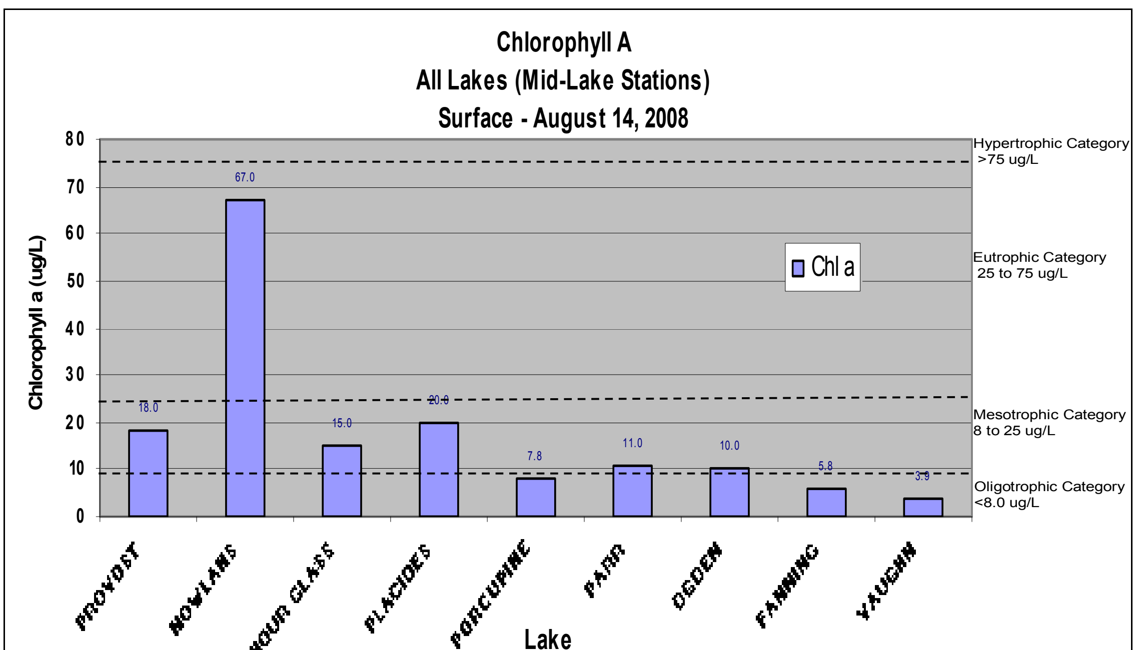


Figure 11 A

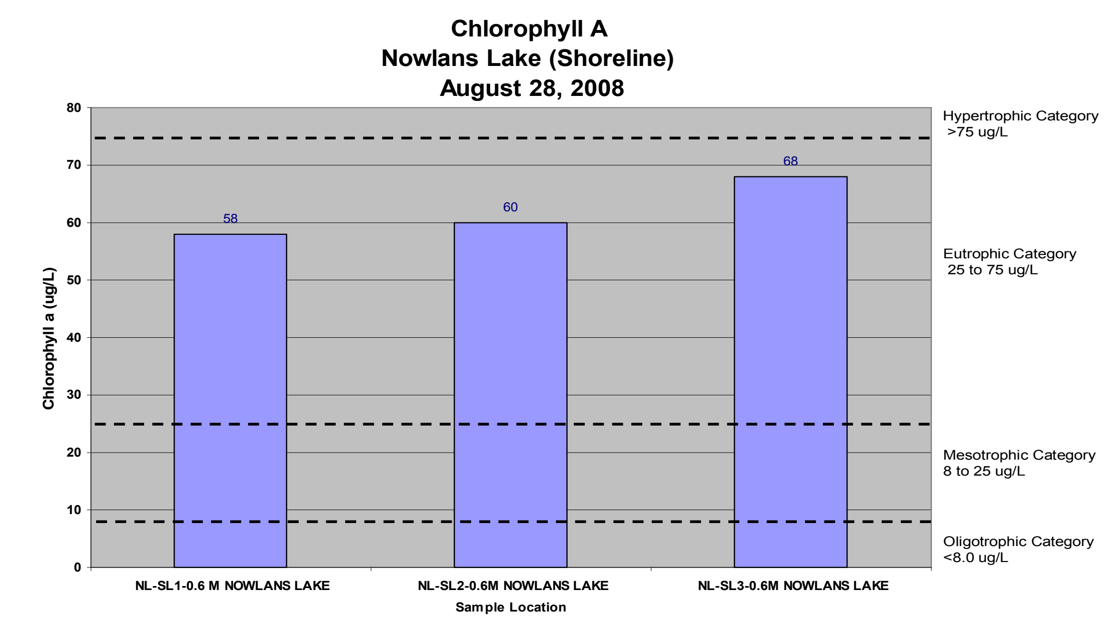


Figure 11B

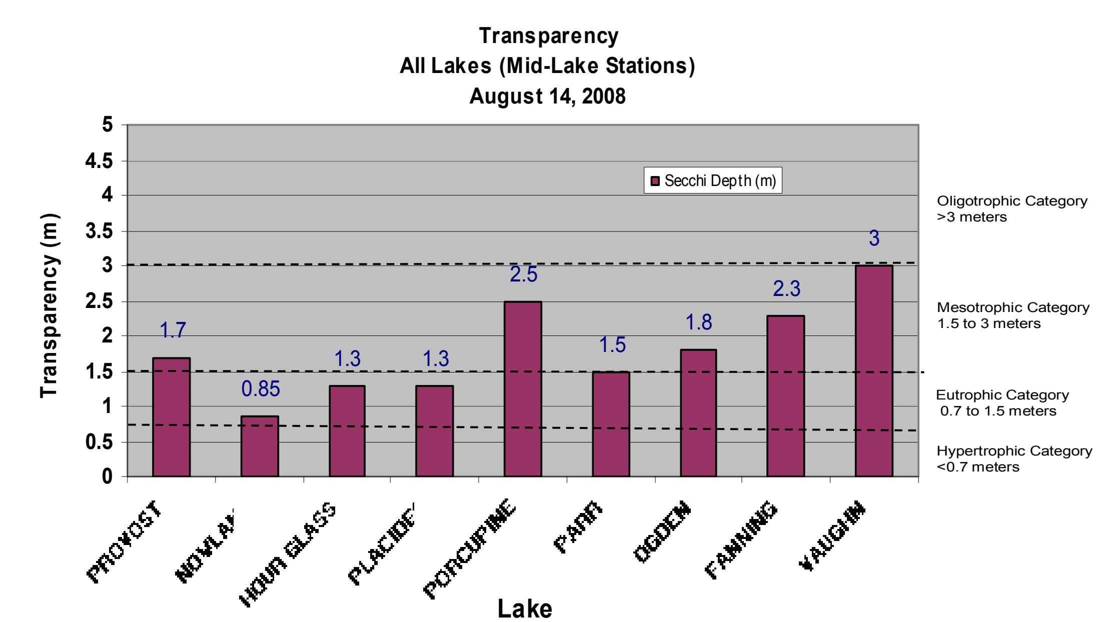


Figure 12 A

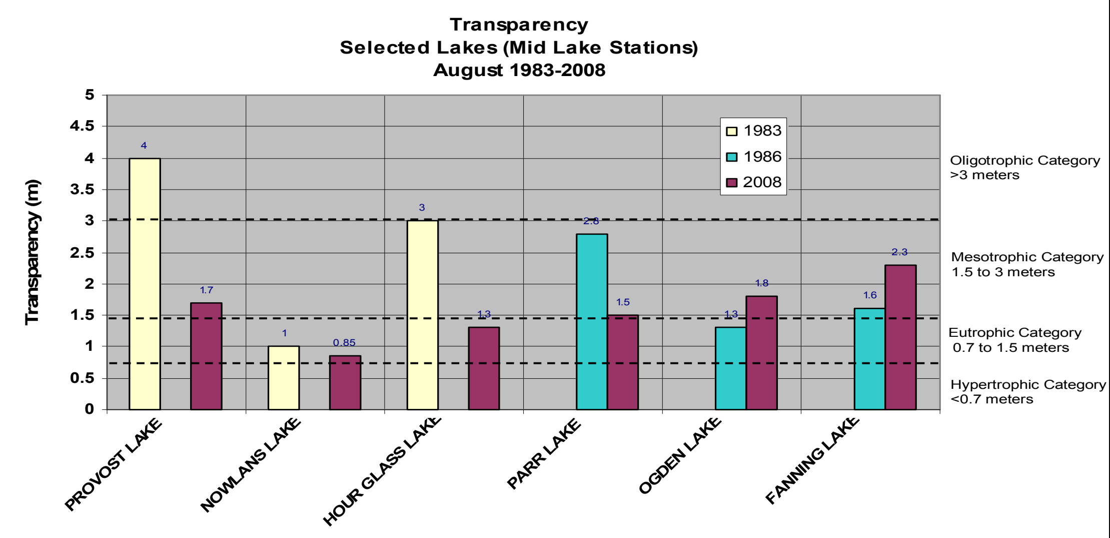


Figure 12 B

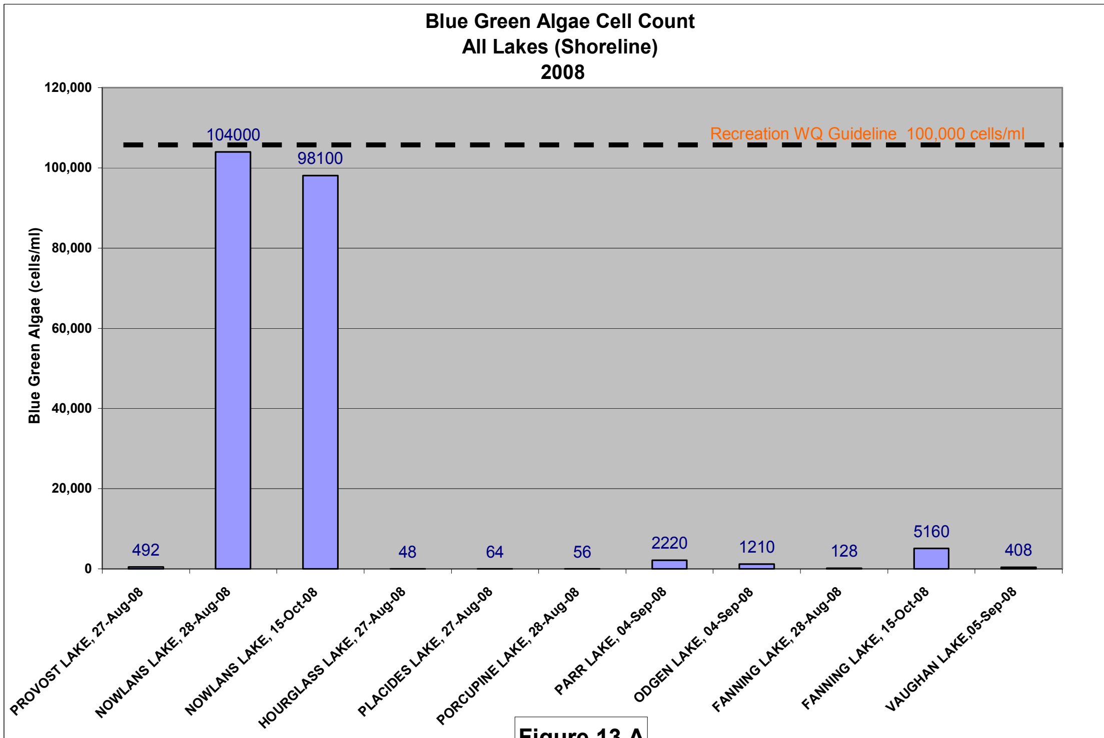


Figure 13 A

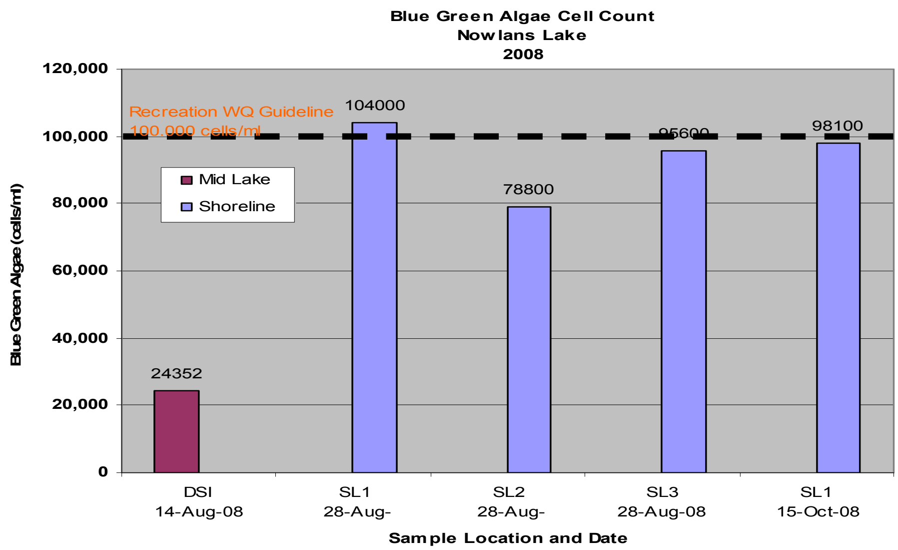


Figure 13 B

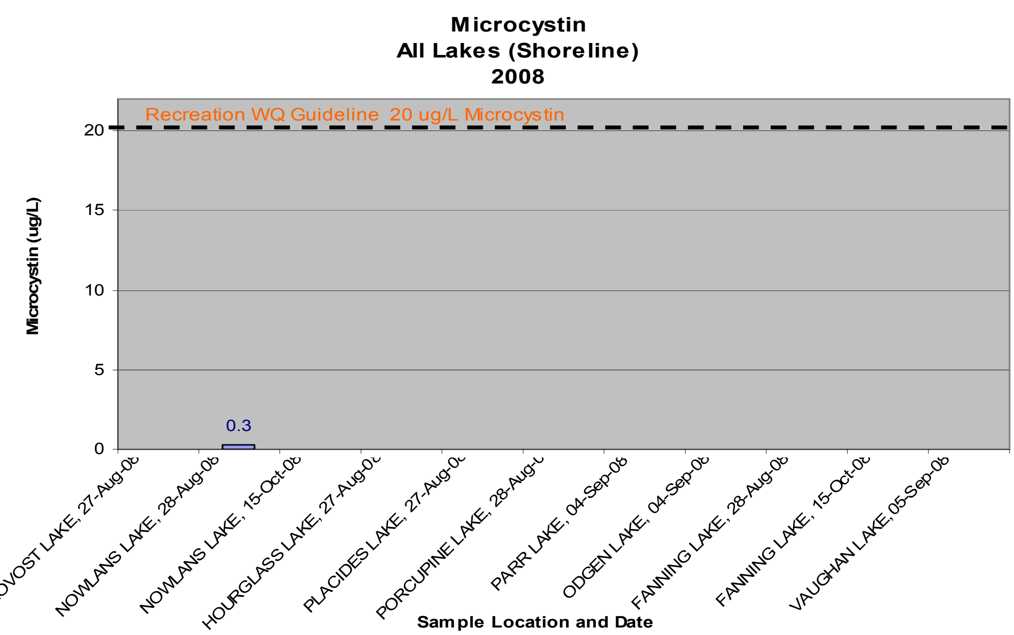


Figure 13 C

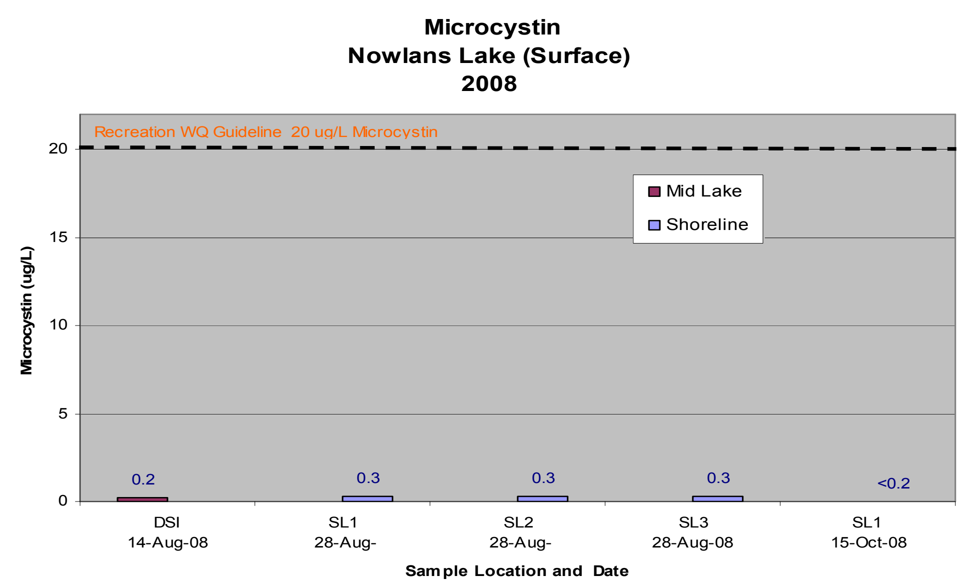

Microcystin
Nowlans Lake (Surface)
2008
Recreation WQ Guideline 20 ug/L Microcystin
Mid Lake
Shoreline
Microcystin (ug/L)
20
15
10
5
0
0.2
0.3
0.3
0.3
<0.2
DSI
14-Aug-08
SL1
28-Aug-
SL2
28-Aug-
SL3
28-Aug-08
SL1
15-Oct-08
Sample Location and Date

Figure 13 D

APPENDIX C

Table 2 *SL- Shoreline Sample* *ML - Mid-Lake Sample*

Selected Water Quality Parameters 2008

Lake				HOURGLASS LAKE		PLACIDES LAKE			PORCUPINE LAKE			PARR LAKE		OGDEN LAKE				FANNING LAKE				
Sample Location				*SL*	*ML*	*SL*	*ML*	*ML*	*SL*	*ML*	*ML*	*SL*	*ML*	*SL*	*ML*	*ML*	*ML*	*SL*	*SL*	*ML*	*ML*	*ML*
Sample ID				HL-SLI	HL-DSI	PLAL-SL1	PLAL-DS1	PLAL-DS1	PORL-NS1	PORL-DS1	PORL-DS1	PARL-SL1	PARL-DS1	OL-SL1	OL-DS1	OL-DS1	OL-DS1	FL-NS1	FL-SL	FL-DS1	FL-DS1	FL-DS1
Depth (m)				1.5	0	0.7	0	7	0.7	0	6	0.25	0	0.25	0	9	18	1.0	0.5	0	7	9
Date Sampled				27-Aug	14-Aug	27-Aug	14-Aug	14-Aug	28-Aug	13-Aug	13-Aug	4-Sep	14-Aug	4-Sep	15-Aug	15-Aug	15-Aug	28-Aug	15-Oct	13-Aug	13-Aug	13-Aug
Water Quality Parameters	**Min**	**Max**	**Mean**																			
Aluminum (ug/L)	13	449	108	126	123	61	90	**449**	23	**26**	53	129	138	105	86	140	245	60	91	67	149	207
Calcium (mg/L)	0.9	4.6	1.8	1	1.1	1.4	2	4.6	1.5	1.4	2	1.2	1.2	1.1	1.1	1.1	1.2	1.1	1.1	1.1	1.3	1.6
Copper (ug/L)	<2	45	27	<2	<2	<2	<2	23	<2	<2	25	<2	<2	<2	<2	19	35	<2	<2	<2	18	45
Iron (ug/L)	153	9661	1405	791	825	422	532	9661	207	217	3066	452	491	385	271	544	3432	168	286	187	1029	5138
Magnesium (mg/L)	0.6	1.8	0.99	1.1	1	1.2	1.4	1.7	1	0.9	1	0.7	0.7	0.7	0.7	0.6	0.7	0.7	0.7	0.6	0.7	0.7
Hardness as CaCO3 (mg/L)	5.1	18.5	8.6	7	6.8	8.4	10.8	18.5	7.8	7.2	9.1	5.9	5.9	5.6	5.6	5.2	5.9	5.6	5.6	5.2	6.1	6.9
Manganese (ug/L)	24	1774	342.9	88	128	56	61	642	24	38	1489	28	34	41	53	288	782	29	42	59	868	1366
Potassium (mg/L)	<0.5	2.1	1.1	0.6	0.6	1.4	1.7	1.9	0.6	0.6	0.7	0.5	<0.5	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	>0.5
Sodium (mg/L)	4.3	9.3	6.1	8.3	8.1	7.8	8.6	6.8	5.9	5.4	5.4	5.1	5	5.1	5	4.8	4.7	5.2	5.2	4.5	4.4	4.6
Zinc (ug/L)	<5	154	76.11	<5	<5	<5	<5	98	<5	<5	75	10	<5	<5	<5	68	58	<5	<5	<5	48	93
Conductivity (umho/cm)	37.7	88.66	56.44	61.35	62.5	63.58	74.2	87.8	51.23	51.9	59.8	42.6	43	42.8	41.9	42.1	45.1	42.22	45.13	42.3	45.7	50.6
pH	5.8	7.6	6.6	7.2	6.2	7.6	6.5	6.3	7.2	6.6	6.3	6.9	6.2	6.3	6.1	5.8	5.9	6.1	6.6	6.4	6.3	6.5
Turbidity (NTU)	0.53	25.2	7.49	0.95	1.09	1.69	2.02	16.5	0.53	0.95	25.2	1.13	1.38	1.15	1.28	10.15	11.8	0.8	2.24	0.85	3.5	7.72
Alkalinity as CaCO3 (mg/L)	<3	24	9.7	<3.0	3.4	4.2	3.4	24	<3.0	<3.0	9.5	<3.0	<3.0	<3.0	<3.0	<3.0	5	<3.0	<3.0	<3.0	4.2	10
Chloride (mg/L)	7.3	16	10.5	14	13	13	14	11	10	10	10	8.2	8.1	8	8	8.3	8.3	8.6	8.5	8.3	8.2	8.6
Colour (TCU)	16	202	59	53	60	52	68	202	23	25	87	55	64	42	39	45	152	29	40	31	57	137
Silica (mg/L)	1.1	5.1	1.8	1.2	1.2	<1.0	<1.0	5.1	1.5	1.3	2.8	1.7	1.5	1.2	<1.0	<1.0	1.6	<1.0	1.7	<1.0	1.1	2.1
Sulfate (mg/L)	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5.	<5	<5.00	<5	<5	<5
Total Nitrogen (mg/L)	0.17	2.95	0.62	0.47	0.57	0.39	1.69	2.95	0.21	0.22	0.4	0.27	0.27	0.27	0.25	0.24	0.8	0.24	0.24	0.21	0.19	0.62
Total Phosphorus (mg/L)	0.005	5.2	0.29	0.051	0.069	0.39	0.74	**5.2**	0.009	0.012	0.021	0.021	0.033	0.017	0.014	0.018	0.097	0.009	0.014	0.011	0.023	0.097
Nitrate + Nitrite (mg/L)	<0.01	0.35	0.09	<0.01	0.03	<0.01	0.35	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.03	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Ammonia (mg/L)	<0.01	1.93	0.19	0.08	0.12	0.04	0.11	1.93	<0.01	0.04	0.18	0.02	0.02	0.03	0.3	0.05	0.41	0.03	<0.01	0.02	0.02	0.39
Ortho Phosphorus (mg/L)	0.005	3.44	0.39	0.03	0.034	0.34	0.58	**3.44**	<0.005	<0.005	<0.005	<0.005	0.012	0.005	<0.005	0.008	0.051	<0.005	<0.005	<0.005	<0.005	0.055
Total Dissolved Solids (mg/L)	6	100	56.43	62.5	52.5	60	100		42.5	50		45	57.5	50	47.5			60		80		
Suspended Solids (mg/L)	<3.0	16	6.50	<3.0	<3.0	<3.0	<3.0		<3.0	<3.0		5	<3.0	<3.0	<3.0			<3.0	3	<3.0		
Total Organic Carbon (mg/L)	4.2	16.7	6.70	7.1	7.6	8.6	9.9	16.7	4.2	4.6	5.3	7.2	8.2	6.3	5.9	5.5	8.8	4.9	6.2	5.4	6	7.6
Chlorophyll A (ug/L) *<corrected>*	1.9	84	22.2	4.5	15	8.1	20		1.9	7.8		9.1	11	11	10			4.4	7	5.8		
SD Transparency (m)	0.85	3.0	1.57		1.3		1.3			2.5			1.5		1.8					2.3		
TN / TP Ratio					8/1		2/1			18/1			8/1		18/1					19/1		

Table 2

SL- Shoreline Sample

			Lake	**VAUGHAN LAKE**				**PROVOST LAKE**		**NOWLANS LAKE**				
			Sample Location	*SL*	*ML*	*ML*	*ML*	*SL*	*ML*	*SL*	*SL*	*SL*	*SL*	*ML*
			Sample ID	VL-SL1	VL-DS1	VL-DS1	VL-DS1	PROL-SL1	PROL-DS1	NL-SL1	NL-SL2	NL-SL3	NL-SL1	NL-DS1
			Depth (m)	0.25	0	9.5	14	1.5	0	0.6	0.6	0.6	0.5	0
			Date Sampled	5-Sep	5-Sep	5-Sep	5-Sep	27-Aug	15-Aug	28-Aug	28-Aug	28-Aug	15-Oct	14-Aug
Water Quality Parameters	**Min**	**Max**	**Mean**											
Aluminum (ug/L)	13	449	108	152	51	144	192	105	105	29	39	29	24	**13**
Calcium (mg/L)	0.9	4.6	1.8	1.1	1.1	1.5	1.5	0.9	0.9	4.2	4	3.9	3.5	3.7
Copper (ug/L)	<2	45	27	<2	<2	18	31	<2	<2	<2	<2	<2	<2	<2
Iron (ug/L)	153	9661	1405	250	160	3779	6899	354	452	739	500	451	153	323
Magnesium (mg/L)	0.6	1.8	0.99	0.6	0.7	0.8	0.8	0.7	0.7	1.8	1.8	1.7	1.7	1.8
Hardness as CaCO3 (mg/L)	5.1	18.5	8.6	5.2	5.6	7	7	5.1	5.1	17.9	17.4	16.7	15.7	16.6
Manganese (ug/L)	24	1774	342.9	28	39	1774	1317	37	63	213	256	194	40	211
Potassium (mg/L)	<0.5	2.1	1.1	<0.5	<0.5	<0.5	0.5	0.5	0.5	2.1	1.9	2	2	1.8
Sodium (mg/L)	4.3	9.3	6.1	4.3	4.9	4.7	4.7	5	4.9	9.2	9.1	9.3	9.3	8.8
Zinc (ug/L)	<5	154	76.11	<5	<5	81	154	<5	<5	<5	<5	<5	<5	<5
Conductivity (umho/cm)	37.7	88.66	56.44	37.7	41.4	50.3	48.8	41.06	43	87.1	86.75	87.23	88.66	85.3
pH	5.8	7.6	6.6	7.2	6.3	6.3	6.3	6.2	6.1	7	7.5	7.5	7.6	6.5
Turbidity (NTU)	0.53	25.2	7.49	0.64	0.71	12.8	7	2.47	2.6	22.1	20.7	24.3	20.8	19.6
Alkalinity as CaCO3 (mg/L)	<3	24	9.7	<3.0	<3.0	8.1	9.1	<3.0	<3.0	13	14	13	13	12
Chloride (mg/L)	7.3	16	10.5	7.3	8	8.7	8.4	8.2	8.4	16	16	16	16	15
Colour (TCU)	16	202	59	52	22	94	148	35	32	20	52	19	32	16
Silica (mg/L)	1.1	5.1	1.8	<1.0	<1.0	1.5	1.7	<1.0	<1.0	1.7	1.6	1.7	3.2	1.5
Sulfate (mg/L)	<5	<5	<5	<5	<5	<5	<5	<5	<5.	<5	<5	<5	<5.00	<5
Total Nitrogen (mg/L)	0.17	2.95	0.62	0.21	0.17	0.45	0.73	0.36	0.45	1.59	0.86	1.17	1.24	1.01
Total Phosphorus (mg/L)	0.005	5.2	0.29	0.007	0.005	0.012	0.045	0.011	0.011	0.35	0.34	0.46	0.23	0.4
Nitrate + Nitrite (mg/L)	<0.01	0.35	0.09	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.03	<0.01
Ammonia (mg/L)	<0.01	1.93	0.19	0.02	<0.01	0.26	0.56	0.08	0.03	0.01	0.02	0.06	<0.01	<0.01
Ortho Phosphorus (mg/L)	0.005	3.44	0.39	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.28	0.24	0.3	0.17	0.3
Total Dissolved Solids (mg/L)	6	100	56.43	45	25	6	7.9	70	60	90	62.5	82.5		85
Suspended Solids (mg/L)	<3.0	16	6.50	<3.0	<3.0	<3.0	<3.0	<3.0		<3.0	<3.0		12	6
Total Organic Carbon (mg/L)	4.2	16.7	6.70	6.7	4.4	-	-	5.8	5.2	6.1	6.1	6.1	6.3	6.2
Chlorophyll A (ug/L) *<corrected>*	1.9	84	22.2	6.8	3.9	-	-	7.5	18	58	60	68	84	67
SD Transparency (m)	0.85	3.0	1.57		3.0				1.7					0.85
TN / TP Ratio					34/1				41/1					3/1

Dissolved Oxygen/ Temperature Profiles 2008

Table 3

Sample Site	**PROL-DSI-OM PROVOST LAKE**		**NL-DSI-OM NOWLANS LAKE**		**HL-DSI-OM HOUR GLASS LAKE**		**PLAL-DSI-0M PLACIDES LAKE**		**PORL-DS1-OM PORCUPINE LAKE**		**PARL-DSI-OM PARR LAKE**		**OL-DSI-OM ODGEN LAKE**		**FL-DS1-0M FANNING LAKE**		**VL-DS1-0M VAUGHN LAKE**	
Date	14-AUG-08		14-AUG-08		14-AUG-08		14-AUG-08		13-Aug-08		14-AUG-08		15-AUG-08		13-Aug-08		05-Sep-08	
Depth (m)	***Temp. (C)***	***DO (mg/L)***	***Temp. (C)***	***DO (mg/L)***	***Temp. (C)***	***DO (mg/L)***	***Temp. (C)***	***DO (mg/L)***	***Temp. (C)***	***DO (mg/L)***	***Temp. (C)***	***DO (mg/L)***	***Temp. (C)***	***DO (mg/L)***	***Temp. (C)***	***DO (mg/L)***	***Temp. (C)***	***DO (mg/L)***
0	21.2	6.7	21.5	6.9	21.1	6.4	21.5	7.1	23.6	7.1	21.7	6.6	21.3	6.5	23.5	7.31	20.6	7.0
1	21.2	6.6	21.5	6.7	21.1	6.2	21.5	6.9	23	7.1	21.7	6.8	21.3	6.5	22.8	7.51	20.6	6.8
2	21.2	6.6	21.4	6.1	21.1	6.2	21.2	6.1	21.8	6.9	21.7	6.4	21.3	6.6	22.4	7.30	20.6	6.7
3	21.1	6.5	21.4	6.1	20.9	5.5	20.9	5.0	21.5	6.7	21.7	6.5	21.3	6.6	22.3	7.17	20.6	6.7
4	21.1	6.3	21.2	4.4	17.3	1.3	20.6	4.0	21.4	6.5	21.7	6.4	21.3	6.6	22.2	6.92	20.5	6.5
5	21.1	6.3	20.9	1.9	13.5	1.4	17.2	1.1	21.2	6.5	21.7	6.3	21.3	6.6	22.1	6.6	20.3	6.4
6			18.6	1.0	12.5	1.5	13.5	1.1	19.8	1.9	21.7	6.4	21.3	6.4	20.6	0.56	20.2	6.2
7			17.2	1.0			12.7	1.0	15.5	1.5			20.7	4.5	18.1	0.13	19.8	5.7
8			16.9	0.9									18.0	1.5			19.4	5.2
9													15.2	2.9			17.1	0.9
10													14.5	2.4			14.7	0.6
11													14.0	2.8			13.9	0.6
12													13.4	2.3			13.3	0.6
13													13.0	1.3			13	0.5
14													12.8	1.0			12.8	0.5
15													12.7	0.8			12.4	0.5
16													12.7	0.7				
17													12.6	0.7				
18													12.5	0.7				

Historic Water Quality 1983-2002

Table 4

LAKE NAME	DEPTH(M)	SAMPLING DATE	LAB. NO.	LATITUDE	LONGITUDE	COUNTY	NTS	WATERSHED #	HEADWATER LAKE	COND. uohm/cm	pH UNITS	NA mg/l	K mg/l	CA mg/l	MG mg/l	HARDNESS mg/l as CaCO3	ALK. mg/l as CaCO3	SO4 mg/l	CL mg/l	SI mg/l
HOURGLASS	SURFACE 0M	1983-09-01	P4839	44* 20'	65* 56'	DIGBY	21A5	1EA3HH	Y	44.5	5.81	5.2	0.44	1.12	0.94		2.5	3.8	7.8	
HOURGLASS	THERMOCLINE 5M	1983-09-01	P4840	44* 20'	65* 56'	DIGBY	21A5	1EA3HH	Y	50.7	6.11	5.6	0.47	2.35	1.05		7.2	3.2	8.3	
HOURGLASS	BOTTOM 7M	1983-09-01	P4841	44* 20'	65* 56'	DIGBY	21A5	1EA3HH	Y	53.0	6.11	5.3	0.55	2.74	1.27		8.7	2.2	8.5	
PARR	SURFACE 0M	1986-07-03	P8279	44* 05'	65* 54'	YARMOUTH	21A4	1EA3HH	N	46.6	5.78	4.74	0.29	1.27	0.77		1.04	3.9	7.8	
OGDEN	SURFACE 0M	1986-07-09	P8275	44* 03'	65* 54'	YARMOUTH	21A4	1EA3HH	N	46.0	6.19	4.67	0.34	1.31	0.76		1.2	4.1	7.9	
FANNING	SURFACE 0M	1986-07-10	P8349	44*01'	65*55'	YARMOUTH	21A4	1EA3HH	N	45.6	5.53	4.8	0.3	1.36	0.79		1.32	4.1	6.9	
PROVOST	SURFACE 0M	1983-09-26	P4916	44* 21'	65* 51'	DIGBY	21A5	1DB1D	Y	38.9	5.88	4.4	0.46	0.94	0.68		1.8	3.6	6.6	
PROVOST	BOTTOM 8M	1983-09-26	P4917	44* 21'	65* 51'	DIGBY	21A5	1DB1D	Y	36.7	5.57	4.1	0.33	0.93	0.67			3.7	6.3	
NOWLANS	SURFACE 0M	1983-09-27	P4910	44* 19'	65* 56'	DIGBY	21A5	1DA2N	Y	60.4	6.23	5.9	1.2	2.66	1.31		7.7	3.4	9.4	
NOWLANS	BOTTOM 7.5M	1983-09-27	P4911	44* 19'	65* 56'	DIGBY	21A5	1DA2N	Y	63.7	6.01	5.9	1.2	2.61	1.31		6.5	3.7	9.4	
PARR	SURFACE 0M	2002-10-29	270169	44* 05'	65* 54'	YARMOUTH	21A4	1EA3HH	N	42.8	6.3	5.1	0.3	1.3	0.8	6.54	2	3.8	8.2	2.1
OGDEN LAKE POND	SURFACE 0M	1984-09-04	P6354	44* 03'	65* 54'	YARMOUTH	21A4	1EA3HH	N	45.8	5.27	5.4	0.73	1.6	1.02		2.2	3.8	7.6	

Table 4

LAKE NAME	ORTHO P mg/l	TOTAL P mg/l	NO3+NO2 mg/l	NH3 mg/l	TOTAL N mg/l	T.O.C. mg/l	ACIDITY	COLOR TCU	TURBIDITY mg/l	AL ug/l	FE ug/l	MN ug/l	CHLOROPHYLL A mg/m3	TDS mg/l	SS mg/l	Secchi Disk Transparency (M)	AGENCY
HOURGLASS	0.002	0.012	<0.01	0.01	0.29	7.4	5.4	30	1.7	110	241	21				3.0	NSL&F
HOURGLASS	<0.001	0.011	<0.01	0.01	0.41	7.3	8.8	55	7.4	210	2410	316				NA	
HOURGLASS	0.001	0.045	0.27	0.01	0.46	7	16.5	55	15.0	810	4650	429				NA	
PARR		0.006	<0.01		0.23	6.9	6.1	55	0.6	117	183	20				2.8	NSL&F
OGDEN		0.004	<0.01		0.19	5.9	5.2	40	0.6	78.3	66.4	5.19				1.3	NSL&F
FANNING		0.004	<0.01		0.17	6.1	4.54	25	0.8	128	150	19				1.6	NSL&F
PROVOST	<0.001	0.003	<0.01	0.15	0.57	4.6	5.7	15	1.1	61	44	9				4.0	NSL&F
PROVOST	<0.001	0.003	<0.01	<0.01	0.19	4	6.3	15	14.0	1290	956	74				NA	
NOWLANS	0.002	0.006	<0.01	0.3	0.56	5.4	7.7	5	3.2	27	696	296				1.0	NSL&F
NOWLANS	0.02	0.025	<0.01	<0.01	0.78	5	10.2	10	4.5	290	1100	410				NA	
PARR	<0.001	0.012	<0.01	0.02	0.18	5.7		27	0.8	50	150	24	2.7	24		NA	NSDOF
OGDEN LAKE POND	<0.001	0.025	<0.01	0.02	0.51	20	8.3	150	1.4	440	510	23.4					

APPENDIX D

Algae Speciation, Cell Counts, & Toxin Levels 2008

Table 5 ML *Mid-Lake Sample* SL *Shore Sample*

Lake	PROVOST LAKE		NOWLANS LAKE					HOURGLASS LAKE		PLACIDES LAKE		PORCUPINE LAKE		PARR LAKE		ODGEN LAKE		FANNING LAKE			VAUGHAN LAKE	
Sample Location	*ML*	*SL*	*ML*	*SL*	*SL*	*SL*	*SL*	*ML*	*SL*	*ML*	*SL*	*ML*	*SL*	*ML*	*SL*	*ML*	*SL*	*ML*	*SL*	*SL*	*ML*	*SL*
Sample ID	PROL-DSI	PROL-SL1	NL-DSI	NL-SL1	NL-SL2	NL-SL3	NL-SL	HL-DSI	HL-SLI	PLAL-DSI	PLAL-SL1	PORL-DS1	PORL-NS1	PARL-DSI	PARL-SL1	OL-DSI	OL-SL1	FL-DS1	FL-NS1	FL-SL	VL-DS1	VL-SL1
Depth (m)	0	1.5	0	0.6	0.6	0.6	0.5	0	1.5	0	0.7	0	0.7	0	0.25	0	0.25	0	1.0	0.5	0	0.25
Date Sampled	14-Aug	27-Aug	14-Aug	28-Aug	28-Aug	28-Aug	15-Oct	14-Aug	27-Aug	14-Aug	27-Aug	13-Aug	28-Aug	14-Aug	04-Sep	15-Aug	4-Sep	13-Aug	28-Aug	15-Oct		5-Sep
Taxonomy																						
Actinastrum (Chlorophyceae)	-		-					-		small number				-		-						
Anabaena (Myxophyceae)	small number	484	small number	1230	704	2000	1620	-	-	-	-		-	small number	824	small number	940		24.0	5140		-
Anabaena (Myxophyceae)							mod. amnt													mod. amnt.		
Ankistrodesmus (Chlorophyceae)							-													small amount		
Aphanizomenon (Myxophyceae)		8.0		272	688	640	608		48.0		64.0		-		1390		256		72.0	-		408
Aphanizomenon (Myxophyceae)	-		small number				small amount	-		-				-		-				-		
Asterionella (Bacillariophyceae)	small number		-				-	-		-				-		small number				small amount		
Blue Green Algae	-	492	24352	104000	78800	95600	98100	-	48.0	2800	64.0		56.0	-	2220	-	1210		128	5160		408
Ceratium (Peridineae)	-		small number					-		-				-		-						
Chlamydomonas (Chlorophyceae)							small amount													small amount		
Closterium (Chlorophyceae)							small amount													small amount		
Coelastrum (Chlorophyceae)							small amount													-		
Cosmarium (Chlorophyceae)							-													small amount		
Crucigenia (Chlorophyceae)							-													small amount		
Cryptomonas (Cryptophyceae)	small number		small number				-	small number		small number				small number		small number				small amount		
Cyclotella (Bacillariophyceae)	-		small number					-		-				-		-				small amount		
Dictyosphaerium (Chlorophyceae)	small number		-				small amount	-		small number				small number		-				Small amount		
Dinobryon (Chrysophyceae)							-													small amount		
Eudorina (Chlorophyceae)	-		small number					-		small number				-		-						
Fragilaria (Bacillariophyceae)	-		-					small number		-				-		-						
Gomphosphaeria (Myxophyceae)		-		73500	61200	75400	95000		-		-		-		-		-		-	-		-
Gomphosphaeria (Myxophyceae)							large amount													-		
Kirchneriella (Chlorophyceae)	-		-					-		small number				-		small number						
Mallomonas (Chrysophyceae)	-		-				small amount	small number		small number				small number		small number				small amount		
Melosira (Bacillariophyceae)	small number		small number					small number		mod number				-		-						
Microcystis (Myxophyceae)	-	-	mod. number	28600	16200	17600	840	-	-	-	-		-	-	-	-	-		-	-		-

Algae Speciation, Cell Counts, & Toxin Levels 2008

Table 5

ML *Mid-Lake Sample* SL *Shore Sample*

Lake	PROVOST LAKE		NOWLANS LAKE					HOURGLASS LAKE		PLACIDES LAKE		PORCUPINE LAKE		PARR LAKE		ODGEN LAKE		FANNING LAKE			VAUGHAN LAKE	
Sample Location	*ML*	*SL*	*ML*	*SL*	*SL*	*SL*	*SL*	*ML*	*SL*	*ML*	*SL*	*ML*	*SL*	*ML*	*SL*	*ML*	*SL*	*ML*	*SL*	*SL*	*ML*	*SL*
Sample ID	PROL-DSI	PROL-SL1	NL-DSI	NL-SL1	NL-SL2	NL-SL3	NL-SL	HL-DSI	HL-SLI	PLAL-DSI	PLAL-SL1	PORL-DS1	PORL-NS1	PARL-DSI	PARL-SL1	OL-DSI	OL-SL1	FL-DS1	FL-NS1	FL-SL	VL-DS1	VL-SL1
Depth (m)	0	1.5	0	0.6	0.6	0.6	0.5	0	1.5	0	0.7	0	0.7	0	0.25	0	0.25	0	1.0	0.5	0	0.25
Date Sampled	14-Aug	27-Aug	14-Aug	28-Aug	28-Aug	28-Aug	15-Oct	14-Aug	27-Aug	14-Aug	27-Aug	13-Aug	28-Aug	14-Aug	04-Sep	15-Aug	4-Sep	13-Aug	28-Aug	15-Oct		5-Sep
Microcystis (Myxophyceae)							small amount													-		
Monoraphidium (Chlorophyceae)	-		-				-	small number		small number				-		-				small amount		
Navicula (Bacillariophyceae)	-		-					-		small number				-		-						
Nitzschia (Bacillariophyceae)							-													small amount		
Oocystis (Chlorophyceae)							small amount													-		
Oscillatoria (Myxophyceae)	-	-	-	-	-	-		-	-	small number	-		56.0	small number	-	-	16.0		32.0			-
Pediastrum (Chlorophyceae)	-		small number				small amount	-		-				-		-				-		
Peridinium (Peridineae)	small number		-					-		-				small number		-						
Pseudoanabaena (Myxophyceae)							-													6.0		
Pseudoanabaena (Myxophyceae)							-													small amount		
Rhodomonas (Cryptophyceae)	small number		small number				-	small number		small number				small number		-				small amount		
Scenedesmus (Chlorophyceae)	-		-				-	-		small number				-		-				small amount		
Small Chrysophytes (Chrysophyceae)	-		-					small number		small number				-		small number						
Spondylosium (Chlorophyceae)							-													small amount		
Staurastrum (Chlorophyceae)	small number		small number				small amount	-		-				small number		-				-		
Synedra (Bacillariophyceae)	-		-				-	-		small number				-		-				small amount		
Synura (Chrysophyceae)							-													small amount		
Tabellaria (Bacillariophyceae)	-		-					-		-				-		small number						
Trachelomonas (Euglenophyceae)	-		-					small number		small number				small number		small number						
Ulothrix (Chlorophyceae)	-		-					-		-				-		small number						
Organic Parameters																						
Microcystin	-	<0.2	0.2	0.3	0.3	0.3	<0.2	-	<0.2	<0.2	<0.2		<0.2	-	<0.2	-	<0.2		<0.2	<0.2		<0.2
XNo class																						
Planktolyngbya (Myxophyceae)							small amount													small amount		
Planktolyngbya (Myxophyceae)							2.0													17.0		