Pockwock Lake Water Quality Assessment

Effects of Forest Harvesting Activity on Surface Water Quality

Final Report

Prepared by

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For

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EXECUTIVE SUMMARY

The Centre for Water Resources Studies, Dalhousie University, was contracted by NSEL to assist in a review and assessment of water quality data collected by the Department as part of its contribution to the Pockwock-Bowater Watershed Project (PBWP).

The Pockwock-Bowater Watershed Project (PBWP), a multi-disciplinary study, was initiated in the spring of 1999 to assess effects of forest harvesting activities on various components of terrestrial and aquatic ecosystems.

The main objectives of the lake study were to assess changes in lake-water quality resulting from forest harvesting activities in the watershed, with the primary areas of interest relating to acidification, eutrophication, siltation, and the drinking water supply.

The study focused on tributary and lake water quality. Peggy Brook, tributary of the "Control" watershed, and Moose Cove Brook, tributary of the "Treated" watershed, were selected as the test drainages. Three stations were identified on these brooks, 1 on Peggy Brook and 2 on Moose Cove Brook. A total of 8 stations were established on Pockwock Lake, of which 6 (4 near-shore and 2 deep-lake) were maintained for the duration of the monitoring period.

The harvested area in the Moose Cove Brook watershed involved 18.8 hectares, or approximately 16.7 percent of the total area. Harvesting occurred between June 28 and October 17, 2001. Although the Peggy Brook watershed served as the "Control" for the study, a small amount of pre-commercial thinning did take place during the summer of 2002.

The period of record under review was May 1999 to November 2003.

Subtle changes in water quality were observed in Moose Cove Brook during the harvesting period. However, similar changes were also recorded in Peggy Brook draining the control watershed. Upon review of the hydrologic data, these changes were

considered to be related to factors associated with stream flow and not the harvesting itself. It was discovered that water levels in Peggy Brook were extremely low during the entire harvesting period, a situation presumed duplicated in Moose Cove Brook. During baseflow conditions, groundwater chemistry plays more of a role in the determination of stream water quality. Low-flow conditions coincidentally came to an end with the cessation of harvesting activity. A 68mm rainfall event caused flows in the brook to increase dramatically from less than 5 L^{-sec} to more than 390 L^{-sec}, accompanied by elevated levels of conductivity. Because of the predominance of baseflow conditions during the harvest period and the similarity between water chemistries in both the control and treated watershed streams, suspicions are that the changes in water quality are more likely a reflection of normal seasonal and annual variation.

Based on the application of total phosphorus, chlorophyll_a, and Secchi disk measurements to a fixed-boundary classification system, the trophic status of Pockwock Lake is considered to be oligotrophic.

There was no indication that the forest harvesting had an impact on suspended solids and turbidity levels in receiving waters. Whether this was an effect of the frequency of sample collection or the BMPs applied to the site is uncertain.

The harvesting also appeared not to have an impact on the acidity of stream runoff. Annual mean pH measurements for the both the control and treated watersheds remained constant throughout the entire study period.

CCME water quality guidelines for drinking water use and freshwater aquatic life were compared with Pockwock Lake stations DS2 and DS4 data. With the exceptions of aluminum, pH, manganese, and turbidity, all measured values at the two lake stations were below CCME limits in both categories. The majority of aluminum, pH and manganese measurements taken during the study period were above the limits and the exceedences evenly distributed throughout the study period. This suggests that this is a normal occurrence and not a reflection of the harvesting activity. While none of the readings taken at the deep-lake station (DS2) exceeded the drinking water limit for turbidity, only 4 of 46 turbidity readings at Station DS4 were seen to exceed that limit.

A preliminary review of the NSEL precipitation study has been included in this report. Prior to any further examination of the data, adjustment of the database for missing data would need to be performed.

Recommendations

1. Integrate findings of all studies carried out in the Pockwock Lake watershed in a summary report.
2. Examine reason why EXCEL files generated from the water quality database contain alphanumeric values.
3. Address the issue of missing data in the NSEL precipitation database.
4. Address the issue of duplicate data in the NSEL water quality database.
5. With safety in mind, attempt to collect water quality data from Pockwock Lake deep-lake station DS2 at sometime during the period of ice cover, preferably in February.
6. Expand water quality monitoring program to include monthly sampling for Pockwock Lake at either DS2 or DS4, or a combination of both. The purpose of this is to maintain an on-going surveillance of the drinking water resource.
7. Install a hydrologic metering station on Moose Cove Brook to document daily flows.

ACKNOWLEDGEMENTS

A considerable amount of time and effort went into the design and implementation of the water quality and quantity monitoring programs associated with this study. The lead investigator responsible for program design and co-ordination was Mr. Darrell Taylor of Nova Scotia Environment & Labour (NSEL).

Surface water sample collection duties were shared by Mr. Joe MacCarthy and Mr. John Gass of Halifax Regional Water Commission (HRWC) and Mr. Alan Tattrie of NSEL. Program logistics were handled by Mr. Jeremy Beals and Mr. John Gass of HRWC. Boat and motor arrangements were looked after by Mr. Peter Flinn with support by other treatment plant staff.

Management of all surface water quality data was provided by Mr. Alan Tattrie and Mr. Charlie Williams of NSEL.

Hydrometric data considered in this report was gathered by Environment Canada (EC) under the direction of Mr. Fred Lindeijer. Mr. Todd Smith of the Environmental Conservation Branch of Environment Canada was responsible for the management of the data.

The Hydrolab pilot project was commissioned by Mr. Joe Pomeroy and Mr. Todd Smith of EC. Installation and maintenance of the hydrolab unit were performed by Mr. Joe MacCarthy of HWRC.

The precipitation monitoring program was carried out by Mr. Johnny MacPherson of NSEL. Excel files were supplied to CWRS by Ms. Fran Di Cesare.

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1.0 BACKGROUND

The Pockwock-Bowater Watershed Project (PBWP), a multi-disciplinary study, was initiated in the spring of 1999 to assess effects of forest harvesting activities on various components of terrestrial and aquatic ecosystems. The intent of this research project, in part, was to determine suitable Best Management Practices (BMPs) which would support sustainable forestry while ensuring the protection of water resources. Another aspect was to see if findings from the Hayward Brook Studies in the Fundy Model Forest would be duplicated in this particular geographical setting.

One component of the PBWP, the Pockwock Lake study, was initiated by the NSEL, supported by Halifax Regional Water Commission and Environment Canada staff, to examine trends in lake water quality during pre- and post-harvest periods. Given that the lake is used as a drinking water supply for the Halifax Regional Municipality, the main objective of the study was to determine whether these harvesting activities had any impact on lake water quality. Tributary stream, lake height, and precipitation monitoring were included in this study to aid interpretation of results.

An overall description of the PBWP study approach is as follows, as outlined in Annual Reports for 2002 and 2003: “The study is located in central Nova Scotia near Halifax on the western limits of the Nova Forest Alliance region. Four sub-watersheds within the Pockwock Lake watershed and four watersheds within the Five Mile Lake watershed will be monitored. One sub-watershed in each area will receive no forest treatments and will be considered a “control”. The other three sub-watersheds in each area will have approximately 25-40 percent of the timber clear cut up to a buffer zone along each watercourse. One sub-watershed will maintain a 20 metre buffer without harvesting, a second will maintain a 20metre buffer in combination with a selection harvest and, the third watershed will have a 30 metre buffer in combination with a selection harvest.”

To examine the potential effects on surface water quality, the lake study focused its efforts on Pockwock Lake and two tributaries, Peggy Brook and Moose Cove Brook. Peggy Brook watershed was to serve as the “Control” watershed, while Moose Cove

Brook watershed acted as the “Treated” watershed. The extent of the harvesting in these two sub-watersheds has been described elsewhere by McCurdy et al. (2003). In brief, 18.8 hectares, or approximately 16.7 percent of the total Moose Cove Brook sub-watershed area were harvested between June 28 and October 17, 2001. Although it was the intention to use the Peggy Brook sub-watershed as the “Control” for the study, pre-commercial thinning of 3.4 hectares approximately 400 meters from the confluence of Peggy Brook and Pockwock Lake (east side of Peggy Brook, south of main road) occurred during the summer of 2002. In addition, two box culverts were installed on the access road to this site. Drainage through these culverts emptied directly into Peggy Brook (Beal, 2004).

The Centre for Water Resources Studies, Dalhousie University, was contracted by NSEL to assist in a review and assessment of water quality data collected by the Department as part of its contribution to the PBWP. The main objectives of the lake study were to assess changes in lake-water quality resulting from forest harvesting activities in the watershed, with the primary areas of interest relating to acidification, eutrophication, siltation, and the drinking water supply.

The period of record under review is May 1999 to November 2003.

2.0 INTRODUCTION

Several authors have investigated the impact of forestry operations on surface waters (Bormann et al. 1968; Likens et al. 1969; Freedman, 1980; Hornbeck et al. 1982; Likens 1985). From this research, it has been found that in some situations, forest harvesting can result in significant losses of soils and nutrients by erosion and leaching. It has been documented that the observed losses are highly variable, due to several factors – type of forest activity and techniques applied, soil type, topography, and meteorology. The proportion of the forestry operation to the watershed and proximity to receiving waters are other factors.

Impacts noted from this research included:

- increased runoff resulting in higher streamflows,
- increase in loss of soluble nutrients, e.g. nitrogen (mainly as nitrate), calcium, potassium, magnesium, sodium, and aluminum,
- increase in erosional potential due to the disturbance of forest soils resulting in higher streamflow suspended solids concentrations,
- increase losses of particulate phosphorus associated with increases in suspended solids,
- increase in streamflow temperature,
- increase in hydrogen ion concentration in soil and stream water, and
- decrease in sulfate concentration.

In Freedman's review (1980) it was pointed out that with the exception of the Hubbard Brook Experimental Forest studies, few other studies found similar order of magnitude nutrient losses. A few of the studies reported minimal or no effects which demonstrates the high variability in the site to site susceptibility of nutrient loss via this mechanism.

Although the above impact list includes findings associated with more than just water quality, the focus of this report will be directed toward water quality only.

3.0 METHODS

During the study period, water quality and quantity data was collected to characterize surface water resources in the Pockwock Lake watershed. The water quality program described here was carried out by NSEL. Water quantity measurements were undertaken by Environment Canada and are described in detail elsewhere. Although a precipitation monitoring program was undertaken by NSEL in a separate study and will be the subject of future reporting, this document contains a brief description of the program and includes very preliminary summary of results.

3.1 Surface Water Quality Monitoring Program

During the open-water season between 1999 and 2003, a monthly sampling program was undertaken in the Pockwock Lake watershed whereby physical and chemical characteristics of lake and stream water were documented. The main focus of the study focused on the potential impacts of the forest harvesting on water quality in general, with special interests in lake eutrophication and trophic status, siltation, acidification, and drinking water quality. Water quality parameters measured included pH, conductivity, colour, nutrients, chlorophyll$_a$, major ions, and heavy metals. A complete list of chemical and biological parameters selected for the program is provided in Appendix I, Table AI.1.

The original program design incorporates eleven sampling locations. Three are deep-lake stations positioned along the mid-line of the lake, one is located in the Douglas Kline Treatment Plant pumping station forebay, two are stream-lake confluences, two are within 100 metres of the these confluence sites, and three are in-stream locations. Table 1 provides water sampling station codes and site descriptions. Figure 1 identifies sampling locations within the Pockwock Lake watershed.

3.1.1 Water Sampling Sites

3.1.1.1 Deep-Lake Stations

At the start of the program, lake water was tested at three deep-station locations, DS1, DS2, and DS3. The purpose of multiple stations was to investigate the possible existence of chemical gradients in the central areas of the lake.

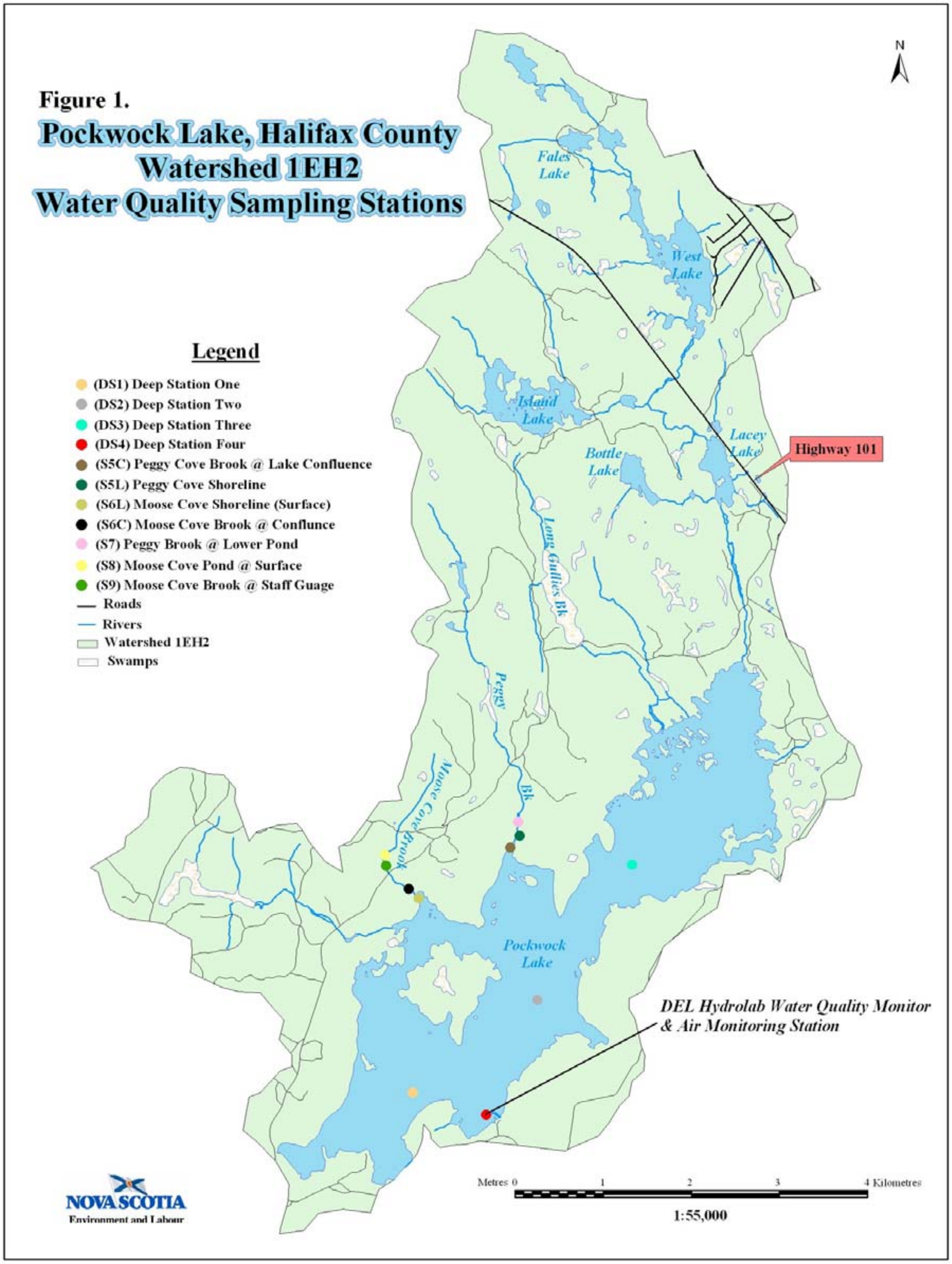


Figure 1. Pockwock Lake Watershed with water quality sampling locations.

Water samples at DS1, DS2 and DS3 were collected at various depths through the water column using a Van Dorn type water sampler. The depths chosen were 0.5 metres (m) below the surface (hereafter referred to as “surface” samples), 2 m above the lake bottom (hereafter referred to as “bottom” samples), and at the thermocline, if present. Chlorophyll$_a$ concentrations were determined from surface samples and samples taken at a depth equal to twice the Secchi disk depth on that day. This depth represents the lower boundary of the euphotic zone (depth at which 1% of surface light penetrates the water column).

Table 1. Water quality monitoring program sampling stations.

Sample Station	Description
S7	Peggy Brook at Lower Pond
S8	Moose Cove Brook Pond
S9	Moose Cove Brook at Staff Gauge Above Road
S5L	Peggy Cove Shoreline
S5C	Peggy Brook at Pockwock Lake Confluence
S6L	Moose Cove Shoreline
S6C	Moose Cove Brook at Pockwock Lake Confluence
DS1	Pockwock Lake Mid-Lake Deep Station #1
DS2	Pockwock Lake Mid-Lake Deep Station #2
DS3	Pockwock Lake Mid-Lake Deep Station #3
DS4	Pockwock Lake at Pumping Station Forebay

In-situ measurements taken at each of the deep-station locations included water temperature and dissolved oxygen profiles and water transparency. The profiles were performed using a Model 57 YSI meter. A 20cm Secchi disk was used to measure water transparency.

After reviewing the results from the first two set of sampling runs (May and June 1999), it was decided that there was no discernible difference between data sets, and that only one of the deep station locations, DS2, would continue to be monitored.

3.1.1.2 In-Stream Stations

Surface water impacts from forest harvesting would presumably first appear in tributary streams. For this reason, stations on the two major receiving waters draining the cut (Moose Cove Brook) and uncut (Peggy Brook) watersheds were established. Peggy Brook (S7) maintained a single station, while two stations, a small pond through which the brook flowed (S8), and at the flow metering station (S9), were positioned on Moose Cove Brook. Water samples from the two stream sites were collected at mid-stream at mid-depth. Station S8 samples were collected near the shoreline of the pond at approximately 0.5 metres depth.

3.1.1.3 Confluence and Lake Shoreline Stations

Confluence and lake shoreline stations were established to get a feel for the distances associated with an impact zone when considering the effect of tributary stream discharge on lake water quality. The three focal points in the system used to investigate this were the brook, the mixing zone (confluence), and a short distance into the main body of the lake. Confluence and lake stations associated with Peggy Brook and Moose Cove Brook are S5C and S5L, and S6C and S6L, respectively. Monthly water samples were collected at 0.5 metre depths at all of these stations.

Figure 2. Pumphouse forebay water quality monitoring station. Hydrolab equipment used to collect real-time data.

3.1.1.4 Pumphouse Forebay Station

Water samples were collected at a depth of 5 metres in the intake basin from the lakeside access walkway of the pumphouse structure (Figure 2).

3.1.2. Water Sampling Frequency

Water samples were collected from deep-lake station DS2 on a monthly basis during the ice-free season for the period May 1999 to November 2003. For all other locations (DS4, S7, S8, S9, DS5, DS6, S5L, S6L), samples were collected monthly for the entire study period, with the exception of the occasional month when access to a particular site was impossible because of winter and/or early spring road conditions.

3.1.3 Sample Handling and Laboratory Analysis

All water samples submitted for chemical analysis were placed in 500 mL polyethylene bottles rinsed three times with sample water and kept cool and in the dark prior to shipment or delivery to the individual laboratories for processing. The CAEAL accredited labs performing the chemical analyses were the Environmental Chemistry Lab of the Queen Elizabeth II Health Sciences Centre in Halifax and the Environment Canada Lab in Moncton, New Brunswick. Sample receiving logs for the Halifax lab indicate that the majority of samples had reached this point in processing within 24 hours of collection. All had been registered within 48 hours of collection. Because of the disparity between methods used to described the QEII and EC processed water samples (the EC database does not contain collection dates and has to be cross-referenced with the QEII data using a sample ID number), an accurate indication of a comparable time frame for the EC lab was not acquired. An effort was made to look at times for the 2000 EC data set and determined that it took between 2 and 14 days after collection for registration. The effect of this extended handling time on the accuracy of the data produced is unknown.

Analytical methods undertaken at each facility are assumed to have been in accordance with established protocols such as those outlined in “Standard Methods for the Examination of Water and Waste Water” (Clesceri et al., 1998).

3.2 Hydrolab Pilot Study

A permanent automatic monitoring station employing a multi-electrode Hydrolab unit was installed at the pumphouse forebay station to collect hourly measurements for temperature, dissolved oxygen, pH, specific conductance and turbidity (Figure 2). A Datasonde Model 4 installed at the start of the pilot was replaced in 2003 with a Datasonde Model 4a. A Sutron data logger was used to store the Hydrolab data until such time that it was down-loaded and taken back to the NSEL office for entry into the main database.

3.3 Surface Water Quality Database

Water quality data gathered by NSEL is stored in a data management system using ACCESS software, and was subsequently used by CWRS in EXCEL spreadsheet format. Data were received in files that were sub-divided by year and source of information, being either the Halifax or Moncton lab. These files were cross-referenced by sample identification numbers.

3.3.1 Lake and Stream Water Quality Data Manipulation

The first step in the manipulation of data was to reorganize and compile the EXCEL files by station. A single worksheet per sampling station containing water quality data for the entire study period was the result.

Due to the brevity of the data records for in-lake stations DS1 and DS3 and their limited usefulness for this review, information for these two sites was not considered in this report.

Treatment of water quality data for the two remaining in-lake deep stations (DS2 and DS4), in-lake shoreline stations (S6L and S5L), stream stations (S7, S8 and S9), and stream-lake confluence stations (S5C and S6C) varied and shall be explained separately in the following sections.

3.3.1.1 In-Lake Deep Stations DS2 and DS4

Stations DS2 and DS4 were used to represent water quality in Pockwock Lake. To facilitate the reporting and interpretative process, the data from DS2 were volume-weighted by date for each parameter measured to produce a single volume-weighted mean value for comparison with the other lake and stream stations. Whole-lake stratum volumes from Table AI.3 in Appendix I were used in the weighting calculation. The fact that only a single sample was collected at DS4 on each sampling date negated the need for this step. Temperature and dissolved oxygen profiles indicated that the water column at this location was in a mixed state. Water samples retrieved from the 5m depth were therefore considered to be representative of the entire water column at this location. This assumption was supported by analytical testing performed during the early stages of the study.

3.3.1.2 Stream Stations S7, S8 and S9

Water quality monitoring stations were established on Peggy Brook and Moose Cove Brook, two waterways emptying into Pockwock Lake. The Moose Cove Brook sub-watershed was the site of forest harvesting activity and its drainage the focus of the potential surface water quality effects. Runoff from the Peggy Brook sub-watershed, an area void of forest harvesting, was to act as the control. Forest harvesting in the Moose Cove Brook watershed occurred between June 28 and October 17, 2001 totalling 18.8 hectares (ha) (McCurdy et al., 2003), or approximately 16.7 percent of the watershed. As previously stated, a small area in the Peggy Brook watershed was thinned during the summer of 2002.

3.3.1.3 Stream-Lake Confluence Stations S5C and S6C and In-Lake Shoreline Stations S5Land S6L

Water chemistries for stream-lake confluence stations S5C and S6C for Peggy Brook and in-lake shoreline stations S5Land S6L for Moose Cove Brook were considered to be transition chemistries between streamflow and deep station in-lake locations. For these locations, annual arithmetic means were calculated for all parameters for comparison with arithmetic or volume-weighted annual means of in-stream and in-lake locations. A summary of means is available in Table AII.1 in Appendix II.

3.4 Volume-Weighting of Water Quality Data

To facilitate the presentation and interpretation of lake and stream water quality, volume-weighting of data was carried out in two ways. The first applied the volume-weighting technique to deep-station data to generate single values for each chemical parameter measured to represent the entire water column at the time of sample collection. A detailed description of the technique used for these calculations is presented in Appendix I, Section AI.2.

The second way related to the calculation of chemical loads for Peggy Brook. At the time of report preparation, Environment Canada flow data for this brook for the years 1999-2002 were all that was available. The annual load, or total amount of each chemical constituent exported by the brook over a 12-month period, is the product of the concentration times the volume of water being discharged by the brook in a year. Where several quality measurements are available, the method used for volume-weighting is as follows. Each measured quality value in a specific water year (to maximize the usefulness of the data set available in this study, August to July was used), was multiplied by a specific volume of water. The volume equalled the amount of water flowing by the gauged site during the period of time bounded by the mid-points of the observed chemical measurements immediately preceding and following the concentration in question. The sum of these individual loads during the water year equals the total annual load. This load can then be expressed as a unit area load which is simply obtained by dividing the total annual load (i.e. kg yr^{-1}) by the area of the watershed (i.e. km^2).

3.5 Precipitation Water Quality

A precipitation study was initiated by NSEL in 1999 to assess trends in precipitation quality over time related to both acidifying substances and nutrients. Although a separate and independent study, linkages with the lake study were to help interpret any recognizable trends in lake water quality. That is, precipitation data was intended in part to provide a basis of separating atmospheric influences from watershed influences.

Manipulation of the data to address the mass balance approach to impacts of forest harvesting on receiving water quality was not possible due to the presence of missing data in the precipitation record, a procedure beyond the scope of this review. Any further review of the precipitation data set should address this issue.

3.5.1 Precipitation Study and Data Collection

3.5.1.1 Sampling Equipment

Figure 3. Precipitation collector.

Precipitation was collected using an automated system (Figure 3) with samples prepared and submitted for analysis on a weekly basis. On occasion, complete analysis was not possible due to insufficient sample volume. A list of the parameters tested are presented in Table 2

Calculations of deposition loading rates were based on a collection area of 0.0814m^2 (collection vessel diameter 32.2 cm.) (Di Cesare, 2004).

Table 2. Precipitation monitoring program analytical parameter list.

Acidity
Alkalinity
Aluminum
Ammonia
Calcium
Chloride
Conductivity
Magnesium
Nitrate
pH
Potassium
pH
Sodium
Sulfate
Total Phosphorus

4.0 RESULTS AND DISCUSSION

Section 4.1 to 4.6 deal with the surface water component of the study. Section 4.7 reviews preliminary findings of the precipitation study.

Water quality data was compiled and analyzed for 9 of the 11 sites monitored during the study period. The two stations excluded from the review were deep-lake stations DS1 and DS3, which were dropped from the monitoring program during its early stages.

Monitoring sites were visited between 18 and 48 times over the 55-month study period with levels of twenty-six chemical and physical characteristics being documented.

Data is presented either in tabular or figure format that is relevant to each of the following sections. Because of the number of tables and figures related to the section that describes the effects of forestry operations on water quality, these have been included in Appendix II. Specifically, Table AII.1 in Appendix II contains annual means for each of the 26 parameters. Figures AII.1-16, AII.17-32, AII.33-48, AII.49- 64 and AII.65 – 78 are time plots for selected parameters representing stations S7, S8, S9, DS2, and DS4, respectively.

A major weakness of the quantity data available for this review is the absence of mean daily flows for Moose Cove Brook. These were only available for Peggy Brook where an automated hydrometric station was in operation. Flow data for Moose Cove Brook was limited to instantaneous flows at the time of water sample collection. A rating curve developed for the site was used to convert manual staff gauge readings to instantaneous flow. At no other time were staff gauge readings taken. The quality of the flow record available for this tributary stream was insufficient to permit the estimation of annual chemical loads. The calculations were only possible for Peggy Brook given the more extensive flow history.

Water quality station S7 is located on Peggy Brook. The data from this site were expressed in two ways – in a time series as a concentration and as an annual load. In addition, unit area loading figures for total phosphorus were calculated and presented. Quantity data used to estimate loading figures were obtained as daily flows from Environment Canada, a PBWP partner. The area of the watershed draining to the gauged section of the brook is 226 hectares (Smith, 2004). This value was used to calculate the unit area loading of total phosphorus. Loadings for Moose Cove Brook could not be determined since similar quantity data was not available at the time of report preparation.

Water quality stations S8 (edge of pond located upstream of S9) and S9 (in-stream) are located on Moose Cove Brook. In the absence of continuous flow data, data from these two stations was presented as a series of time plots and annual arithmetic means only. Water quality data collection began in July 1999 at S8, while monitoring at S9 started about a year later in August 2000. In addition to the different of start-up dates, sampling frequencies at the two stations also differed. For the period when both stations were operational (August 2000 to November 2003), 31 samples were collected at Station S9, 15 more than for S8. It was rare that either of the two locations were sampled between January and May, due to access difficulties (poor road conditions and travel distance).

Water chemistries for stations S8 and S9 were treated separately in this report. It was suggested that because of their close proximity to each other on the watercourse, it might be possible to combine the data sets as one to generate a more complete record. However, this would not be a reasonable approach to take since the sites represent two physically different sections of the brook, one lotic (moving), the other, lentic (standing). A quick review of the data revealed chemical differences between samples collected on the same date, some considerable. It would be in error to combine both data sets into one without first evaluating the significance of those differences. This action was not undertaken in this review.

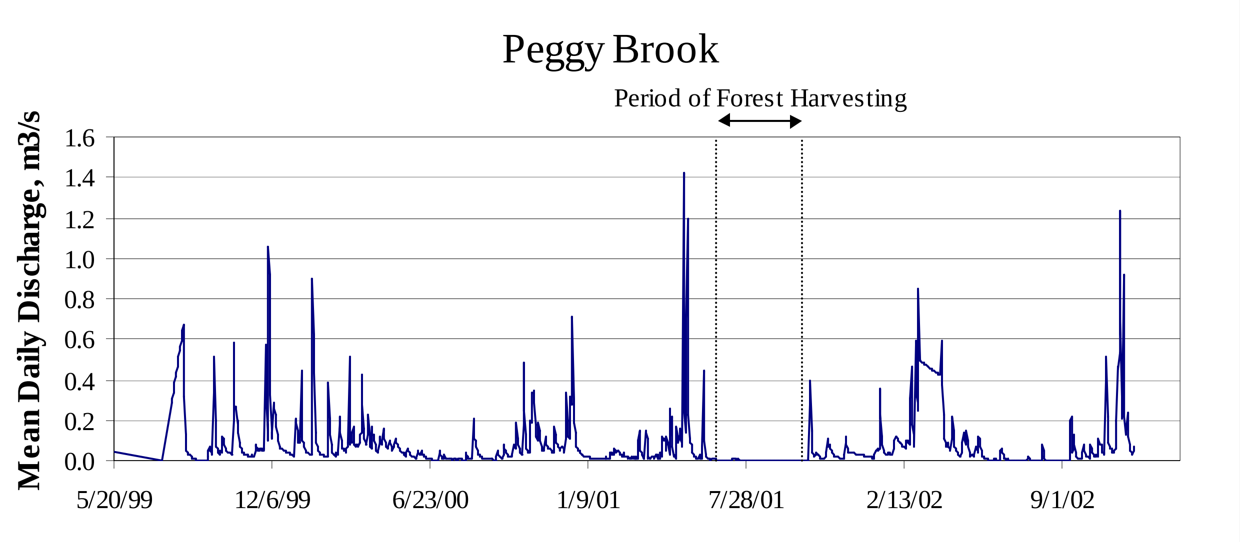
4.1 Effects of Forest Harvesting on Surface Water Quality

Water quality of runoff from two Pockwock Lake sub-watersheds, Peggy Brook and Moose Cove Brook, were used to assess the potential impacts from forest harvesting. Of the two, Peggy Brook served as the control watershed, while the Moose Cove Brook sub-watershed was the site of forest harvesting. Specific details of the harvesting activity taking place in the Pockwock Lake watershed during the period of record have been described by McCurdy et al. (2003). In brief, 18.8 hectares, or approximately 16.7 percent of the total Moose Cove Brook sub-watershed area was harvested between June 28 and October 17, 2001.

It was expected that any effect on water quality attributable to the harvesting should first be detected in Moose Cove Brook at either Station S8 and/or Station S9. The first step was to review the time plots for changes in water quality around the time of forest harvesting. The plots (Appendix II, Figures AII.17-32 (S8) and AII.33-49 (S9)) revealed an increase in concentrations above seasonal or longterm trend levels for certain parameters at some time during or within three months following the period of forest harvesting, namely alkalinity, hardness, turbidity, TOC, colour, and calcium. In the absence of chemical data for Peggy Brook, it might have been logical to consider attributing these changes to the forest harvesting. However, the changes in water quality observed in Moose Cove Brook were consistent with those changes also observed in Peggy Brook (S7), the control watershed. Exact reasons for the similarities are unknown but one factor that may have played a role is hydrology.

The hydrograph for Peggy Brook (Figure 4) indicates that flows during the entire harvesting period were minimal, between 0 and 3 L^{-sec}, quite different than flows observed during periods during pre- and post-harvest. During this period of baseflow conditions, it is suspected that the influence of groundwater chemistry on stream flow water quality would have been greatest. It would be interesting to compare findings of the groundwater component of the PBWP with stream chemistry at this time. Another occasion when constituent levels were seen to increase occurred when flows near the conclusion of harvesting (October 18, 2001) were seen to dramatically rise from baseflow levels to approximately 393 L^{-sec}. The timing of the response in stream flow is consistent with NSEL precipitation records which documented 68mm of rainfall between October 16 and 23, 2001. It is possible that the temporary shifts in water quality observed for both brooks at this time in 2001 were in response to the increased flows. The rate at which flows rebound during the fall of each year may also be a factor in the degree to which water quality is affected. For example, a flow pattern similar to that which occurred in 2001 also occurred in 2002, however, without the same response in water quality. The exact reason for this is unknown but the transition from baseline to fall flow conditions appeared to be a more gradual one in 2002 than in 2001. A question arises, what role did the combination of type of rainfall events (quantity and intensity) and antecedent soil moisture conditions occurring in the fall of 2001, as compared to those characteristic of 2002, contribute to the overall effects on stream water quality? Does the rate at which fall streamflows increase contribute to the degree to which water quality is affected? Elevated levels recorded during the October 2001 freshet were reported for pH, conductivity, hardness, turbidity, calcium, magnesium and sulfate.

Figure 4. Peggy Brook hydrograph for the study period.



Comparison of pre-, harvest, and post-harvest annual mean values presented in Table AII.1 in Appendix II for Stations S7, Peggy Brook, and S9, Moose Cove Brook, reveals a similar shift in water quality to that seen in the time series plots. The short monitoring record (4-5 years) and sampling frequency, however, makes it extremely difficult to attribute these changes in water chemistry to specific causes, especially in a stream environment where water quality is forever changing. Because of the predominance of baseflow conditions during the harvest period and the similarity between water chemistries in both the control and treated watershed streams, suspicions are that the changes in water quality are more likely a reflection of normal seasonal and annual variation.

4.2 Lake Eutrophication and Trophic Status

Eutrophication and trophic status for this review are considered in terms of nutrient enrichment, i.e. phosphorus, biological indicators, i.e. chlorophyll$_a$, and water transparency, i.e. Secchi Disk, using measurements from deep-lake stations only.

The fixed-boundary classification system for the three indicators selected are presented in Table 3.

Table 3. Trophic classification based on annual mean values for total phosphorus, chlorophylla, and Secchi depth (after Environment Canada, 2004).

Trophic Level	Total Phosphorus ug L^{-1}	Chlorophylla ug L^{-1}	Secchi Depth (m)
Oligotrophic	≤10	<2.5	>6
Mesotrophic	10-35	2.5 – 8	6 – 3
Eutrophic	≥35	≥8	≤3

Pockwock Lake (Station DS2) total phosphorus mean annual concentrations ranged from 0.005 to 0.010 mg L^{-1} (or 5 – 10 ug L^{-1}) (Appendix II, Table AII.1). Using the fixed-boundary system (Table 3) to classify the trophic status of Pockwock Lake, the lake is considered to be at or below the oligotrophic trophic boundary (<0.010 mg L^{-1} or 10 ug L^{-1}). Based on results for DS4 where mean annual total phosphorus ranged from 0.005 to 0.009 mg L^{-1},(5 – 9 ug L^{-1}) the trophic category is oligotrophic.

Pockwock Lake is also considered to be in the oligotrophic category when using chlorophylla results from both DS2 (0.4 – 0.7 mg m^3 of 0.4 – 0.7 ug L^{-1}) and 0.5 – 0.9 mg m^3 of 0.5 – 0.9 ug L^{-1}).

Secchi depth was only measured at Pockwock Lake deep-station DS2. Based on an annual mean depth ranging from 6.0 to 7.2 metres, the trophic level of the lake is oligotrophic.

When looking at the potential impact of the harvesting on the trophic status of Pockwock Lake, phosphorus data from Moose Cove Brook (harvested watershed) indicates that the annual mean stream concentration was actually lower during the harvesting year (0.017 mg L^{-1}) when compared with both pre- (0.021 mg L^{-1}) and post-harvest (0.018 and 0.022 mg L^{-1}) years. This suggests that no additional export of phosphorus occurred as the result of forest harvesting in the Moose Cove Brook sub-watershed. This comparison is however better served using loads and not concentrations, a detail not possible for this review since adequate flow records for the brook were unavailable. It is recommended that for future studies of this nature, a daily record of flow is available for all stream locations where water quality measurements are being taken.

Although it is not considered to be relevant to the main objective of this study, ancillary information made possible from available data, are phosphorus export coefficients. The coefficient itself is an integral part of the phosphorus loading model approach to watershed management. Export coefficients for Peggy Brook for the periods 1999-00, 2000-01, and 2001-02 were determined to be 0.282, 0.160, and 0.144 kg ha^{-1} yr^{-1}, respectively (Table 4), with a mean of 0.195 kg ha^{-1} yr^{-1}. These loading rates can also be expressed more commonly as 28.2, 16.0 and 14.4, and 19.5 mg m^{-2} yr^{-1}, respectively.

According to a study by Scott et al. (2000), in which runoff from a series of Nova Scotia watersheds with varying land use and geology was monitored for flow and total phosphorus concentration, the range of phosphorus export from similarly classified watersheds (assuming that the Peggy Brook watershed can be considered forested and overlies an igneous bedrock) was 0.042 to 0.132 kg ha^{-1} yr^{-1} (based on results from 4 watersheds). Although the values for Peggy Brook are outside the range observed for that study, they are still valid and can be used to expand on that previously documented.

Examples of the phosphorus models applied in Nova Scotia are described in Scott et al. (2003) and Brylinsky (2004).

Table 4. Average volume-weighted annual concentrations (mg L^{-1}) and input (tonne) of dissolved substances from Peggy Brook (S7) to Pockwock Lake for the years 1999-00 through 2001-02 (Water Year: August - July). Units of bracketed values for TP are kg ha^{-1} yr^{-1} (multiplying by 100 will convert values to mg m^{-2} yr^{-1}).

	Peggy Brook Watershed (Area = 22.6 ha.) at Env. Canada Gauging Station					
	1999-00	**2000-01**	**2001-02**	**1999-00**	**2000-01**	**2001-02**
Substance	**mg L^{-1}**			**tonne (1000 kg)**		
Ca^{2+}	0.9	0.8	1.0	2.92	1.72	2.40
Mg^{2+}	0.42	0.35	0.43	1.36	0.76	1.06
K^{+}	0.3	0.2	0.2	0.98	0.45	0.55
Na^{+}	2.4	2.7	2.0	7.78	5.81	4.93
H^{+}	0.02934	0.02025	0.03255	0.094	0.044	0.081
SO_4^{2-}	4.9	4.2	4.0	15.61	9.14	9.89
Cl^{-}	4.6	3.2	3.3	14.87	6.89	8.25
TP	0.020	0.017	0.013	0.064 (0.282)	0.036 (0.160)	0.032 (0.144)
TOC	11.8	13.2	12.3	37.97	28.54	30.47
pH	4.5	4.7	4.5	-	-	-
TN	0.22	0.20	0.22	0.70	0.43	0.56
Dissolved Si	4.5	4.1	3.3	14.55	8.80	8.27
Al^{3+}	0.47	0.49	0.45	1.52	1.05	1.11
Fe^{2+}	0.20	0.24	0.17	0.70	0.52	0.41
Mn^{2+}	0.03	0.03	0.03	0.11	0.07	0.07
Water (m^3 x 10^3)	3215	2161	2465	-	-	-

4.3 Siltation

The two parameters considered from the data set to examine the topic of siltation and forest harvesting and its associated impairment of surface water quality were total suspended solids (TSS) and turbidity. The TSS test was performed only on an occasional basis, and the majority of measurements taken were reported as less than values, ranging from <1 to <5 mg/L. At these levels, the potential short-term and long-term effects on instream fish and fish habitat is considered negligible. TSS levels observed at shoreline stations S5L and S6L, deep-lake station DS2 and lake station DS4 were also observed to be at or below detection, which suggests the following. The TSS loads in these two tributary streams draining to Pockwock Lake have no impact on the TSS levels observed at all in-lake stations, implying no negative impact on the drinking water supply.

The frequency of turbidity measurements offered a better means of examining the issue. Table AII.1 in Appendix II contains annual means for each of the monitoring sites. It is clear when looking at these data, that the clarity of surface water in the Pockwock Lake watershed is excellent. All nine stations posted mean turbidity levels below 1 NTU. Only rarely did discrete measurements exceed this limit and seldom for two consecutive sampling dates. Data for Moose Cove Brook produced an increase in turbidity levels during the harvesting period (6.17 NTU). However, as discussed and suggested earlier, this increase can likely be attributed to the hydrology rather than to the harvesting, since a similar response was observed to occur in Peggy Brook (the control watershed).

It has been reported by Beal (2004) that fines from the main road in the vicinity of the Peggy Brook bridge are observed to enter the brook in runoff on a seasonal basis, typically in the spring of the year. An on-going road maintenance program has attempted to isolate and eliminate the problem. In March of 2003, one of two culverts near the main road crossing washed out during a precipitation event. It was replaced in May 2003. Any effects of these events on stream water quality were not detected by the roughly monthly sample collection frequency of the water quality monitoring program. It is likely that any impact would have been isolated to periods of precipitation, a time when water sample collection would probably not have taken place.

4.4 Acidification

For the purposes of evaluating the potential acidifying impacts of forest harvesting on surface waters, pH measurements were used. As previously mentioned in the introduction, several other studies have reported seeing an increase in pH as a result of this activity. Results from this study, represented by pH measurements gathered from both sampling locations on Moose Cove Brook and the single site on Peggy Brook, expressed as annual means, indicate no effect. In fact, pH levels at each location remained constant during the entire study period.

4.5 CCME Water Quality Guidelines

Surface water quality at lake stations DS2 and DS4 were used for comparison with guidelines established by the CCME for drinking water use and freshwater aquatic life (Health Canada, 2003). Table 5 lists selected parameters and corresponding frequency of exceedences.

With the exceptions of aluminum, pH, manganese, and turbidity, all measured values at the two lake stations were below CCME limits in both categories. The majority of aluminum, pH and manganese measurements taken during the study were above the limits and the exceedences evenly distributed throughout the study period. This suggests that the elevated values are a normal occurrence and not a reflection of the harvesting activity. While none of the readings taken at DS2 exceeded the drinking water limit for turbidity, only 4 of 46 turbidity readings at Station DS4 were seen to exceed that limit.

Table 5. Frequency of exceedences when comparing Pockwock Lake water quality to CCME water quality guidelines for drinking water use and freshwater aquatic life. Excedences have been reported where limits are established.

Parameter	**Units**	**CCME**	**DS2**	**DS4**	**CCME**	**DS2**	**DS4**
		Drinking Water Use			Freshwater Aquatic Use		
Aluminum	mg/L	0.1[3]	27 of 33	37 of 47	0.005 @ pH ≤6.5	33 of 33	47 of 47
Barium	mg/L	1.0[3]	0 of 21	0 of 16			
Boron	mg/L	5.0	0 of 13	0 of 17			
Cadmium	mg/L	0.005	0 of 13	0 of 17	0.2	0 of 13	0 of 17
Chloride	mg/L	<250	0 of 33	0 of 46			
Chromium	mg/L	0.05	0 of 12	0 of 16	0.02	0 of 13	0 of 17
Colour	TCU	≤15[2]	0 of 33	0 of 46			
Copper	mg/L	≤1.0[2]	0 of 32	0 of 46	0.002	0 of 10	3 of 26
Iron	mg/L	≤0.3[2]	0 of 33	0 of 35	0.3	0 of 33	0 of 35
Lead	mg/L	0.01		0 of 16	0.001		0 of 16
Manganese	mg/L	≤0.05[2]	33 of 33	44 of 46			
Nitrate	mg/L	45.0	0 of 33	0 of 47			
pH		6.5-8.5[2]	33 o 34	39 of 46	6.5-9.0	33 of 34	39 of 46
Selenium	mg/L	0.01	0 of 13	0 of 17	0.001	[4]	[4]
Sodium	mg/L	<200[2]	0 of 33	0 of 46			
Sulfate	mg/L	≤500[2]	0 of 33	0 of 46			
Turbidity	NTU	1.0[1]	0 of 33	4 of 46			
Zinc	mg/L	≤5.0[2]	0 of 32	0 of 46	0.03	0 of 32	0 of 46

[1] Maximum Acceptable Concentration

[2] Aesthetic Objective

[3] "A health-based guideline for aluminum in drinking water has not been established. However, water treatment plants using aluminum-based coagulants should optimize their operations to reduce residual aluminum levels in treated water to the lowest extent possible as a precautionary measure. Operational guidance values of less than 100 µg/L total aluminum for conventional treatment plants and less than 200 µg/L total aluminum for other types of treatment systems are recommended. Any attempt to minimize aluminum residuals must not compromise the effectiveness of disinfection processes or interfere with the removal of disinfection by-product precursors." (Health Canada 2003)

[4] Measured to 0.002 only

4.6 Hydrolab Pilot Study

The Hydrolab unit installed at Pockwock Lake station DS4 was intended to record continuous real-time levels of pH, temperature, turbidity, conductivity and dissolved oxygen. The data record generated was sporadic prior to the harvesting period offering no useful baseline for comparison with post-harvest conditions. Data normalization, a procedure beyond the scope of this review, had not been carried out. For these reasons, the information gathered was not incorporated into this review.

4.7 Precipitation

The data gathered by NSEL as part of the precipitation monitoring program is summarized in Appendix III, Table AIII.1. For comparison, mean annual concentrations and loads for three additional monitoring sites maintained by Environment Canada, are presented in Appendix III, Table AIII.2.

4.7.1 Raw Data and Data Screening

The raw data supplied in EXCEL format by NSEL documented a total of 164 precipitation events for the period May 2000 to November 2003. Precipitation amounts were recorded for all 164 events, while only 131 of the events reported chemical results for one or more of the 15 water quality parameters selected for testing. Data representing 16 of these 131 events was later eliminated from the data set that under went the review. Reasons for the exclusion are explained in the following.

The raw data was screened to identify and exclude questionable results. Operator field notes, specific conductance measurements, and chemical outliers were the factors applied in the sample screening process.

In all, 16 samples were considered to be contaminated and in turn rejected from the data set - 1 for the presence of leaves, 1 for insects, 2 for particulate matter, 1 for grass clippings, 8 for plant material, 1 for seeds, and 2 for elevated conductivity. An additional sample was excluded that had a total phosphorus measurement that was unusually high when compared with the rest of the phosphorus results. Sample identification numbers for those samples excluded are given in Table 6.

Table 6. Sample numbers of those samples rejected from the data set.

20000620c
20000711a
20000718b
20001024a
20001219a
20010320a
20010619a
20010807a
20010828a
20011002a
20011009a
20011113a
20020409a
20020702a
20030506b
20031028a
20031117a

Basis for rejection: a - debris; b - elevated conductivity; c - elevated phosphorus

Of the 115 sets of water quality data making up the final data set, 109 represented wet deposition (precipitation) and 6 represented bulk (precipitation + dry fallout) deposition. The significance of wet versus bulk deposition for a study of this nature rests with the need to distinguish between what is deposited on the watershed via precipitation (wet) and that via atmospheric dust and aerosols (dry). For any chemical mass balance, documentation of both sources would be necessary.

4.7.2 Missing or Rejected Data

There are several instances in the final working data set where water chemistry is missing, either as a result of it missing from the original data records received from NSEL or as the result of the data screening process. In cases where one or more measurements for a specific parameter in a month are absent, the value present, be it preceding or following the missing value in that month, was assumed to be representative of chemistry for the entire period. Then to normalize the data, the total amount of precipitation for the corresponding events was used for the calculation of loading values. Because of the specialized and time consuming data manipulation techniques used when dealing with missing data, no attempt was made to generate missing values. Although this form of data manipulation is standard practice when determining annual loading figures, the process is beyond the scope of this review. As a result, these months were ignored in the calculations.

The precipitation data set should undergo this form of treatment if a more detailed review of the data is performed.

4.7.3 Data Manipulation

From the screened data set, equivalents and mass and equivalent loadings were calculated; annual means were calculated for pH using both pH and hydrogen ion (H^+) concentration; non-marine values for selected ions (Na, K, Mg, Ca, and SO_4) were calculated using chloride ratios (see Section 5.1.5).

Data collected from the standard rain gauge on site were used to volume-weight the data when calculating loading. Sample weights reported in the NSEL "Precip Notes" file were not used as it was decided that the actual technique applied would provide more reliable estimates. No attempt was made to determine the catch efficiency of the precipitation collector.

4.7.4 Sea-Salt Correction

The influence of natural terrestrial or anthropogenic sources on precipitation chemistry can be examined if the effects of sea-salt are first separated from the ion pool. The non-marine component for specific ions was determined using milli-equivalent (meq) values of chloride (Underwood, 1984). The formulae, which consider the ratio of the ion to chloride in sea water, are as follows:

nm Na = Na – (Cl x 0.858)
nm K = K – (Cl x 0.019)
nm Ca = Ca – (Cl x 0.038)
nmMg = Mg – (Cl x 0.194)
nm SO_4 = SO_4 – (Cl x 0.103)

Conversions

mg/L x mm precipitation = mg m^{-2}
mg m^{-2} x milliequivalents = meq m^{-2}
mg m^{-2}/100 = kg ha^{-1}

Milligrams per liter to milliequivalents per litre = mg/L x "Factor"

	"Factor"
Cations	
Na^+	0.0435
K^+	0.02558
Ca^{2+}	0.0499
Mg^{2+}	0.08229

H^+	0.9921
NH_4-N	0.0714

Anions

Cl^-	0.02821
SO_4^{2-}	0.02082
NO_3-N	0.0714

4.7.5 Comparative Precipitation Data

Although there is no direct benefit to this study, precipitation records from three additional locations in Nova Scotia were obtained from Environment Canada to give the reader an appreciation of the spatial variability in precipitation chemistry and respective loading rates. The three sites included Jackson, Cumberland County; Sherbrooke, Guysborough County; and Kejimkujik National Park, Annapolis County. The reader must be cautioned that the techniques used to generate the annual concentrations and loadings in both data sets are not identical and therefore direct comparisons should be avoided until such time that the Pockwock data is treated similarly.

A description of the Environment Canada summary data and the technique used to estimate non-sea-salt sulfate is provided in Appendix III.

4.8 Data Management Issues

The use of two laboratories for sample analyses has meant that there is some duplication of parameter results found in the database for same date/same location samples. Users of the database should be aware of this when using the data.

This method of data storage i.e. results from each lab stored in separate databases, proved somewhat troublesome. The major complaint rests with the fact that a considerable amount of time is required to sort and arrange the data for simple interpretative functions. To make the system more efficient, it is recommended that the databases be combined into one.

It was discovered during the processing of data that the original data set transferred from NSEL contained alphanumeric values which were not being recognized when executing any mathematical function in Excel. As a consequence, it was necessary to repeat the process and by first converting all of the compiled data to numeric values. It is unclear why data from the NSEL data management system (Access) ended up being stored in the Excel files in this form. It is recommended that NSEL staff examine this shortcoming of the current data transfer process.

5.0 CONCLUSIONS AND RECOMMENDATIONS

Conclusions

1. Water quality changes were observed for Moose Cove Brook and Peggy Brook during and immediately following forest harvesting.
2. These water quality changes appear to be related to changes in surface water hydrology and not the forest clearing activity.
3. Weak seasonal and annual trends were observed for conductivity at mid-lake station DS2. These trends are typical of water bodies exposed to a maritime climate.
4. Water quality data collected does not indicate that the forest harvesting taking place between June 28 to October 17, 2001 impacted on the water quality of Pockwock Lake.
5. With the exception of aluminum, pH, manganese, and turbidity, water quality at the two deep-lake stations in Pockwock Lake is within limits set by CCME for both drinking water use and freshwater aquatic life.
6. Observed CCME exceedences for the two deep-lake stations are considered to be a reflection of typical lake water quality and not an impact of forest harvesting activity.
7. Water quality sampling at Pockwock Lake deep-lake station DS2 was performed in the ice-free season only representing the months of May to November.
8. Water quality sampling at Pockwock Lake station DS4 was more frequent than that for DS2 on an annual basis, but still did not cover the entire 12-month period.
9. Water quality observed at Pockwock Lake stations DS2 and DS4 were similar.

Recommendations

1. Integrate findings of all studies carried out in the Pockwock Lake watershed in a summary report.
2. Examine reason why EXCEL files generated from the water quality database contain alphanumeric values.
3. Address the issue of missing data in the NSEL precipitation database.
4. Address the issue of duplicate data in the NSEL water quality database.

5. With safety in mind, attempt to collect water quality data from Pockwock Lake deep-lake station DS2 at sometime during the period of ice cover, preferably in February.
6. Expand water quality monitoring program to include monthly sampling for Pockwock Lake at either DS2 or DS4, or a combination of both. The purpose of this is to maintain an on-going surveillance of the drinking water resource.
7. Install a hydrologic metering station on Moose Cove Brook to document daily flows.

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APPENDIX I

AI.1 NSEL Water Quality Monitoring Program Parameter List

and

AI.2 Estimation of Lake and Stratum Areas and Volumes

AI.1 NSEL Water Quality Monitoring Program Parameter List

The following table identifies the various chemical and biological parameters incorporated into the NSEL monitoring program for the Pockwock Lake Watershed study. Although all data has been reviewed for this report, not all have been mentioned.

Table AI.1. Water Quality Parameter List

Alkalinity
Aluminum
Ammonia
Antimony
Arsenic
Barium
Beryllium
Bicarbonate
Boron
Cadmium
Calcium
Carbonate
Chloride
Chlorophylla
Chromium
Cobalt
Colour
Conductivity
Copper
Hardness
Iron
Lead
Magnesium
Manganese
Nickel
Nitrate-Nitrite
Ortho-Phosphorus
pH
Pheophytin
Potassium
Selenium
Silica
Sodium
Sulfate
Suspended Solids
Total Nitrogen
Total Organic Carbon
Total Phosphorus
Turbidity
Vanadium
Zinc

AI.2. Estimation of Lake and Stratum Areas and Volumes

Methodology

A bathymetric map of Pockwock Lake, made available by the Halifax Regional Water Commission (HRWC), was the source document for lake depth contours. The map, recovered from HRWC files, appeared to be a reproduction of a map originally produced by CBCL in the early to mid-1970’s as part of the planning and design phase for the existing water treatment plant.

Verification of the map scale was performed using 1:10,000 topographical mapping obtained from the Nova Scotia Land Information Service. This information was based on 1997 aerial photography.

There were discrepancies in water surface and island areas for the two maps. These differences may be explained by varying water levels on the dates that aerial photography was flown upon which each map was based. Water level, however, cannot explain why the total lake areas differed between maps, the value of lake area for the HRWC being greater (Table AI.2). If an elevated water level is used to explain the greater total lake area seen for the HWRC bathymetric map, then it would follow that the island area should be smaller and the water surface area higher for the topographic map. This is not the case. One possible explanation for the discrepancy is a distortion of the true lake shape, as recorded on the original map, through the duplication process. It's possible that through countless duplications a slight stretching of map lines occurred, which does happen when using some techniques. This stretching of lines would be magnified with each subsequent reproduction.

Table AI.2. A comparison of HRWC bathymetric map and LIS 1:10,000 topographic map lake and island areas.

	HRWC Bathymetric Map	**LIS 1:10,000 Topographic Map**	**Percent Difference Bath./Topo.**
Total Lake Area, ha	1003.9	989.8	+1.4
Island Area, ha	119.8	87.0	+27.4
Water Surface Area, ha	884.1	902.8	-2.1
Island Area by Sub-Basin, ha			
DS1	86.3	68.7	+20.4
DS2	7.6	2.2	+71.1
DS3	25.9	16.1	+37.8

It was decided that the lake area (989.8 hectares), water surface area (902.8 hectares) and island area (87.0 hectares) derived from the 1:10,000 topographic map would be more accurate and therefore should be used for the calculations. As a result of this decision, it was necessary to adjust the stratum interface areas below 0 metres from the bathymetric map by the same percentage difference observed between the total lake areas for the two maps. From these adjusted areas, stratum and total lake volumes were calculated. These data are presented in Table AI.3.

Table AI.3. Pockwock Lake surface and stratum interface areas, stratum volumes and sub-basin and whole lake volumes.

Depth, ft	**Depth, m**	**Water Surface Area, ha**				**%Total Water Surface Area**				**Volume, x $10^4 m^3$**			
		Whole Lake	**DS1**	**DS2**	**DS3**	**Whole Lake**	**DS1**	**DS2**	**DS3**	**Whole Lake**	**DS1**	**DS2**	**DS3**
0	0.0	902.8	249.4	321.7	331.7	100.0	100.0	100.0	100.0				
										2538	725	930	883
10	3.05	764.9	226.4	288.7	249.8	84.7	90.8	89.7	75.3				
										2115	630	824	661
20	6.10	625.6	187.9	252.2	185.5	81.8	83.0	87.4	74.3				
										1702	515	687	501
30	9.14	494.0	150.6	199.4	144.0	79.0	80.1	79.1	77.6				
										1348	398	564	385
40	12.19	392.4	111.7	171.0	109.7	79.4	74.2	85.8	76.2				
										1026	282	462	282
50	15.24	283.9	74.6	132.8	76.5	72.3	66.8	77.7	69.7				
										1315	324	651	340
70	21.34	154.4	34.3	82.7	37.4	54.4	46.0	62.3	48.9				
										630	138	351	141
90	27.43	59.9	12.7	35.8	11.4	38.8	37.0	43.3	30.5				
										227	49	152	26
110	33.53	19.9	4.2	15.6	0.1	33.2	33.1	43.6	0.9				
										39	5	34	
120	36.58	7.1	0.1	7.0		35.7	2.4	44.9					
										11		11	
130	39.62	1.2		1.2		16.9		17.1					
										2		2	
140	42.67	0.1		0.1		8.3		8.3					
									Totals	10953	3067	4667	3220

	Hectares	**Acres**
Total Water Surface Area	902.8	2230.9
Island Area	87.0	215.0
Total Lake Area	989.8	2445.9
Total Lake Volume		
in cubic metres, 10^4	10953	
in imperial gallons, 10^6	24106	

APPENDIX II

Water Quality Summaries

and

Time plots of Selected Parameters

Table AII.1. Annual means of selected parameters for the period 1999 to 2003. Pre-harvest years are 1999 and 2000; post-harvest years are 2002 and 2003. Harvesting took place in 2001.

Year	**pH**	**Alk mg/L**	**Gran Alk mg/L**	**Conductivity umhos/cm**	**Hardness mg/L**	**Color TCU**	**Turbidity NTU**	**Total P mg/L**
Peggy Brook, S7								
1999	4.6	0.5	-1.62	42.5	4.1	80	0.27	0.019
2000	4.6	0.6	-1.56	34.8	3.5	103	0.43	0.017
2001	4.6	0.8	-1.21	35.9	4.5	63	0.60	0.011
2002	4.6	0.4	-1.38	32.7	3.6	90	0.59	0.016
2003	4.6	0.1	-1.94	33.7	4.6	97	0.48	0.019

	Total N mg/L	**Chl A mg/m3**	**TOC mg/L**	**Ortho P mg/L**	**NO3+N02 mg/L**	**NH3 mg/L**	**Na mg/L**	**K mg/L**
1999	0.27	0.3	14.7	0.0005	0.02	0.01	2.7	0.3
2000	0.24	0.2	13.5	0.0007	0.02	0.01	2.7	0.2
2001	0.29	0.7	10.9	0.0007	0.02	0.01	2.9	0.2
2002	0.26	0.3	14.0	0.0005	0.02	0.01	2.2	0.1
2003	0.29	0.3	16.4	0.0006	0.02	0.01	2.4	0.3

	Ca mg/L	**Mg mg/L**	**SO_4 mg/L**	**Cl mg/L**	**Si mg/L**	**Al mg/L**	**Fe mg/L**	**Mn mg/L**
1999	0.9	0.44	5.5	4.7	4.4	0.53	0.28	0.04
2000	0.8	0.37	3.9	4.2	3.7	0.50	0.24	0.03
2001	1.0	0.48	5.1	3.5	2.9	0.37	0.17	0.04
2002	0.8	0.36	3.2	3.1	3.5	0.46	0.21	0.02
2003	0.7	0.29	2.7	3.5	3.5	0.52	0.33	0.03

Year	**pH**	**Alk**	**Gran Alk**	**Conductivity umhos/cm**	**Hardness mg/L**	**Color TCU**	**Turbidity NTU**	**Total P mg/L**
Moose Cove Brook, S8								
1999	4.4	0.1	-2.40	47.3	3.8	81	0.30	0.020
2000	4.4	0.1	-1.95	36.2	3.1	86	0.40	0.025
2001	4.4	0.4	-1.83	44.9	5.0	118	1.72	0.017
2002	4.4	0.1	-1.77	38.3	3.3	87	0.34	0.018
2003	4.4	0.1	-2.34	40.6	4.1	99	0.53	0.025

Moose Cove Brook, S8

	Total N mg/L	Chl A mg/m^3	TOC mg/L	Ortho P mg/L	NO3+N02 mg/L	NH3 mg/L	Na mg/L	K mg/L
1999	0.28	0.22	17.2	0.0005	0.01	0.01	2.8	0.2
2000	0.23	0.16	11.4	0.0005	0.01	0.01	2.5	0.2
2001	0.43	5.75	15.5	0.0005	0.01	0.01	3.0	0.2
2002	0.21	0.11	14.4	0.0005	0.01	0.01	2.5	0.2
2003	0.29	4.28	17.6	0.0006	0.01	0.01	2.8	0.4

	Ca mg/L	Mg mg/L	SO_4 mg/L	Cl mg/L	Si mg/L	S Solids mg/L	Al mg/L	Fe mg/L
1999	0.8	0.42	5.3	5.2	5.4	0.7	0.66	0.29
2000	0.7	0.34	3.2	4.6	4.1	1.8	0.47	0.24
2001	1.1	0.54	5.2	4.9	4.0	3.3	0.54	0.32
2002	0.8	0.34	3.3	3.8	5.2	1.1	0.51	0.22
2003	0.7	0.29	2.6	4.3	5.3	3.0	0.63	0.39

	Mn mg/L
1999	0.05
2000	0.03
2001	0.05
2002	0.04
2003	0.04

Year	Secchi m	pH	Alk mg/L	Gran Alk mg/L	Conductivity umhos/cm	Hardness mg/L	Color TCU	Turbidity NTU
Moose Cove Brook, S9								
2000		4.5	0.4	-2.40	43.2	3.4	151	0.52
2001		4.5	0.6	-1.70	42.6	6.2	84	0.83
2002		4.5	0.3	-1.93	39.2	3.5	86	0.47
2003		4.5	0.1	-2.40	38.5	na	98	0.39

	Total P mg/L	Total N mg/L	Chl A mg/m3	TOC mg/L	Ortho P mg/L	NO3+N02 mg/L	NH3 mg/L	Na mg/L
2000	0.021	0.30	0.2	19.0	0.0009	0.01	0.01	3.3
2001	0.017	0.23	2.4	12.2	0.0007	0.01	0.01	3.2
2002	0.018	0.22	0.2	14.6	0.0005	0.01	0.01	2.6
2003	0.022	0.28	0.3	16.6	0.0006	0.01	0.01	2.6

Moose Cove Brook, S9

	K mg/L	Ca mg/L	Mg mg/L	SO_4 mg/L	Cl mg/L	Si mg/L	Al mg/L	Fe mg/L
2000	0.2	0.7	0.37	4.7	4.1	6.6	0.75	0.36
2001	0.2	1.5	0.57	5.7	4.0	5.3	0.50	0.25
2002	0.2	0.8	0.36	3.3	4.4	4.9	0.52	0.19
2003	0.3	0.7	0.25	3.3	3.9	4.8	0.59	0.31

	Mn mg/L
2000	0.04
2001	0.04
2002	0.04
2003	0.03

Year	pH	Alk	Gran Alk	Conductivity umhos/cm	Hardness mg/L	Color TCU	Turbidity NTU	Total P mg/L
S5C								
1999	4.5	na	na	73.0	4.3	70	0.25	0.022
2000	4.7	na	na	36.5	3.7	98	0.44	0.014
2001	4.6	0.6	-1.61	43.2	5.6	72	0.53	0.018
2002	4.5	0.1	-1.92	35.5	3.6	69	0.65	0.015
2003	4.7	0.3	-1.81	21.8	na	61	0.53	0.005

	Total N mg/L	Chl A mg/m^3	TOC mg/L	NO3+N02 mg/L	NH3 mg/L	Na mg/L	K mg/L	Ca mg/L
1999	0.25	0.25	15.7	0.01	0.01	2.7	0.2	0.9
2000	0.23	0.14	13.6	0.01	0.01	2.7	0.2	0.8
2001	0.27	0.31	12.5	0.01	0.01	3.1	0.3	1.3
2002	0.23	0.10	11.9	0.01	0.01	2.6	0.1	0.8
2003	0.27	0.20	9.1	0.01	0.01	1.5	0.3	0.3

	Mg mg/L	SO_4 mg/L	Cl mg/L	Si mg/L	Al mg/L	Fe mg/L	Mn mg/L
1999	0.47	6.0	5.3	5.9	0.60	0.27	0.05
2000	0.40	3.8	4.2	4.3	0.51	0.22	0.03
2001	0.59	5.6	4.0	5.2	0.50	0.18	0.05
2002	0.37	2.9	3.6	4.7	0.49	0.16	0.03
2003	0.25	4.0	1.5	3.0	0.33	0.12	0.01

Year	**pH**	**Alk**	**Gran Alk**	**Conductivity umhos/cm**	**Hardness mg/L**	**Color TCU**	**Turbidity NTU**	**Total P mg/L**
S5L								
1999	5.7	na	na	35.9	4.0	8	0.30	0.004
2000	4.9	na	na	33.6	3.8	46	0.42	0.009
2001	5.0	1.5	-0.95	40.8	5.3	23	0.69	0.007
2002	5.1	1.5	-0.54	38.6	4.9	15	0.36	0.004
2003	5.1	1.3	-1.21	37.4	5.0	16	0.50	0.010

	Total N mg/L	**Chl A mg/m^3**	**TOC mg/L**	**Ortho P mg/L**	**NO3+N02 mg/L**	**NH3 mg/L**	**Na mg/L**	**K mg/L**
1999	0.12	0.70	2.7	0.0005	0.01	0.01	3.3	0.3
2000	0.20	0.46	7.3	0.0005	0.01	0.01	3.3	0.2
2001	0.18	0.81	5.2	0.0008	0.01	0.01	4.2	0.3
2002	0.15	0.67	3.4	0.0005	0.03	0.01	4.0	0.2
2003	0.17	0.85	4.1	0.0006	0.02	0.01	4.0	0.3

	Ca mg/L	**Mg mg/L**	**SO_4 mg/L**	**Cl mg/L**	**Si mg/L**	**S Solids mg/L**	**Al mg/L**	**Fe mg/L**
1999	0.9	0.43	4.7	6.1	1.0	0.8	0.11	0.07
2000	0.9	0.40	4.2	5.3	1.7	0.6	0.30	0.15
2001	1.2	0.57	5.5	6.0	1.8	1.2	0.22	0.11
2002	1.1	0.50	4.4	6.3	1.2	0.8	0.10	0.05
2003	1.1	0.42	4.0	6.3	1.5	1.7	0.16	0.07

	Mn mg/L
1999	0.06
2000	0.05
2001	0.07
2002	0.05
2003	0.06

Year	**pH**	**Alk**	**Gran Alk**	**Conductivity umhos/cm**	**Hardness mg/L**	**Color TCU**	**Turbidity NTU**	**Total P mg/L**
S6C								
1999	4.7	na	na	40.8	4.3	43	0.32	0.013
2000	4.5	na	na	39.6	3.6	94	0.43	0.016
2001	4.4	0.1	-2.06	48.1	5.7	69	0.55	0.019
2002	4.4	0.1	-2.32	40.4	3.5	74	0.66	0.016

S6C

	Total N mg/L	Chl A mg/m^3	TOC mg/L	Ortho P mg/L	NO3+N02 mg/L	NH3 mg/L	Na mg/L	K mg/L
1999	0.19	0.70	8.2	0.0005	0.01	0.02	3.1	0.3
2000	0.23	0.67	13.1	0.0007	0.01	0.01	3.1	0.2
2001	0.24	0.10	12.4	0.0005	0.01	0.01	3.4	0.4
2002	0.21	0.10	13.8	0.0005	0.01	0.01	2.6	0.3

	Ca mg/L	Mg mg/L	SO_4 mg/L	Cl mg/L	Si mg/L	Al mg/L	Fe mg/L	Mn mg/L
1999	1.0	0.45	6.0	5.7	3.4	0.35	0.16	0.07
2000	0.8	0.40	4.2	4.6	5.4	0.58	0.26	0.04
2001	1.3	0.61	6.1	4.6	6.5	0.60	0.20	0.06
2002	0.8	0.38	3.2	4.2	4.8	0.53	0.18	0.04

Year	pH	Alk	Gran Alk	Conductivity umhos/cm	Hardness mg/L	Color TCU	Turbidity NTU	Total P mg/L
S6L								
1999	5.5	na	na	35.9	4.1	8	0.30	0.004
2000	5.2	na	na	36.0	4.2	23	0.44	0.007
2001	5.4	1.6	-0.95	37.7	4.8	10	0.53	0.005
2002	5.2	1.6	-0.57	38.5	5.0	11	0.31	0.006
2003	4.9	0.1	-2.10	35.2	4.9	31	0.45	0.010

	Total N mg/L	Chl A mg/m^3	TOC mg/L	Ortho P mg/L	NO3+N02 mg/L	NH3 mg/L	Na mg/L	K mg/L
1999	0.13	0.77	2.7	0.0005	0.01	0.01	3.3	0.3
2000	0.14	0.84	4.2	0.0005	0.01	0.01	3.8	0.2
2001	0.13	0.86	2.8	0.0008	0.02	0.01	4.2	0.2
2002	0.16	0.70	2.8	0.0005	0.03	0.01	4.3	0.2
2003	0.17	0.88	6.1	0.0006	0.01	0.01	3.5	0.3

	Ca mg/L	Mg mg/L	SO_4 mg/L	Cl mg/L	Si mg/L	S Solids mg/L	Al mg/L	Fe mg/L
1999	0.9	0.43	4.9	6.1	1.0	0.7	0.14	0.06
2000	1.0	0.45	4.7	5.9	1.6	0.7	0.19	0.10
2001	1.1	0.50	5.0	6.2	1.1	0.7	0.11	0.06
2002	1.2	0.50	4.4	6.5	1.2	0.7	0.11	0.05
2003	0.9	0.39	4.1	5.4	1.9	1.3	0.22	0.09

S6C

	Mn mg/L
1999	0.06
2000	0.06
2001	0.07
2002	0.06
2003	0.05

Year	Secchi m	pH	Alk mg/L	Gran Alk mg/L	Conductivity umhos/cm	Hardness mg/L	Color TCU	Turbidity NTU
Pockwock Lake, DS2								
1999	7.2	5.4	1.6	0.10	35.8	4.3	8	0.30
2000	6.0	5.4	1.6	-.074	36.9	4.6	8	0.36
2001	6.4	5.5	1.5	-0.94	37.9	4.8	9	0.40
2002	7.2	5.3	1.5	-0.52	39.9	5.0	8	0.31
2003	6.1	5.3	na	na	38.3	5.1	9	0.34

	Total P mg/L	Total N mg/L	Chl A mg/m3	TOC mg/L	Ortho P mg/L	NO3+N02 mg/L	NH3 mg/L	Na mg/L
1999	0.005	0.13	0.7	2.7	0.0005	0.03	0.01	3.4
2000	0.005	0.13	0.8	2.3	0.0005	0.02	0.01	3.8
2001	0.005	0.14	0.4	2.5	0.0009	0.03	0.01	4.4
2002	0.008	0.15	0.5	2.5	0.0005	0.05	0.01	4.2
2003	0.010	0.15	0.7	3.2	0.0006	0.03	0.01	4.1

	K mg/L	Ca mg/L	Mg mg/L	SO_4 mg/L	Cl mg/L	Si mg/L	Al mg/L	Fe mg/L
1999	0.3	1.0	0.4	4.8	6.2	1.2	0.13	0.03
2000	0.3	1.0	0.5	4.7	6.4	1.3	0.13	0.02
2001	0.2	1.1	0.5	4.7	6.2	1.3	0.12	0.04
2002	0.2	1.2	0.5	4.7	6.8	1.3	0.11	0.02
2003	0.3	1.1	0.4	4.4	7.1	1.3	0.13	0.04

Pockwock Lake, DS2

	Mn mg/L	Zn mg/L	Ba mg/L
1999	0.06	0.006	0.0025
2000	0.07	0.005	na
2001	0.07	0.005	0.0025
2002	0.06	0.005	0.0060
2003	0.06	0.004	0.0053

Year	pH	Alk mg/L	Gran Alk mg/L	Conductivity umhos/cm	Hardness mg/L	Color TCU	Turbidity NTU	Total P mg/L
Pockwock Lake, DS4								
1999	5.5	0.1	-2.40	35.7	4.3	8	0.29	0.005
2000	5.5	0.1	-1.95	36.3	4.5	8	0.37	0.009
2001	5.6	0.4	-1.83	37.4	4.7	8	0.70	0.007
2002	5.3	0.1	-1.77	39.3	4.9	8	0.77	0.005
2003	5.4	0.1	-2.34	37.9	5.0	10	0.47	0.007

	Total N mg/L	Chl A mg/m3	TOC mg/L	NO3+N02 mg/L	NH3 mg/L	Na mg/L	K mg/L	Ca mg/L
1999	0.12	0.8	2.7	0.01	0.01	3.4	0.3	1.0
2000	0.14	0.9	2.4	0.02	0.01	3.7	0.3	1.0
2001	0.13	0.5	2.3	0.02	0.01	4.2	0.2	1.1
2002	0.15	0.5	3.0	0.04	0.01	4.3	0.3	1.1
2003	0.15	0.6	3.3	0.02	0.01	4.0	0.3	1.1

	Mg mg/L	SO_4 mg/L	Cl mg/L	Si mg/L	Al mg/L	Fe mg/L	Mn mg/L	Zn mg/L
1999	0.5	4.7	6.3	1.1	0.12	0.04	0.06	0.01
2000	0.5	4.8	6.4	1.2	0.12	0.03	0.06	0.01
2001	0.5	4.9	6.3	1.2	0.11	0.03	0.06	0.01
2002	0.5	4.3	6.7	1.2	0.11	0.05	0.06	0.01
2003	0.4	4.3	6.7	1.4	0.13	0.04	0.06	0.01

	Ba mg/L
1999	0.00
2000	0.01
2001	0.01
2002	0.01
2003	0.01

APPENDIX III

This section contains NSEL and EC precipitation information

Table AIII.1. NSEL Precipitation Summary Data.[1]

For the Period: May 2000 - Nov. 2003	Rain	Snow	Total Precip	# Events n	pH	H^+	Na	K	Ca	Mg
Total, mm	3636.9	795	4431.9	164						
Total, mg m^{-2}						61.97	2216.98	190.22	494.59	422.15
Total # of Months	42	42	42			36	36	17	28	26
Mean Annual, mm yr^{-1}	1053.5	230.3	1283.8							
Mean Annual					4.85					
Mean Annual, mg $m^{-2}yr^{-1}$						20.94	749.26	136.14	214.91	197.54
Mean Annual, meq $m^{-2}yr^{-1}$						20.78	32.59	3.48	10.72	16.26
Mean Annual, kg $ha^{-1}yr^{-1}$						0.21	7.49	1.36	2.15	1.98
Non-Marine(nm), meq $m^{-2}yr^{-1}$							3.66	2.84	9.44	9.71
nm Mean Annual, kg $ha^{-1}yr^{-1}$							0.84	1.11	1.89	1.18

	Acidity	Alkalinity	Cl	SO_4	NO_3	NH_4	Total Phosphorus	Aluminum	Hardness	Conductivity
Total, mg m^{-2}	6036.35	-1612.72	3635.49	6694.83	589.62	444.58	19.36	22.52	2020.53	
Total # of Months	36	36	37	37	36	36	14	36	28	36
Mean Annual										14.6
Mean Annual, mg $m^{-2}yr^{-1}$	2040.06	-545.04	1195.45	2201.45	199.27	150.25	16.82	7.61	877.97	
Mean Annual, meq $m^{-2}yr^{-1}$			33.72	45.83	14.23	10.73				
Mean Annual, kg $ha^{-1}yr^{-1}$	20.40	-5.45	11.95	22.01	1.99	1.50	0.17	0.08	8.78	
Non-Marine(nm), meq $m^{-2}yr^{-1}$				42.36						
nm Mean Annual, kg $ha^{-1}yr^{-1}$				20.35						

Notes:

[1] Since the treatment of missing data was beyond the scope of this review, the data was lumped into one reporting period and the results expressed as annual means

"Total Number of Months" refers to the number of months in which data was reported.

"Conductivity Mean" is a volume-weighted mean monthly value.

Based on the Anion-Cation Balance method for checking correctness of analyses (Clesceri et al., 1998), the data are considered to be acceptable.

Table AIII.2. Environment Canada Precipitation Summary Data.

YEAR	Total Precip	pH	H^+	Na	K	Ca	Mg	Cl	SO_4	Non-Sea-Salt SO_4	NO_3	NH_4	NNO_3	NNH_4	NTOT
	mm		mg L^{-1}												
Jackson, N.S.															
2000	1653	4.71	0.0195	0.538	0.032	0.051	0.068	0.954	0.974	0.839	0.723	0.124	0.163	0.096	0.260
2001	1088	4.72	0.0190	0.361	0.027	0.048	0.047	0.636	0.801	0.710	0.692	0.120	0.156	0.094	0.250
2002	1810	4.82	0.0152	0.325	0.025	0.040	0.040	0.564	0.654	0.573	0.527	0.094	0.119	0.073	0.192
Kejimkujik National Park, N.S.															
2000	1386	4.65	0.0226	0.701	0.037	0.054	0.089	1.207	1.077	0.901	0.879	0.136	0.199	0.106	0.305
2001	1070	4.69	0.0204	0.471	0.025	0.042	0.059	0.837	0.815	0.697	0.792	0.100	0.179	0.078	0.257
2002	1625	4.72	0.0188	0.642	0.033	0.058	0.079	1.115	0.837	0.675	0.701	0.114	0.158	0.088	0.247
Sherbrooke, N.S.															
2000	1719	4.82	0.0150	0.921	0.046	0.058	0.123	1.655	0.867	.	0.506	0.084	0.114	0.065	0.180
2001	1339	4.80	0.0158	0.586	0.035	0.051	0.074	1.037	0.788	.	0.530	0.086	0.120	0.067	0.186
2002	1850	4.83	0.0149	0.869	0.050	0.074	0.105	1.435	0.795	0.590	0.508	0.086	0.115	0.067	0.181
			kg ha^{-1} yr^{-1}												
Pockwock Lake, N.S.															
2000-03	1284	4.85	0.21	7.49	1.36	2.15	1.98	11.95	22.01	20.35	1.99	1.54			
Jackson, N.S.															
2000	1653	4.71	0.3224	8.896	0.530	0.843	1.122	15.763	16.094	13.863	11.957	2.048	2.700	1.593	4.293
2001	1088	4.72	0.2062	3.927	0.292	0.523	0.507	6.920	8.709	7.720	7.531	1.310	1.701	1.019	2.720
2002	1810	4.82	0.2752	5.887	0.446	0.731	0.729	10.203	11.836	10.366	9.538	1.696	2.154	1.319	3.473
Kejimkujik National Park, N.S.															
2000	1386	4.65	0.3135	9.723	0.515	0.751	1.240	16.736	14.932	12.496	12.187	1.891	2.752	1.471	4.223
2001	1070	4.69	0.2185	5.038	0.270	0.452	0.631	8.955	8.718	7.455	8.476	1.072	1.914	0.834	2.747
2002	1625	4.72	0.3063	10.437	0.530	0.944	1.282	18.119	13.608	10.968	11.398	1.849	2.574	1.438	4.012

YEAR	Total Precip mm	pH	H^+	Na	K	Ca	Mg	Cl	SO_4	Non-Sea-Salt SO_4	NO_3	NH_4	NNO_3	NNH_4	NTOT
			kg ha^{-1} yr^{-1}												
Sherbrooke, N.S.															
2000	1719	4.82	0.2583	15.833	0.791	0.998	2.111	28.435	14.904	.	8.695	1.444	1.963	1.123	3.087
2001	1339	4.80	0.2119	7.837	0.475	0.681	0.991	13.877	10.553	.	7.095	1.149	1.602	0.894	2.496
2002	1850	4.83	0.2764	16.076	0.922	1.367	1.945	26.549	14.706	10.908	9.393	1.586	2.121	1.234	3.355

AIII.1 Environment Canada Precipitation Summary Data

Chul-Un Ro, a Senior Scientist with the National Atmospheric Chemistry Database Meteorological Service of Canada of Environment Canada (EC), provided the data and offers the following supporting information pertaining to the EC data set contained in this report. The data can be found in Appendix II.

AIII.2 Missing Data

In any summary period during which there was no sampling or (more likely) poor data completeness, no deposition value is given and the cell contains a "." instead of a numerical value.

AIII.3 Data Completeness

The data completeness criteria that EC uses to assess the data are as follows (a reference can be provided by EC if necessary). For a summary period to be considered as meeting the summary period data completeness criterion, it must have had >=70% of its data as valid and not missing (this means that the valid and non-missing concentration data from the wet deposition collector must represent more than 70% of the precipitation that fell during that period).

AIII.4 Deposition

The summary period deposition values were calculated as the product of the precipitation-weighted mean concentration times the precipitation depth.

AIII.5 Rating

Site representativeness level for the site. Values may be 1, 2a, 2b or 3. Level 1 sites do not suffer from any interferences and are considered to be regionally representative. Level 3 sites are subjected to local interferences (e.g., dusty surroundings, significant emission sources within 40 km) and are considered regionally unrepresentative. Level 2a sites fail in some site criteria and are potentially regionally representative. Level 2b sites have more problems but are not considered to have a level 3 rating by the network managers.

AIII.6 Calculation of Sea-Salt Corrected Sulfate

The $XSO_4^=$ (Excess $SO_4^=$) concentration is that portion of the measured $SO_4^=$ concentration which is in excess of the sea salt $SO_4^=$ concentration. $XSO_4^=$ is calculated as the difference between the measured $SO_4^=$ concentration and the sea salt $SO_4^=$ contribution where the latter is estimated by multiplying the concentration of a sea salt tracer in the sample (e.g., Na^+, Cl^-, Mg^{++}) by the ratio of $SO_4^=$ to that tracer in bulk sea water.

The algorithm for calculating $XSO_4^=$ contains two steps. Step 1 determines the most suitable chemical species in each sample to act as a tracer for sea salt. Step 2 calculates the X $SO_4^=$ concentration using the concentration of the tracer in the sample.

The determination of the most suitable sea salt tracer for each sample is done by comparing ratios of Na^+/Mg^{++}, Na^+/Cl^- and Mg^{++}/Cl^- in the sample to the same ratios in bulk sea water. When the ratio of Na+/Mg++ in the sample is within ±25% of that in sea water then this is considered to be the 'best case' and $XSO_4^=$ is calculated using the sample's Na^+ concentration as the tracer, i.e.,

$$XSO_4^= = SO_4^= - 0.25\ Na^+ \quad \text{...(mg/l)} \qquad \text{Equation 1}$$

and

$XSO_4^=$ FLAG = V0.

If this is not the case, then the other ratios are investigated to determine whether Mg^{++} or Cl^- is the best tracer for sea salt, i.e., which ratio is closest to the bulk sea salt ratio. If Mg^{++} is chosen, then

$$XSO_4^= = SO_4^= - 2.09\ Mg^{++} \quad \text{...(mg/l)} \qquad \text{Equation 2}$$

and

$XSO_4^=$ FLAG = V3.

If Cl^- is chosen, then

$$XSO_4^= = SO_4^= - 0.14\ Cl^- \text{ ...(mg/l)} \qquad \text{Equation 3}$$

and

$$XSO_4^= \text{ FLAG} = V4.$$

If Na^{++} is still the best indicator of sea salt even though the Na^+/Mg^{++} ratio is not within ±25% of the sea water ratio, (i.e., if the Na^+ ratio is closest to that of bulk sea water) then Equation 1 is used but the $XSO_4^=$ FLAG is set equal to V2.

If one or more of the Na^+, Mg^{++} or Cl^- concentrations are missing or invalid, either Equation 1, 2 or 3 is used on a priority basis depending on which of the concentration data are available. If all are missing, then

$$XSO_4^= = SO_4^= \text{ ...(mg/1)} \qquad \text{Equation 4}$$

and

$$XSO_4^= \text{ FLAG} = V5.$$

If the $SO_4^=$ concentration is missing or invalid, then the $XSO_4^=$ concentration is set to missing or invalid and the same $SO_4^=$ invalid (I) flag is assigned to $XSO_4^=$.

If the $SO_4^=$ concentration is NON DETECTABLE (ND), then the $XSO_4^=$ value is assigned the ND value and the appropriate ND flag.

Table 4 in Section 7.6 was generated using the raw data contained in Table AII.2. A description of column headings is provided below.

The Column Headings:

SUMPR	Summary period (month, quarter, season, year)
SITEID	NAtChem site identifier

SITENAME	NAtChem site name	
LAT	latitude (in decimal degrees)	
LON	longitude (in decimal degrees. “-“ means western hemisphere)	
STARTPER	nominal start date of summary period (YYYY/MO/DA)	
ENDPER	nominal end date of summary period	
TOTPRCP	the total precipitation depth (in cm) that was measured during the period	
pH	quarterly or annual precipitation-weighted pH value - calculated as the log of the precipitation-weighted mean H+ concentration for the period	
------CN	Precipitation weighted mean concentration (mg/l)	
------DP	Wet deposition (kg/ha/SUMPR)	
HPLDP	H+ wet deposition (kg/ha/SUMPR)	
SO4DP	SO4 wet deposition (kg/ha/SUMPR)	
XSO4DP	non-sea-salt SO4 (= nssSO4) wet deposition (kg/ha/SUMPR). It is the same as SO4 in the case of the Killarney site so you can ignore it.	
NO3DP	NO3 wet deposition (kg/ha/SUMPR)	NNO3: Nitrogen from NO3
CLDP	Cl wet deposition (kg/ha/SUMPR)	
NH4DP	NH4 wet deposition (kg/ha/SUMPR)	NNH4: Nitrogen from NH4
NADP	Na wet deposition (kg/ha/SUMPR)	
CADP	Ca wet deposition (kg/ha/SUMPR)	
MGDP	Mg wet deposition (kg/ha/SUMPR)	
KDP	K wet deposition (kg/ha/SUMPR)	

NTOT = NNO3+NNH4

%PCL	% PRECIPITATION COVERAGE LENGTH: Percentage of days with measured precipitation plus zero precipitation days in the summary period (i.e., days for which records are known). Calculated as: [(Number of days in summary period) – (Number of days with missing or unknown precipitation)] X 100 / (Number of days in the summary period)

Table AIII.3. EC precipitation raw data.

SUMPER	YEAR	SITEID	SITENAME	LAT	LON	STARTPER	ENDPER	TOTPRCP	pH	HPLCN	HPLDP	SO4CN	SO4DP	XSO4CN	XSO4DP	NO3CN	NO3DP
YEAR	2000	CAPMCANS1JAC	Jackson	45.593	-63.842	1-Jan-00	1-Jan-01	165.3	4.71	0.0195	0.3224	0.974	16.094	0.839	13.863	0.723	11.957
YEAR	2001	CAPMCANS1JAC	Jackson	45.593	-63.842	1-Jan-01	1-Jan-02	108.8	4.72	0.019	0.2062	0.801	8.709	0.71	7.72	0.692	7.531
YEAR	2002	CAPMCANS1JAC	Jackson	45.593	-63.842	1-Jan-02	1-Jan-03	181	4.82	0.0152	0.2752	0.654	11.836	0.573	10.366	0.527	9.538
YEAR	2000	CAPMCANS1KEJ	Kejimkujik	44.434	-65.206	1-Jan-00	1-Jan-01	138.6	4.65	0.0226	0.3135	1.077	14.932	0.901	12.496	0.879	12.187
YEAR	2001	CAPMCANS1KEJ	Kejimkujik	44.434	-65.206	1-Jan-01	1-Jan-02	107	4.69	0.0204	0.2185	0.815	8.718	0.697	7.455	0.792	8.476
YEAR	2002	CAPMCANS1KEJ	Kejimkujik	44.434	-65.206	1-Jan-02	1-Jan-03	162.5	4.72	0.0188	0.3063	0.837	13.608	0.675	10.968	0.701	11.398
YEAR	2000	NSPMCANS1SBK	Sherbrooke	45.16	-61.971	1-Jan-00	1-Jan-01	171.9	4.82	0.015	0.2583	0.867	14.904	.	.	0.506	8.695
YEAR	2001	NSPMCANS1SBK	Sherbrooke	45.16	-61.971	1-Jan-01	1-Jan-02	133.9	4.8	0.0158	0.2119	0.788	10.553	.	.	0.53	7.095
YEAR	2002	NSPMCANS1SBK	Sherbrooke	45.16	-61.971	1-Jan-02	1-Jan-03	185	4.83	0.0149	0.2764	0.795	14.706	0.59	10.908	0.508	9.393

Table AIII.3 continued,

				CLCN	**CLDP**	**NH4CN**	**NH4DP**	**NACN**	**NADP**	**CACN**
YEAR	2000	CAPMCANS1JAC	Jackson	0.954	15.763	0.124	2.048	0.538	8.896	0.051
YEAR	2001	CAPMCANS1JAC	Jackson	0.636	6.92	0.12	1.31	0.361	3.927	0.048
YEAR	2002	CAPMCANS1JAC	Jackson	0.564	10.203	0.094	1.696	0.325	5.887	0.04
YEAR	2000	CAPMCANS1KEJ	Kejimkujik	1.207	16.736	0.136	1.891	0.701	9.723	0.054
YEAR	2001	CAPMCANS1KEJ	Kejimkujik	0.837	8.955	0.1	1.072	0.471	5.038	0.042
YEAR	2002	CAPMCANS1KEJ	Kejimkujik	1.115	18.119	0.114	1.849	0.642	10.437	0.058
YEAR	2000	NSPMCANS1SBK	Sherbrooke	1.655	28.435	0.084	1.444	0.921	15.833	0.058
YEAR	2001	NSPMCANS1SBK	Sherbrooke	1.037	13.877	0.086	1.149	0.586	7.837	0.051
YEAR	2002	NSPMCANS1SBK	Sherbrooke	1.435	26.549	0.086	1.586	0.869	16.076	0.074

				CADP	**MGCN**	**MGDP**	**KCN**	**KDP**	**NNO3CN**	**NNO3DP**
YEAR	2000	CAPMCANS1JAC	Jackson	0.843	0.068	1.122	0.032	0.53	0.163	2.7
YEAR	2001	CAPMCANS1JAC	Jackson	0.523	0.047	0.507	0.027	0.292	0.156	1.701
YEAR	2002	CAPMCANS1JAC	Jackson	0.731	0.04	0.729	0.025	0.446	0.119	2.154
YEAR	2000	CAPMCANS1KEJ	Kejimkujik	0.751	0.089	1.24	0.037	0.515	0.199	2.752
YEAR	2001	CAPMCANS1KEJ	Kejimkujik	0.452	0.059	0.631	0.025	0.27	0.179	1.914
YEAR	2002	CAPMCANS1KEJ	Kejimkujik	0.944	0.079	1.282	0.033	0.53	0.158	2.574
YEAR	2000	NSPMCANS1SBK	Sherbrooke	0.998	0.123	2.111	0.046	0.791	0.114	1.963
YEAR	2001	NSPMCANS1SBK	Sherbrooke	0.681	0.074	0.991	0.035	0.475	0.12	1.602
YEAR	2002	NSPMCANS1SBK	Sherbrooke	1.367	0.105	1.945	0.05	0.922	0.115	2.121

Table AIII.3 continued,

				NNH4CN	**NNH4DP**	**NTOTCN**	**NTOTDP**	**%PCL**	**RATING**
YEAR	2000	CAPMCANS1JAC	Jackson	0.096	1.593	0.26	4.293	100	1
YEAR	2001	CAPMCANS1JAC	Jackson	0.094	1.019	0.25	2.72	100	1
YEAR	2002	CAPMCANS1JAC	Jackson	0.073	1.319	0.192	3.473	100	1
YEAR	2000	CAPMCANS1KEJ	Kejimkujik	0.106	1.471	0.305	4.223	100	1
YEAR	2001	CAPMCANS1KEJ	Kejimkujik	0.078	0.834	0.257	2.747	100	1
YEAR	2002	CAPMCANS1KEJ	Kejimkujik	0.088	1.438	0.247	4.012	100	1
YEAR	2000	NSPMCANS1SBK	Sherbrooke	0.065	1.123	0.18	3.087	100	1
YEAR	2001	NSPMCANS1SBK	Sherbrooke	0.067	0.894	0.186	2.496	100	1
YEAR	2002	NSPMCANS1SBK	Sherbrooke	0.067	1.234	0.181	3.355	100	1