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A WATER QUALITY SURVEY OF LAKES IN THE BLUE MOUNTAIN-BIRCH COVE LAKES REGIONAL PARK, APRIL 2021

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SUMMARY

In April 2021, a team of volunteers conducted a water quality survey by canoe of 21 lakes within the conceptual boundary of the Blue Mountain-Birch Cove Regional Park. Variables measured included Secchi depth (a measure of turbidity), dissolved oxygen, specific conductance, pH and total phosphorus. Vertical profiles indicated that all lakes were well mixed from surface to bottom at the time of sampling. Mean values of each variable at all depths were then calculated for each lake. Mean Secchi depth ranged from 1.5 to 3.0 m, dissolved oxygen ranged from 79 to 101 %, specific conductance ranged from 21 to 208 µS/cm, pH ranged from 3.49 to 6.15 and total phosphorus ranged from 4 to 9 µg/l. The highest values for specific conductance occurred in the lower part of the Kearney Run Watershed and indicate the addition of road salt and other pollutants from surrounding development. The lowest values for pH can be attributed to the bedrock geology and widespread acid precipitation during the latter part of the twentieth century. Overall, the water quality of the lakes appears excellent but continued monitoring is recommended, especially in the lakes in the lower part of the Kearney Run Watershed such as Susies, Quarry, Washmill and Kearney lakes which are currently the most affected by development.

INTRODUCTION

Under the lead of the Halifax Regional Municipality (HRM), the Blue Mountain-Birch Cove Regional Park is currently being established. This urban wilderness park, located just minutes from downtown Halifax, will provide a lasting legacy for existing and future generations with many outstanding benefits including easily accessible recreation (e.g. hiking, paddling, camping, skiing, etc.), health, wildlife protection, habitat conservation, ecosystem services and scientific research. It will be complementary to the many other public parks and protected areas around the Municipality. This urban wilderness park has been envisioned for over thirty years and commitment to create it was made in HRM's 2006 and 2014 Regional Plans.

Strong support for park was recently reaffirmed in 2020 by HRM Council passing unanimously three motions which provided funding to the Nova Scotia Nature Trust toward their purchase of the connector lands, confirmed an expanded conceptual park boundary and directed the establishment of a park planning committee involving all stake holders. Led by HRM, this committee is tasked with preparing an overall park plan, developing a plan for acquiring additional private lands within the conceptual boundary, developing a plan for proper public access points, seeking additional funding from provincial and federal governments and creating an effective program for public information and stake holder engagement.

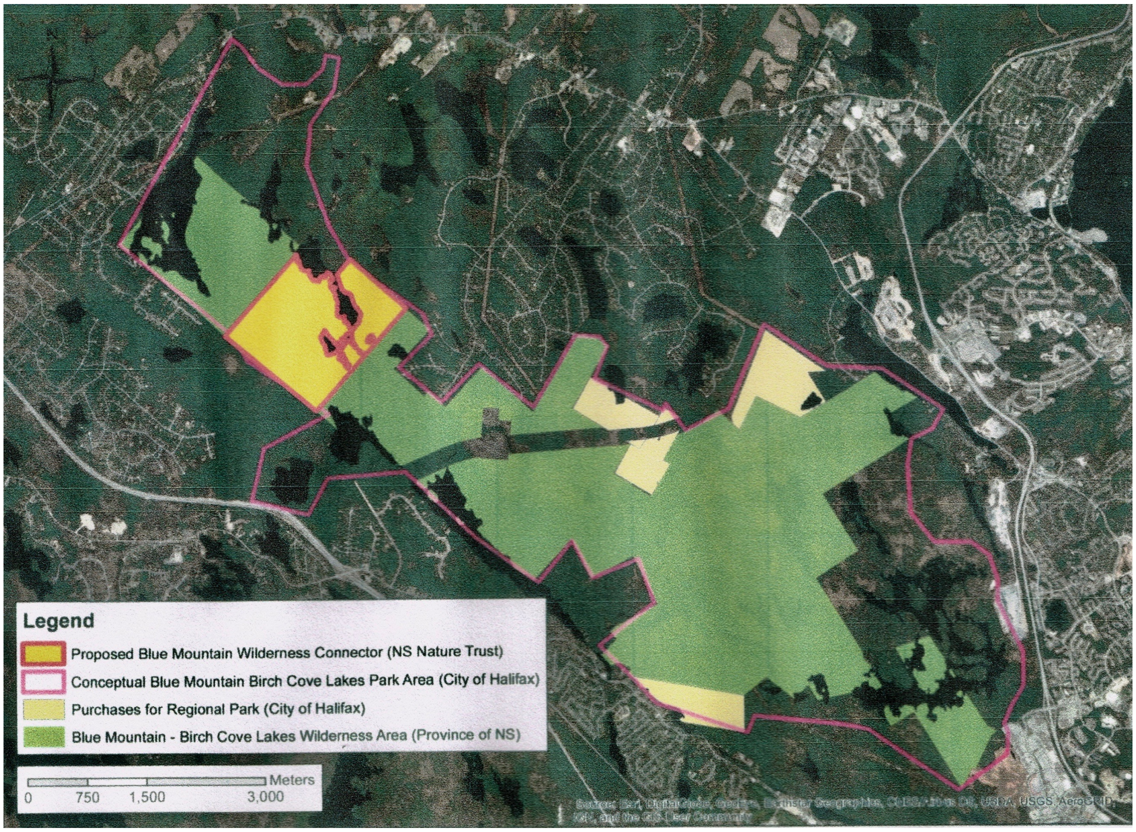
In addition to HRM, other organizations involved in and promoting the creation of this unique urban wilderness park have included the provincial Department of Environment and Climate Change, the Nova Scotia Nature Trust, the Ecology Action Centre, the Friends of Blue Mountain-Birch Cove Lakes and the Canadian Parks and Wilderness Society. This park provides an exceptional opportunity on the doorstep of HRM. If properly developed, it has the potential to become comparable to the well-known Gatineau Park just outside Ottawa (Thompson 1973).

The location of the Blue Mountain-Birch Cove Regional Park is shown in Fig. 1. It occupies much of the area between Highway 102, Highway 103 and the Hammonds Plains Road, extending all the way from the Bayers Lake Business Park in the southeast to Coxs Lake in the northwest. Land use and major landowners in the area were earlier summarized by EDM (2006). The purple line encircling the park indicates the envisioned conceptual boundary which includes an area of approximately 3000 ha. Lands within this boundary that are already protected are shown in three different colours. Green denotes the provincial wilderness areas (1767 ha) (previously Crown Land), the light yellow denotes the three parcels recently purchased by HRM (203 ha) and the dark yellow denotes the parcel of connecting land recently purchased by the Nova Scotia Nature Trust (233 ha). These protected lands currently total 2203 ha. The remaining lands within the conceptual boundary, about 800 ha, are currently privately owned but hopefully many of these can be added to the park in the near future by either purchase, trade, conservation easements or, if necessary, expropriation.

The park includes a large number of lakes and interconnecting waterways. Numerous lake studies have been carried out in the Municipality in recent years and several of these have concentrated in the Kearney Lake area. Kearney Lake was one of the lakes sampled in the HRM lake monitoring program which was conducted between 2006 and 2011 (Stantec 2012). In addition, a detailed study of the Birch Cove Lakes watershed has been carried out (AECOM 2013). Frasers, Susies and Kearney lakes have also been sampled as part of the Metro Area Lakes Synoptic Survey program which has been carried out at decadal intervals since 1980 (Clement and Gordon (2019). Some water quality studies have also been carried out recently in the Nine Mile River Watershed (Five Bridges Wildlife Heritage Trust 2021).

Proper planning and management of the park requires a comprehensive database of key water quality variables for all the lakes within and on the boundary of the park. Therefore, in order to help develop such a database, under the sponsorship of the Friends of Blue Mountain-Birch Cove Lakes and with the assistance of many colleagues, we undertook this comprehensive water quality survey in early April 2021. We are all

Figure 1. Map of the Blue Mountain-Birch Cove lakes area showing the conceptual boundary of the wilderness park in pink and the ownership of protected land. Green denotes provincial wilderness areas, the three light yellow areas denote land purchased by HRM and the darker yellow parcel identifies land recently purchased by the Nova Scotia Nature Trust. The remaining land within the conceptual boundary is privately owned.

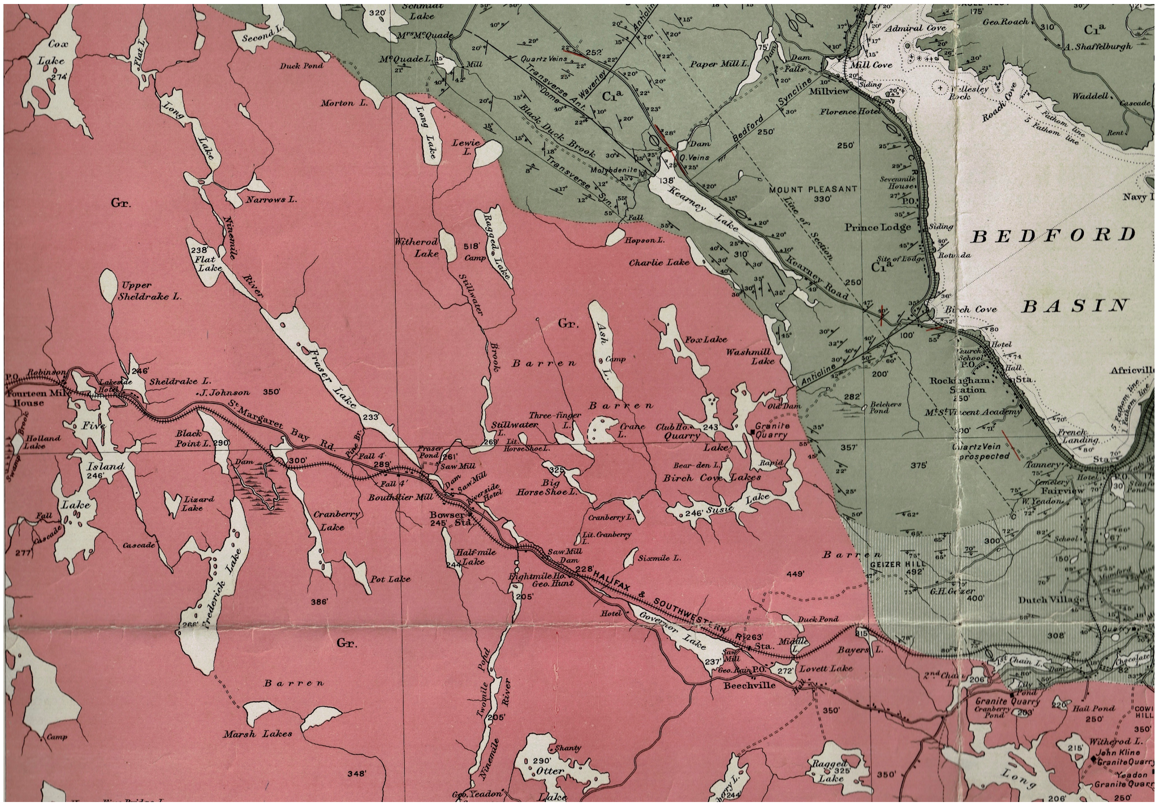


volunteers and strong advocates for the park. In addition, several of us have extensive experience in water quality monitoring. This report presents background information on the lakes, describes the methods used, summarizes the results, interprets their significance and compares them to the results of other recent water quality studies in HRM.

PHYSICAL SETTING

Most of the lakes in the park are underlain by intrusive granite of Devonian age (Fig. 2). However, those on the eastern edge are underlain by the much older metamorphic Goldenville Formation of Cambrian to Ordovician age which is composed principally of slate. Charlies and Washmill lakes are located along the contact between these two formations. The lakes were created during the Wisconsinan glaciation which covered all of Nova Scotia with ice on the order of 1 km thick before it retreated about 12,000 years ago.

Figure 2. Geological map including the study area published by the Canadian Department of Mines in 1908. Grey denotes Goldenville slate of Cambrian to Ordovician age and pink denotes Devonian granite. Charlies and Washmill lakes are located on the contact between the two.



With one exception, the lakes within the conceptual boundary of the Blue Mountain-Birch Cove Regional Park are located in two separate watersheds (Fig. 3). The exception is Upper Sheldrake Lake which drains under Highway 103 into Sheldrake Lake. The lakes in the western portion are part of the Nine Mile River Watershed that drains south from Timberlea and enters the sea at Shad Bay near Prospect while those in the eastern portion are part of the Kearney Run Watershed that drains through Paper Mill Lake and enters Bedford Basin at Mill Cove. The lakes, their elevation and direction of flow in each watershed are identified in Figs. 4 and 5. Numerous lakes in the Nine Mile River Watershed are outside the park conceptual boundary. However, with the exception of McQuade and Washmill lakes, all lakes in the Kearney Run Watershed above Kearney Lake are within the park conceptual boundary.

Figure 3. Boundaries of the Nine Mile and Kearney Run watersheds from the provincial website.

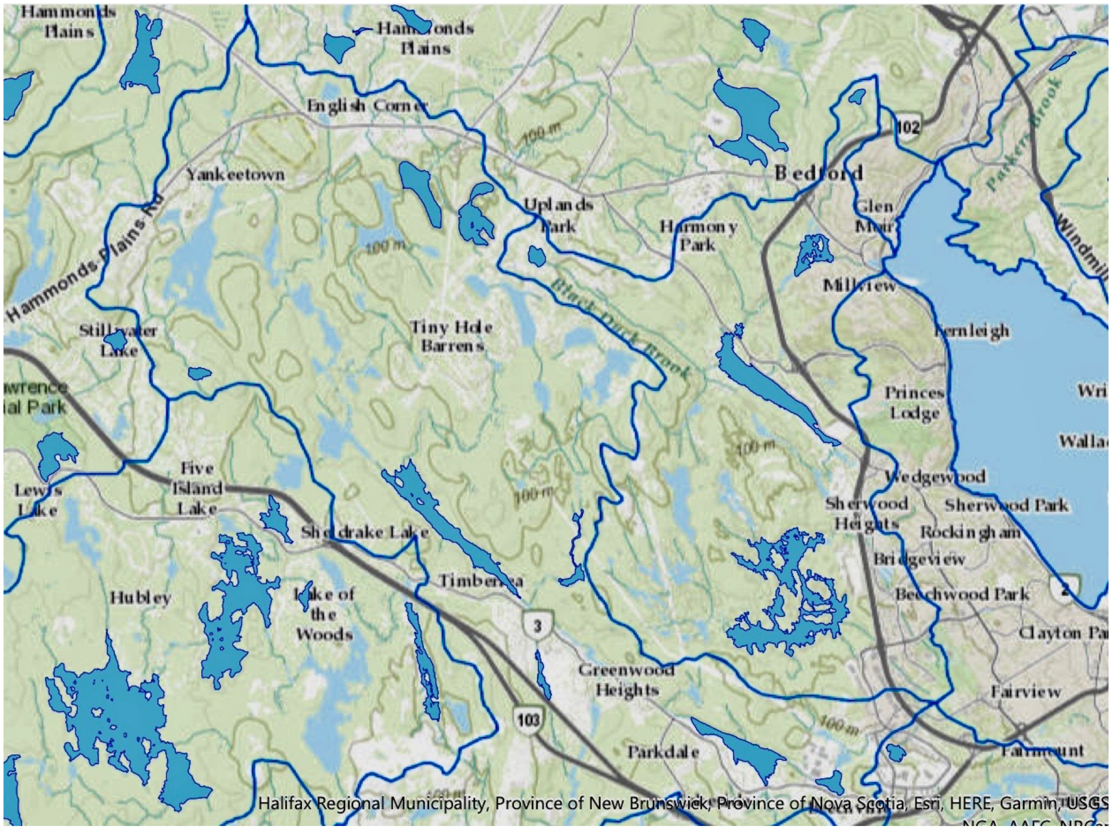


Figure 4. Water flow through the Nine Mile River Watershed down to the outlet of Frasers Lake. Arrows (not to scale) indicate the interconnecting streams and stillwaters. Lakes sampled in this survey are shown in bold. All these are within the conceptual park boundary.

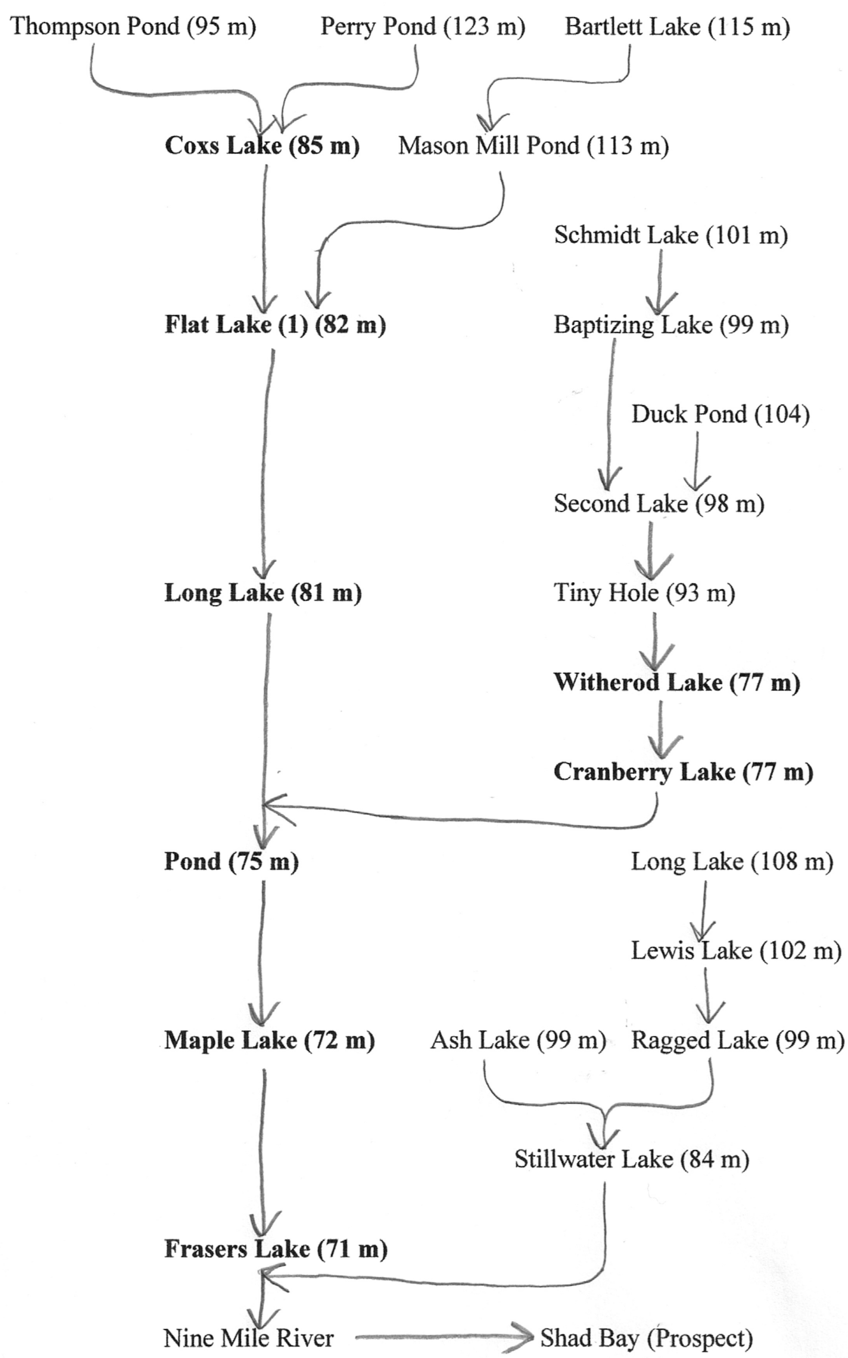
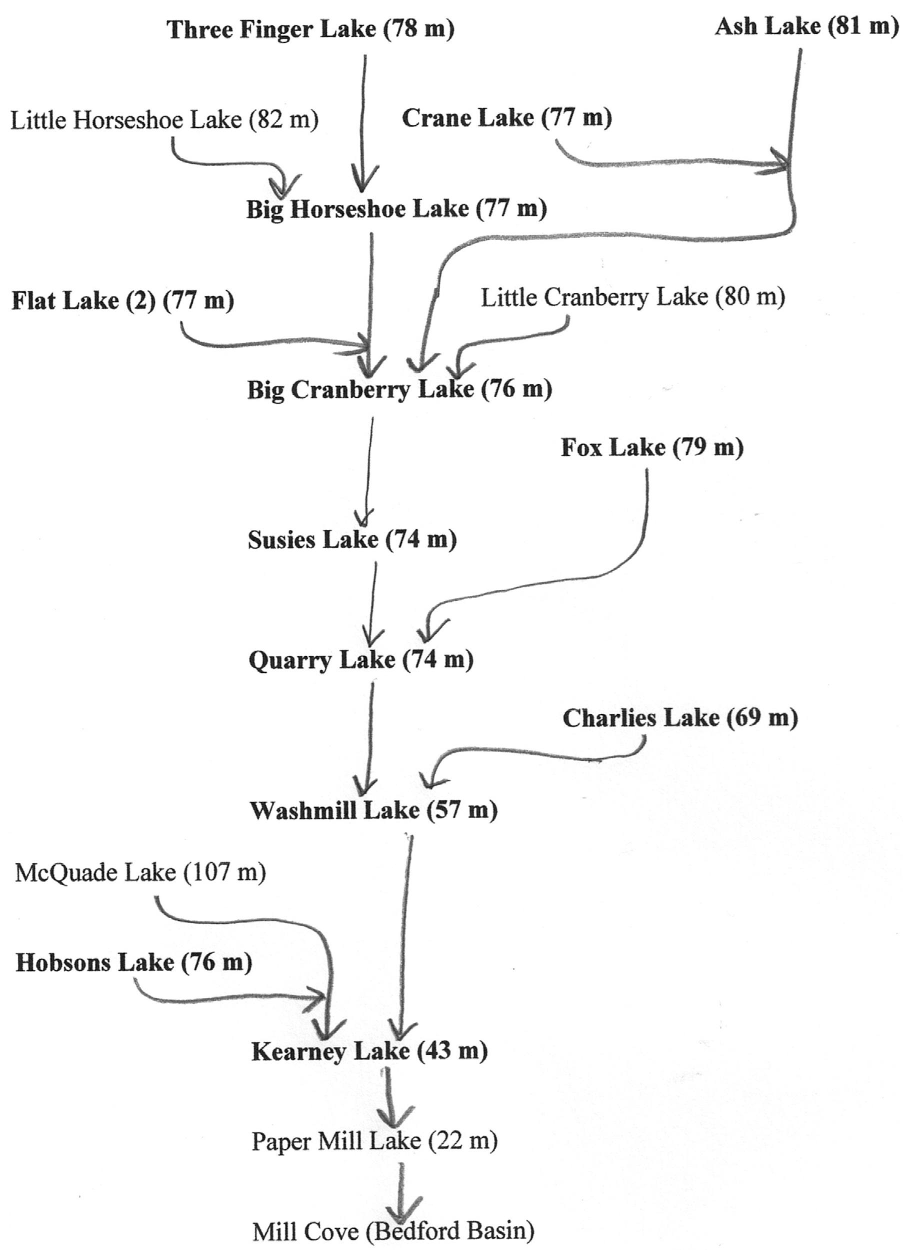


Figure 5. Water flow through the Kearney Run Watershed. Arrows (not to scale) indicate the interconnecting streams and stillwaters. Lakes sampled in this survey are shown in bold. With the exception of Washmill Lake, all these lakes are within the conceptual park boundary.



The lakes sampled during this study in both watersheds are listed in Tables 1 and 2 along with their elevation, area and perimeter. Note that there are two Flat lakes; Flat Lake (1) in the Nine Mile River Watershed and Flat Lake (2) in the Kearney Run Watershed. Some of the lakes sampled straddle the conceptual boundary. Washmill Lake is not within the conceptual boundary but was included in the survey since it is an important component in the Kearney Run Watershed. Lakes within the conceptual boundary not sampled because of their relative inaccessibility were Tiny Hole, Ash Lake and Stillwater Lake in the Nine Mile River Watershed (Fig. 4) and Little Horseshoe and Little Cranberry lakes in the Kearney Run Watershed (Fig. 5).

Table 1. List of lakes sampled within the park conceptual boundary in the Nine Mile River Watershed along with their elevations and estimates of area and perimeter. Lakes in bold straddle the park conceptual boundary.

Lake	Elevation (m)	Area (ha)	Perimeter (km)
Coxs	85	88.24	7.08
Flat (1)	82	14.85	3.38
Long	81	23.77	3.73
Witherod	77	4.13	1.27
Cranberry	77	3.63	1.05
Un-named pond	75	5.06	1.48
Maple	72	29.42	3.23
Frasers	71	71.41	6.64

Table 2. List of lakes sampled within the park conceptual boundary (except Washmill Lake) in the Kearney Run Watershed along with their elevations and estimates of their area and perimeter. Lakes in bold straddle the park conceptual boundary.

Lake	Elevation (m)	Area (ha)	Perimeter (km)
Ash	81	30.64	3.53
Crane	77	11.46	2.96
Three Finger	78	6.71	2.24
Big Horseshoe	77	8.35	3.07
Flat (2)	77	1.94	0.82
Big Cranberry	76	4.96	1.18
Susies	74	79.04	12.89
Fox	79	16.04	3.10
Quarry	74	53.67	6.30
Charlies	69	6.27	1.83
Washmill	57	7.97	2.40
Hobsons	76	3.37	0.82
Kearney	43	66.93	6.44

The outlet from Quarry Lake was dammed some time before 1908. Subsequently, its water level was artificially raised several meters. As a result, it connected with Susies Lake whose level was elevated as well. The outlet of Kearney Lake was also dammed in 1928. All the other lakes within the conceptual park boundary have natural elevations.

The larger lakes around the periphery of the park are subjected to considerable development pressure, both current and pending. Approximately one third of the shoreline of Coxs Lake is privately owned and most of this has been developed for homes in recent years. There is also considerable residential development in a large portion of its watershed. While the land around Maple Lake is currently undeveloped, future residential development has been proposed. The land along the western shore of Frasers Lake is privately owned and much of it has been subjected to residential development. A considerable portion of the shoreline of Kearney Lake is privately owned and most of this has been subjected to residential development. In addition, by way of Black Duck Brook, it receives runoff from McQuade Lake which is surrounded by residential development and the Brookline Subdivision currently under construction. There also is a major road and commercial development along its eastern side. Washmill Lake has a large active quarry immediately adjacent to its eastern shoreline. The immediate shorelines of Quarry and Susies lakes currently remain in a natural state but extensive residential and commercial development has been proposed. Susies Lake also receives storm water runoff from the extensive Clayton Park West development and the Bayers Lake Business Park. The remaining lakes within the park are quite isolated and remain largely in a natural state. Many of the lakes are outside the municipal wastewater service boundary so that any development is serviced by onsite sewage disposal systems.

METHODS

All water quality information was collected by a team of four volunteers using two canoes (Fig. 6) on 8 April, 10 April and 14 April 2021, soon after the ice in the lakes disappeared (the last lake to open was Frasers Lake on 27 March). The routes travelled were recorded on smart phones equipped with GPS and are shown in Fig. 7. The total distance traversed was 48.5 km (41.2 km paddling and 7.3 km portaging). Twenty-one different lakes were sampled. In each lake, a sampling station was selected as close to the deepest part as possible, aided by the bathymetric maps that were available for Coxs, Frasers and Kearney lakes. One or two additional sampling stations were also selected in the larger lakes.

The elevation, area and perimeter of all lakes are listed in Tables 1 and 2. Elevations were obtained from topographic maps or Google Earth. Area and perimeter were estimated using the ruler key function in Google Earth. The elevation, maximum measured depth, number of stations and number of observations made in each lake are listed in Tables 3 and 4. The total number of sampling stations was thirty-nine (Fig. 7).

Figure 6. Collecting water quality information by canoe in Charlies Lake.

Figure 7. GPS tracks of the three paddling and portaging routes followed to sample the 21 lakes. Also shown are the locations of the 39 sampling stations.

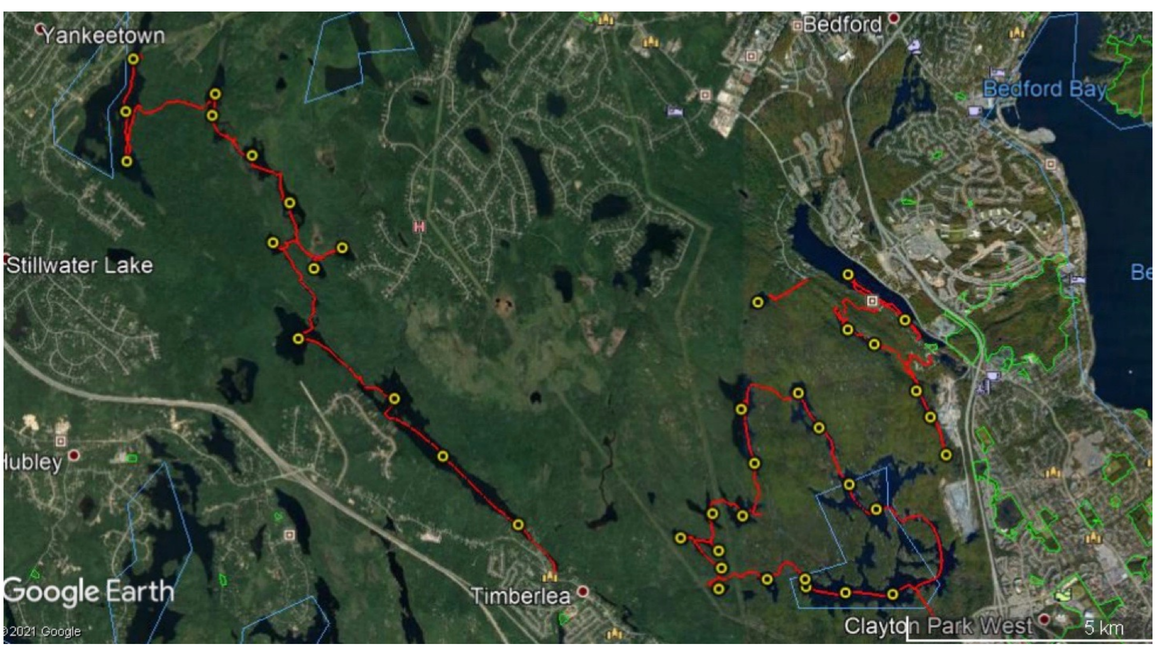


Table 3. Elevation, maximum measured depth, number of stations and number of observations of the lakes sampled within the Nine Mile River Watershed.

Lake	Elevation (m)	Maximum Measured Depth (m)	Number of Stations	Number of Observations
Coxs	85	14.3	3	21
Flat (1)	82	3.5	2	6
Long	81	2.9	2	6
Witherod	77	2.7	1	3
Cranberry	77	4.1	1	4
Un-named pond	75	3.6	1	4
Maple	72	10.5	1	6
Frasers	71	20.2	3	18

Table 4. Elevation, maximum measured depth, number of stations and number of observations of the lakes sampled within the Kearney Run Watershed.

Lake	Elevation (m)	Maximum Measured Depth (m)	Number of Stations	Number of Observations
Ash	81	10.4	3	13
Crane	77	4.6	1	5
Three Finger	78	2.6	1	3
Big Horseshoe	77	2.6	3	8
Flat (2)	77	2.0	1	3
Big Cranberry	76	3.0	1	4
Susies	74	5.8	3	16
Fox	79	8.2	2	9
Quarry	74	5.9	2	10
Charlies	69	5.0	2	8
Washmill	57	8.1	3	12
Hobsons	76	8.0	1	6
Kearney	43	27.9	2	20

In order to help locate sampling locations, water depth was determined using a hand-held HawkEye DepthTrax H1 digital depth recorder. Water transparency was measured at each station with a 20 cm diameter Secchi disk (Fig. 8). This disk was lowered slowly in the water and the depth at which it disappeared was recorded. These readings have low precision when made from a canoe under windy conditions. Readings for both water depth and Secchi depth were recorded by pencil on field sheets.

Figure 8. Secchi disk used to measure turbidity.

Figure 9. The YSI Professional Plus multi-probe equipped with a 30 m cable.

Water quality measurements were made using a YSI Professional Plus multi-probe, provided by the Atlantic Water Network of Saint Mary's University, equipped with a 30 m cable which allowed vertical profiling (Fig. 9). The variables measured were temperature, dissolved oxygen, conductivity, specific conductance, total dissolved solids and pH, all key variables for lake water quality studies. Barometric pressure was also recorded. The multi-probe was properly calibrated before use. The depths at which readings were made were estimated by the length of cable deployed. However, due to windy conditions, the cable was not always vertical so some readings at deeper depths may have been made at depths a few meters shallower than reported. Standard practice was to first lower the probe to the lake bottom and then take readings during recovery. Data were read from the handheld display and recorded by pencil on field sheets. They were also recorded internally for later downloading and processing.

A surface water sample was collected in each lake using a pre-rinsed sterilized 250 ml plastic bottle for the determination of total phosphorus. These were delivered the next day after overnight storage in a refrigerator to the Environmental Services Laboratory of the Nova Scotia Health Authority for analysis. In addition, surface samples were collected in Coxs, Long, Ash and Quarry lakes using two one liter pre-rinsed plastic bottles. These were subsequently delivered to Rob Jamieson at Dalhousie University for processing along with the samples collected on 31 March 2021 during the fifth Metro Area Lake Synoptic Survey. The results are not included in this report.

All data collected were subsequently entered into Excel spreadsheets. One spreadsheet included the data read in the field and recorded on the field sheets while the other included the data later downloaded from the multi-probe. These two data sets were compared and any inconsistencies rectified. The downloaded data set was used in preparing the tables and figures in this report. Conductivity readings are highly sensitive to water temperature and therefore data are reported as specific conductance which is conductivity corrected to the standard temperature of 25 °C so that different water bodies can be compared.

For those interested, the downloaded data will be posted on the Atlantic DataStream website (https://atlanticdatastream.ca/) managed by the Atlantic Water Network (https://atlwaternetwork.ca/) based at Saint Mary's University in Halifax.

RESULTS

Vertical Profiles

Temperature (°C)

Water temperature in both watersheds ranged from approximately 5 to 12 °C (Figs. 10 and 11). There was some evidence of thermal stratification in most lakes, especially in the shallowest. This is to be expected due to solar heating during the few weeks since the ice disappeared and it will intensify as the season progresses.

Figure 10. Vertical profiles of temperature in lakes in the Nine Mile River Watershed.

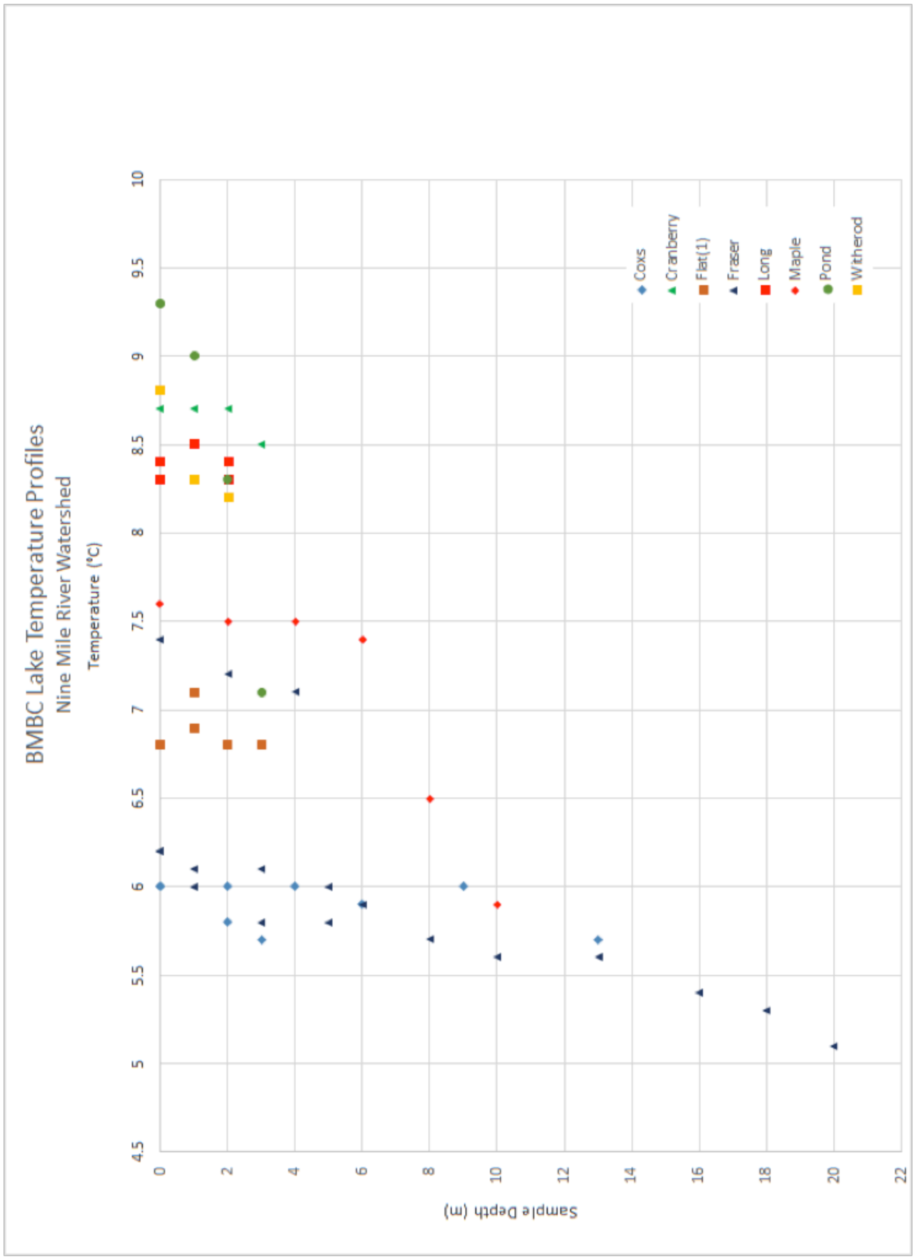
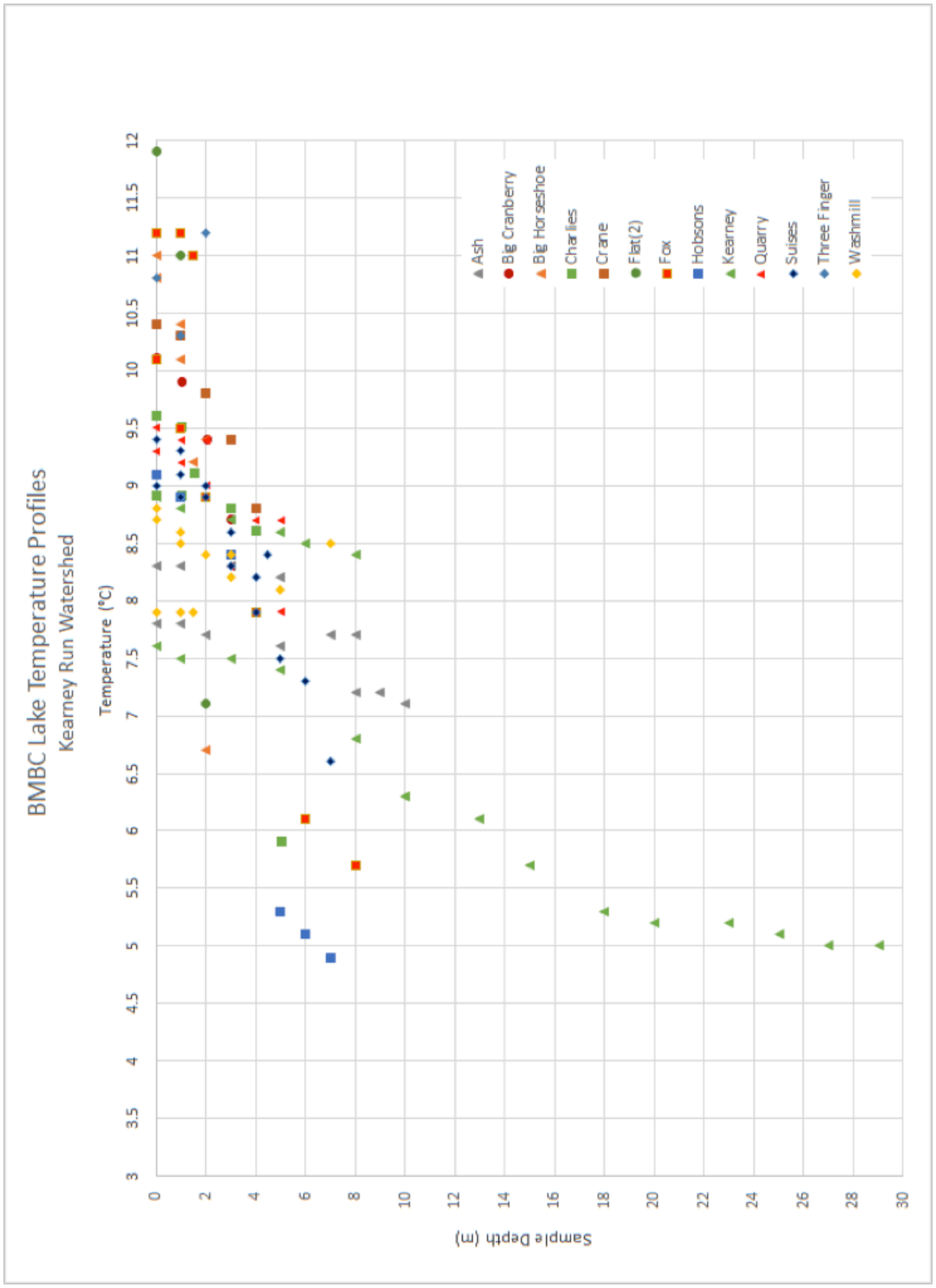


Figure 11. Vertical profiles of temperature in lakes in the Kearney Run Watershed.



Dissolved Oxygen (% saturation)

Dissolved oxygen concentrations ranged from approximately 70 to 104 % saturation (Figs. 12 and 13). There was no evidence of strong stratification but there were some relatively lower oxygen concentrations at certain depths in Frasers and Kearney lakes. In general, deep water in all lakes was well oxygenated. However, this will probably change as the season progresses and thermal stratification develops.

Figure 12. Vertical profiles of oxygen in lakes in the Nine Mile River Watershed.

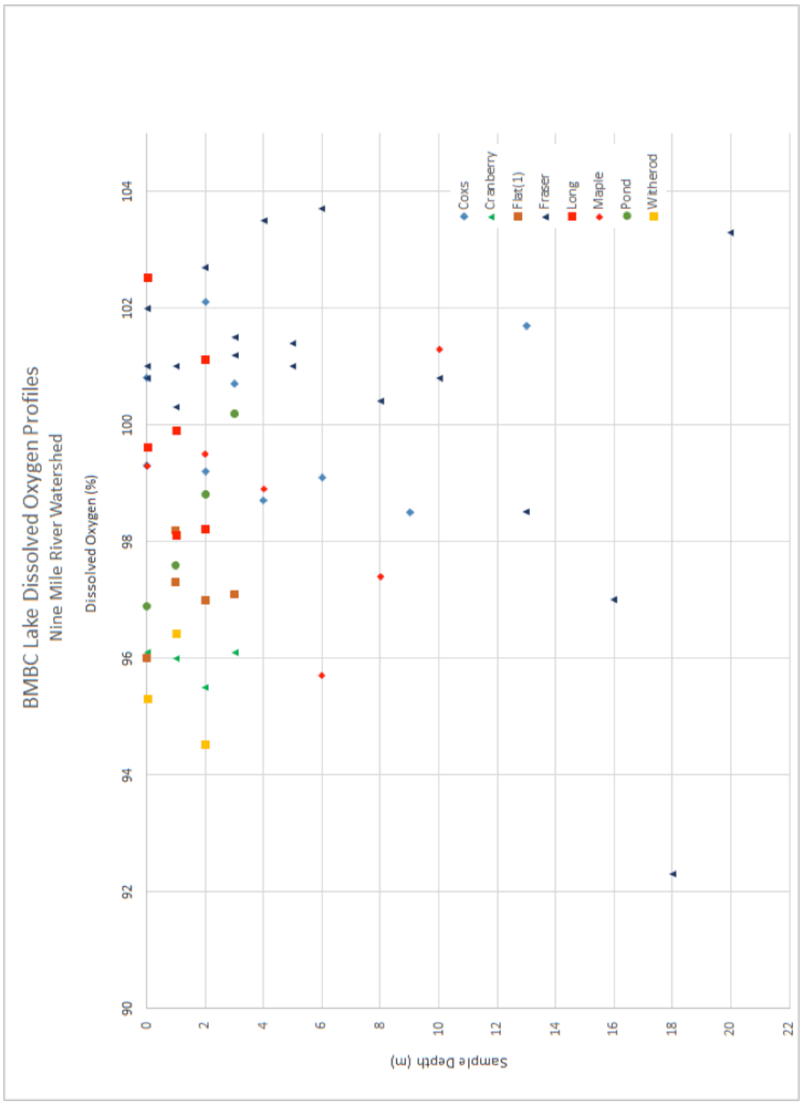
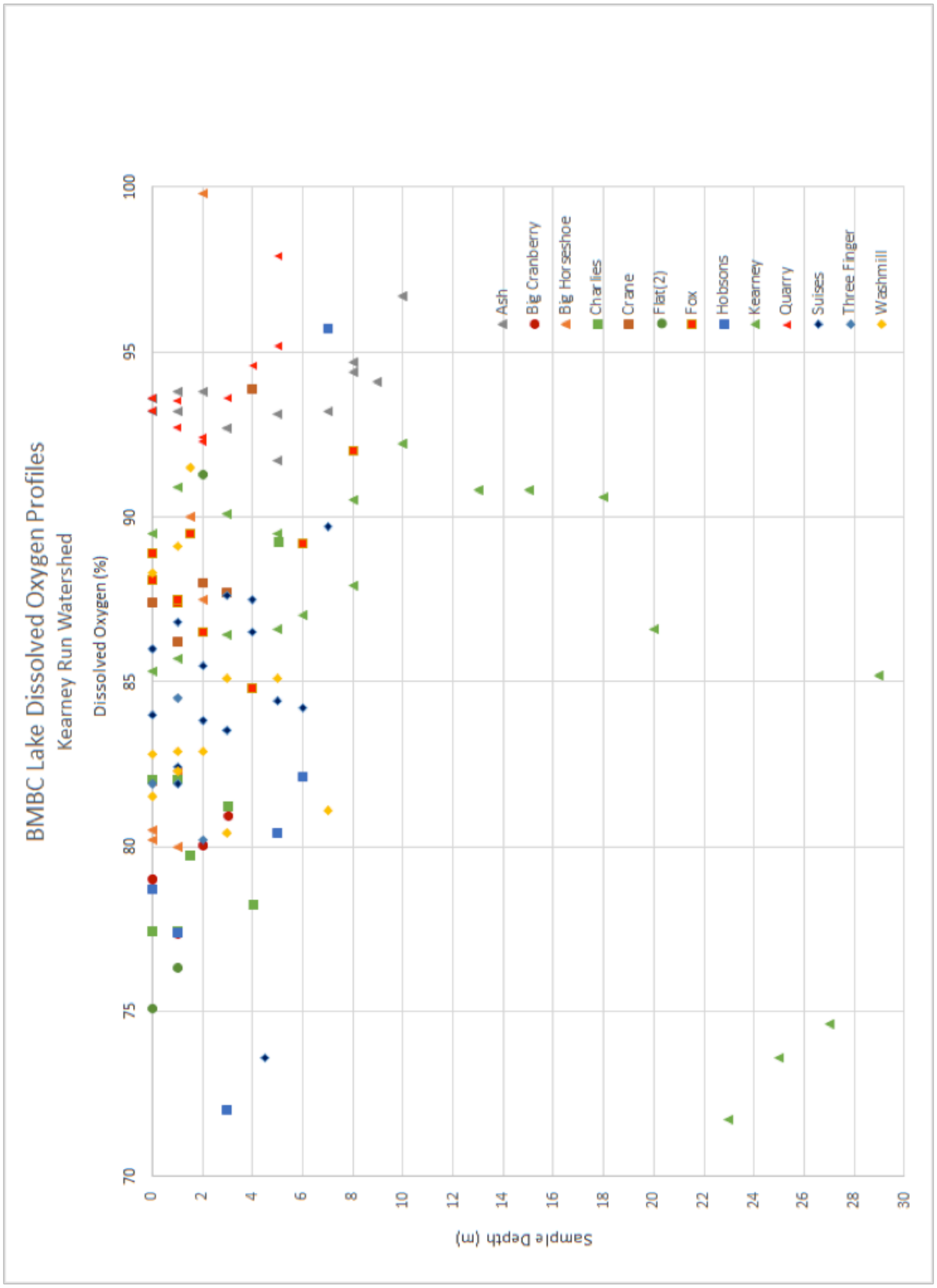


Figure 13. Vertical profiles of oxygen in lakes in the Kearney Run Watershed.



Specific Conductance (µS/cm)

Specific conductance ranged broadly by an order of magnitude from approximately 20 to 210 µS/cm (Figs. 14 and 15). Values were virtually constant with depth in all lakes and there was no evidence that deeper waters have higher values.

Figure 14. Vertical profiles of specific conductance in lakes in the Nine Mile River Watershed.

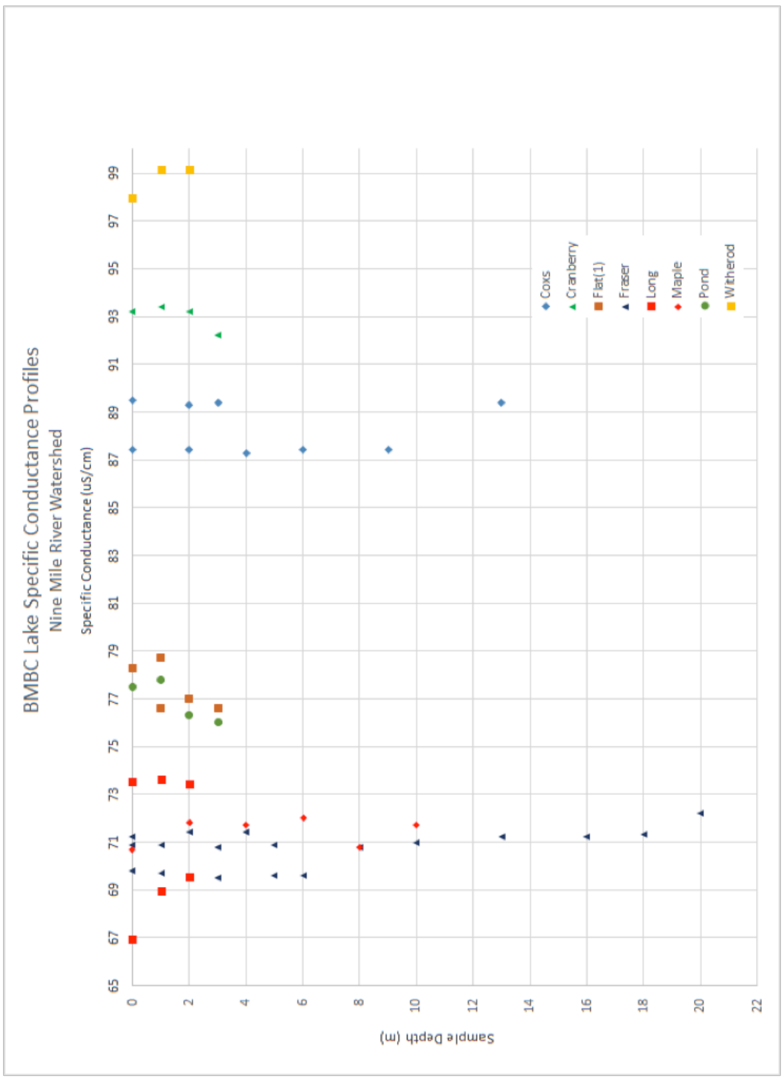
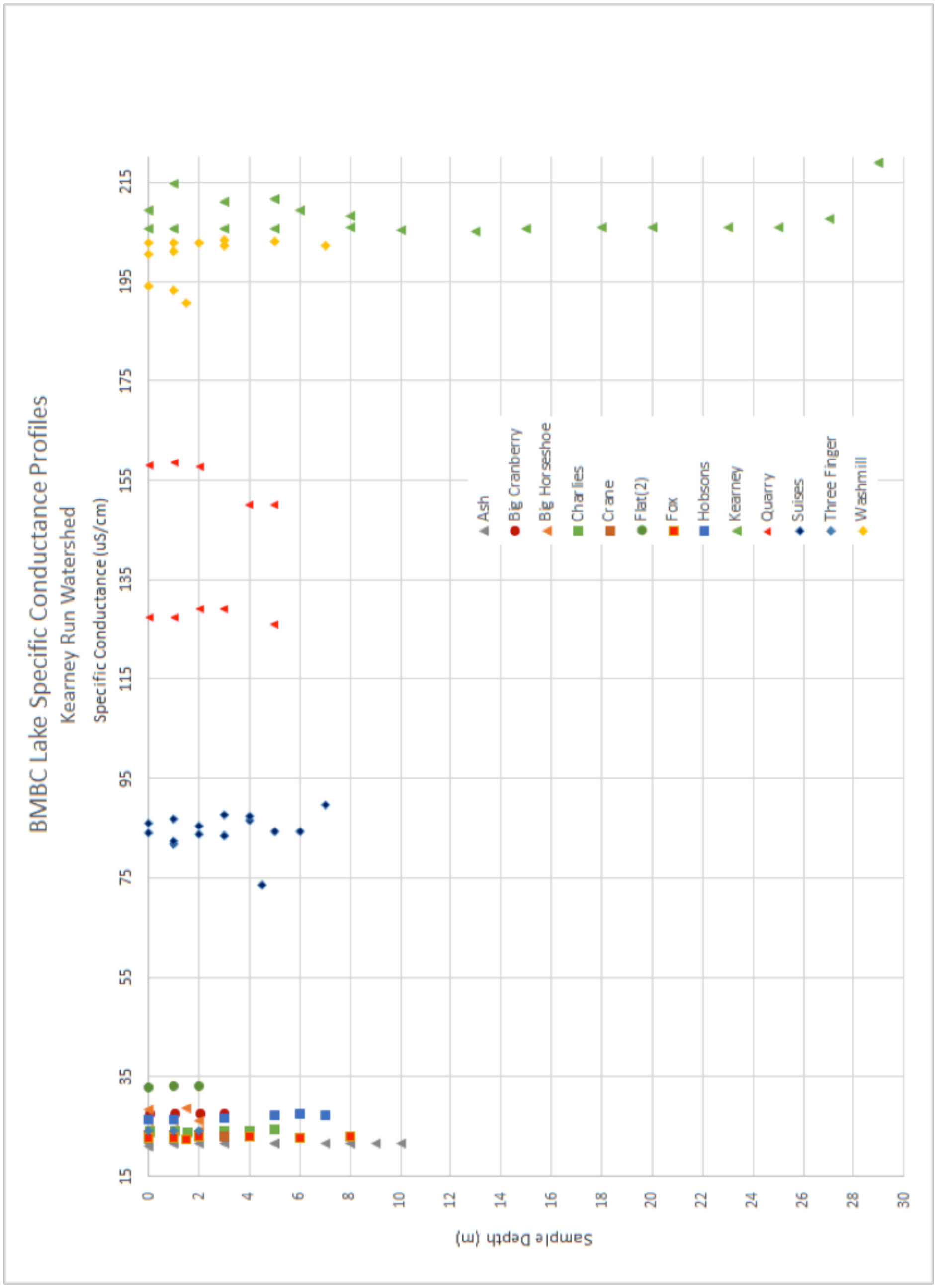


Figure 15. Vertical profiles of specific conductance in lakes in the Kearney Run Watershed.



pH

pH ranged from approximately 3.4 to 6.5 (Figs. 16 and 17). With minor variations, values were essentially constant with depth.

Figure 16. Vertical profiles of pH in lakes in the Nine Mile River Watershed.

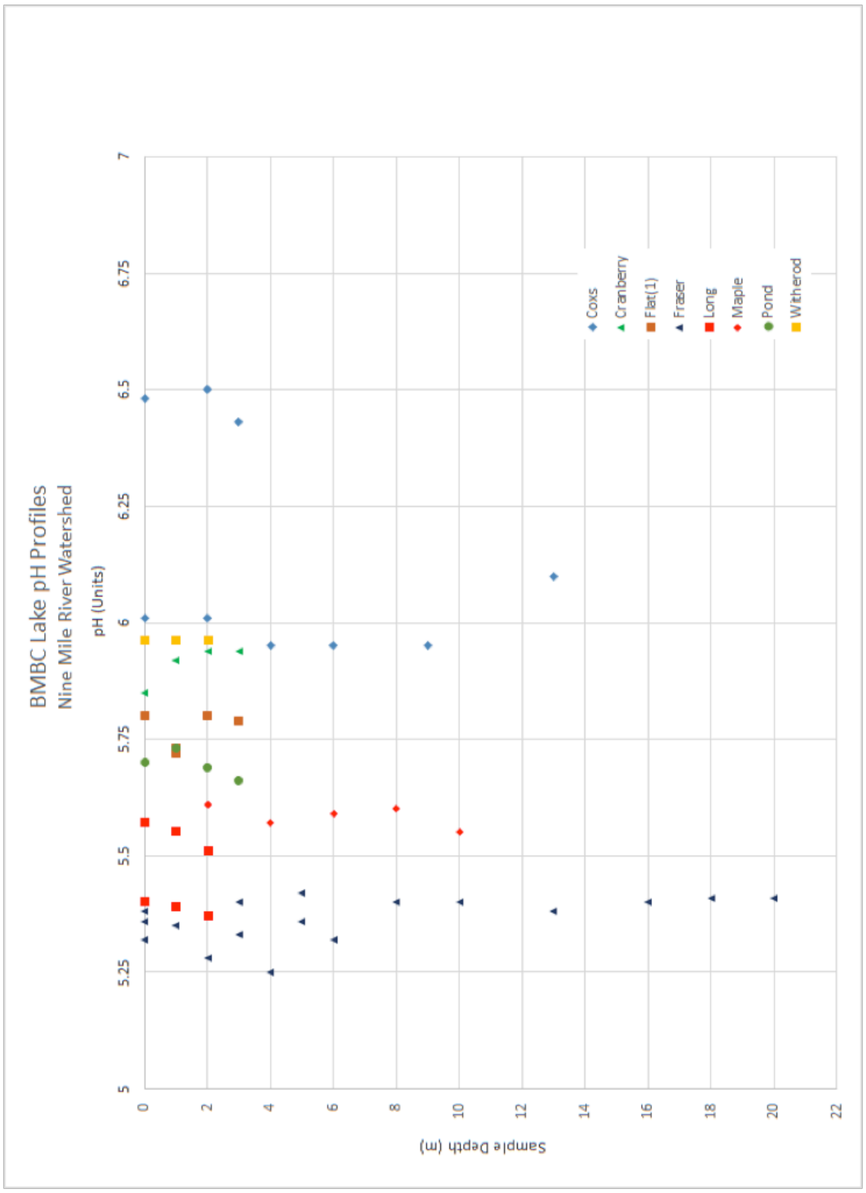
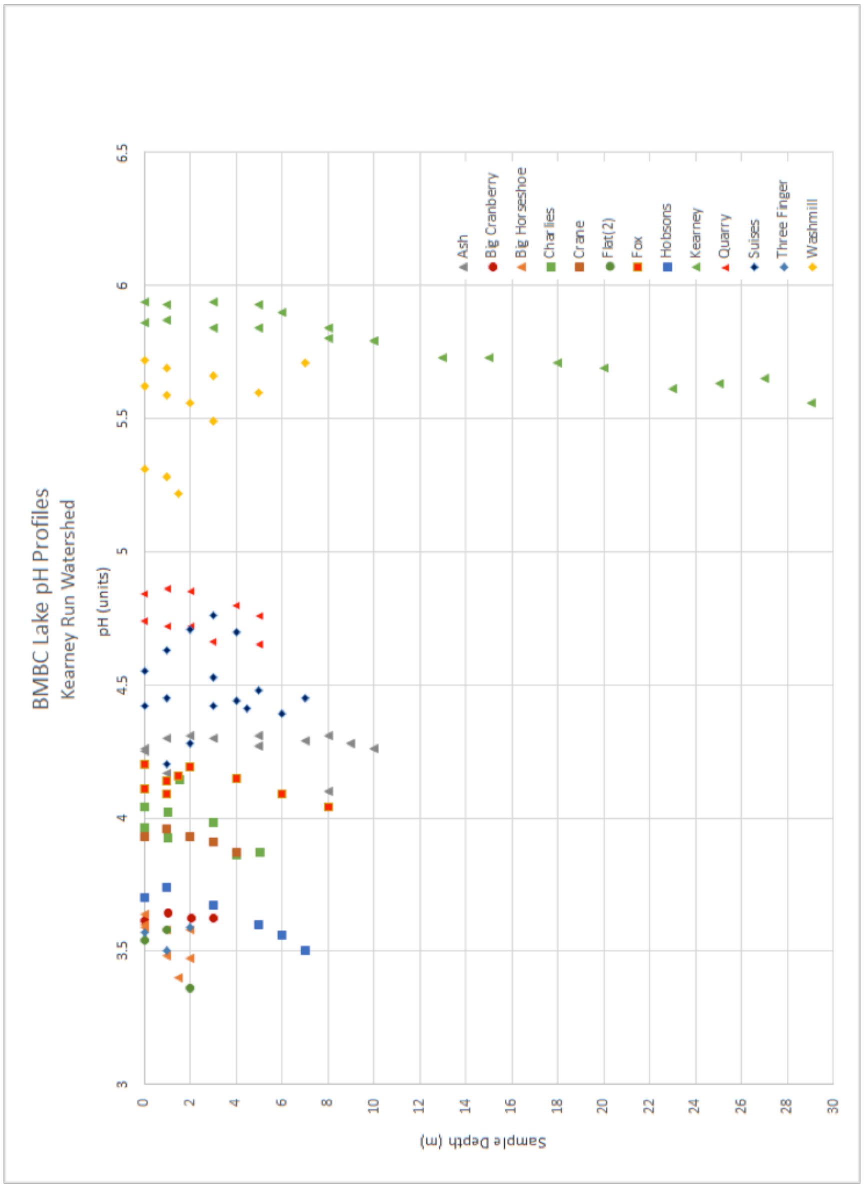


Figure 17. Vertical profiles of pH in lakes in the Kearney Run Watershed.



With the exception of some expected minor temperature stratification in surface water, the combined data of all variables indicate that without exception the lakes were well mixed at the time of sampling. Therefore, it is justifiable to calculate mean values of each variable for all lakes for comparison purposes.

Mean Values

The mean values of Secchi depth, temperature, dissolved oxygen, specific conductance and pH for each lake are listed in Table 5 along with the date of sampling. The lakes are then ranked for each variable, including total phosphorus, in Tables 6-10.

Table 5. Mean values for temperature, Secchi depth, dissolved oxygen, specific conductance and pH in each lake. All stations and depths combined. Calculated from recorded data.

Lake	Date	Temperature (C)	Secchi Depth (m)	Dissolved Oxygen (% Saturation)	Specific Conductance (μS/cm)	pH
Coxs	8 April	5.9	2.5	100	88	6.15
Flat (1)		7.0	2.5	97	77	5.77
Long		8.4	2.5	100	71	5.47
Witherod		8.4	2.5	95	99	5.96
Cranberry		8.7	2.0	96	93	5.91
Un-named pond		8.4	2.0	98	77	5.70
Maple		7.1	2.5	99	72	5.58
Frasers		6.0	2.0	101	71	5.36
Susies	10 April	8.4	2.5	84	128	4.49
Big Cranberry		9.5	2.0	79	27	3.62
Flat (2)		10.0	1.5	81	33	3.49
Big Horseshoe		9.9	2.0	85	26	3.54
Three Finger		10.8	1.5	83	24	3.60
Crane		9.7	2.5	89	23	3.92
Ash		7.8	3.0	94	21	4.26
Fox		9.1	2.0	88	23	4.13
Quarry		8.9	2.0	94	141	4.76
Charlies	14 April	8.7	2.5	81	24	3.97
Washmill		8.3	2.0	84	200	5.54
Hobsons		7.0	2.0	81	27	3.63
Kearney		6.9	1.5	86	208	5.79

Temperature (°C)

The mean water temperature ranged from about 6 in Coxs and Frasers lake to a high of almost 11 °C in Three Finger Lake. The highest values were found in the shallower lakes which heat up faster after the ice disappears.

Secchi Depth (m)

The mean Secchi depth varied by a factor of just two (Table 6). The highest value, 3.0 m, occurred in Ash Lake which is an isolated headwater lake in the Kearney Run Watershed. Kearney Lake was one of three with the lowest value, or most turbid water, of 1.5 m.

Table 6. Ranking of lakes by mean Secchi depth (m).

Lake	Watershed	Secchi Depth (m)
Ash	Kearney Run	3.0
Long	Nine Mile River	2.5
Witherod	Nine Mile River	2.5
Coxs	Nine Mile River	2.5
Flat (1)	Nine Mile River	2.5
Maple	Nine Mile River	2.5
Crane	Kearney Run	2.5
Susies	Kearney Run	2.5
Charlies	Kearney Run	2.5
Quarry	Kearney Run	2.0
Cranberry	Nine Mile River	2.0
Big Cranberry	Kearney Run	2.0
Fox	Kearney Run	2.0
Washmill	Kearney Run	2.0
Un-named pond	Kearney Run	2.0
Frasers	Nine Mile River	2.0
Big Horseshoe	Kearney Run	2.0
Hobsons	Kearney Run	2.0
Flat (2)	Kearney Run	1.5
Kearney	Kearney Run	1.5
Three Finger	Kearney Run	1.5

Dissolved Oxygen (% saturation)

Mean values were at or just below saturation in all the lakes in the Nine Mile River Watershed (Table 7). Those in the Kearney Run Watershed were slightly lower but never averaged less than 79%.

Table 7. Ranking of lakes by mean oxygen concentration (% Saturation).

Lake	Watershed	Mean Oxygen (% Saturation)
Frasers	Nine Mile River	101
Coxs	Nine Mile River	100
Long	Nine Mile River	100
Maple	Nine Mile River	99
Un-named pond	Nine Mile River	98
Flat (1)	Nine Mile River	97
Cranberry	Nine Mile River	96
Witherod	Nine Mile River	95
Ash	Kearney Run	94
Quarry	Kearney Run	94
Fox	Kearney Run	89
Crane	Kearney Run	89
Kearney	Kearney Run	86
Big Horseshoe	Kearney Run	85
Susies	Kearney Run	84
Washmill	Kearney Run	84
Three Finger	Kearney Run	83
Flat (2)	Kearney Run	81
Charlies	Kearney Run	81
Hobsons	Kearney Run	81
Big Cranberry	Kearney Run	79

Specific Conductance (µS/cm)

The highest values, 208 and 200 µS/cm, occurred in Kearney and Washmill lakes (Table 8). The next highest, 141 and 128 µS/cm, were found in Quarry and Susies lakes. All four of these lakes are in the lower part of the Kearney Run Watershed. The lowest values, < 33 µS/cm, occurred in the more isolated lakes in the upper part of the Kearney Run Watershed. The values in the Nine Mile River Watershed were intermediate.

Table 8. Ranking of lakes by mean specific conductance values (µS/cm).

Lake	Watershed	Mean Specific Conductance (µS/cm)
Kearney	Kearney Run	208
Washmill	Kearney Run	200
Quarry	Kearney Run	141
Susies	Kearney Run	128
Witherod	Nine Mile River	99
Cranberry	Nine Mile River	93
Coxs	Nine Mile River	88
Un-named pond	Nine Mile River	77
Flat (1)	Nine Mile River	77
Maple	Nine Mile River	72
Long	Nine Mile River	71
Frasers	Nine Mile River	71
Flat (2)	Kearney Run	33
Big Cranberry	Kearney Run	27
Hobsons	Kearney Run	27
Big Horseshoe	Kearney Run	26
Three Finger	Kearney Run	24
Charlies	Kearney Run	24
Crane	Kearney Run	23
Fox	Kearney Run	23
Ash	Kearney Run	21

pH

The highest values of pH, on the order of 6, occurred in Coxs, Witherod and Cranberry lakes in the Nine Mile River Watershed (Table 9). The lowest values, less than 4, occurred in the more isolated lakes in the upper part of the Kearney Run Watershed.

Table 9. Ranking of lakes by mean pH values.

Lake	Watershed	Mean pH
Coxs	Nine Mile River	6.15
Witherod	Nine Mile River	5.96
Cranberry	Nine Mile River	5.91
Kearney	Kearney Run	5.79
Flat (1)	Nine Mile River	5.77
Un-named pond	Nine Mile River	5.70
Maple	Nine Mile River	5.58
Washmill	Kearney Run	5.54
Long	Nine Mile River	5.47
Frasers	Nine Mile River	5.36
Quarry	Kearney Run	4.76
Susies	Kearney Run	4.49
Ash	Kearney Run	4.26
Fox	Kearney Run	4.13
Charlies	Kearney Run	3.97
Crane	Kearney Run	3.92
Hobsons	Kearney Run	3.63
Big Cranberry	Kearney Run	3.62
Three Finger	Kearney Run	3.60
Big Horseshoe	Kearney Run	3.54
Flat (2)	Kearney Run	3.49

Total Phosphorus (μg/l)

With just one exception, the values of total phosphorus ranged from 4 to 9 μg/l (Table 10). Values tended to be slightly higher in the Nine Mile River Watershed. There was an anomalously high value of 97 μg/l observed in Flat Lake (2) located in the Kearney Run Watershed. This lake is quite different from the others. It is the smallest and shallowest lake sampled, the entire shoreline is organic and it is full of reeds and sphagnum moss. It also had the lowest value for pH (Table 9). Such an organic-rich body of water can be expected to have elevated levels of total phosphorus but likely not by an order of magnitude. Therefore, this value is considered highly suspicious and most likely due to either contamination or analytical error. Before being accepted as real, this value should be confirmed with further sampling.

Table 10. Ranking of lakes by mean total phosphorus concentration (μg/l) and inferred trophic status. The exceptionally high value for Flat Lake (2) is highly suspicious.

Lake	Watershed	Total Phosphorus (μg/l)	Trophic Status
Flat (2)	Kearney Run	97 (?)	Eutrophic
Coxs	Nine Mile River	9	Oligotrophic
Big Horseshoe	Kearney Run	9	Oligotrophic
Flat (1)	Nine Mile River	8	Oligotrophic
Long	Nine Mile River	8	Oligotrophic
Witherod	Nine Mile River	8	Oligotrophic
Cranberry	Nine Mile River	8	Oligotrophic
Un-named pond	Nine Mile River	8	Oligotrophic
Maple	Nine Mile River	8	Oligotrophic
Frasers	Nine Mile River	8	Oligotrophic
Big Cranberry	Kearney Run	8	Oligotrophic
Susies	Kearney Run	7	Oligotrophic
Three Finger	Kearney Run	7	Oligotrophic
Hobsons	Kearney Run	7	Oligotrophic
Crane	Kearney Run	5	Oligotrophic
Fox	Kearney Run	5	Oligotrophic
Quarry	Kearney Run	5	Oligotrophic
Washmill	Kearney Run	5	Oligotrophic
Ash	Kearney Run	4	Oligotrophic
Charlies	Kearney Run	4	Oligotrophic
Kearney	Kearney Run	4	Oligotrophic

DISCUSSION

The number of water quality variables examined in this survey was limited to those which could be measured with the YSI multi-probe, plus Secchi depth and total phosphorus. Nevertheless, these are key variables in lake water quality surveys and offer valuable information at little cost, especially when the data are collected by volunteers.

This water quality survey was somewhat unique compared to others conducted recently in the area. With just a few exceptions, it included all the lakes located within the conceptual boundary of the Blue Mountain-Birch Cove Regional Park. Those few missed are relatively inaccessible and could not be easily included in the limited time available for sampling. All samples were collected within a six-day window so that the lakes can be compared without concerns of temporal variation of properties. By sampling just after the ice disappeared, it is possible to compare the results to those of other surveys also carried out at the time of the spring turnover. Most importantly, the vertical profiling allowed an assessment of possible stratification in the water column while most other studies only sampled surface water. And finally, with the exception of total phosphorus, data could read immediately in the field from the multi-probe and the sampling regime adjusted accordingly if necessary. In most other studies, water samples were returned to the lab for analysis and the results were not known until days or weeks later.

With the exception of temperature, the vertical profiles provided no evidence of stratification in the water column at the time of sampling and confirmed that the lakes were well mixed from top to bottom. This justified calculating mean values for each lake for comparative purposes. This observation also confirmed the assumption made in the Metro Area Lake Synoptic Survey program that values measured in surface samples, collected in the early spring just after the ice disappeared, are representative of the entire lake volume (Clement and Gordon 2019).

The depths of the lakes in the park are in general quite shallow (Tables 3 and 4). Ten of the lakes (48%) have maximum depths less than 5 m, six (29%) have maximum depths between 5 and 10 m while three (14%) have maximum depths between 10 and 15 m. Only Frasers and Kearney lakes have maximum depths greater than 20 m.

The Secchi depths, an estimate of water turbidity, were reasonable and only varied by a factor of two (Table 6). The overall mean value was 2.2 m. In most cases, these seem to represent natural levels. These readings have relatively low precision because they were made from a canoe, often under windy conditions. The lower readings indicate somewhat elevated turbidity which could be caused by algal blooms, high levels of dissolved organic carbon and/or suspended sediment. It was too early in the season to have algal blooms but the relatively low reading in Kearney Lake of 1.5 m may represent elevated suspended sediment concentrations due to the current extensive development activity in its immediate watershed.

The mean values of dissolved oxygen were high and never dropped below 79% saturation (Table 7). This healthy condition is to be expected at this time of the year soon after the spring turnover. Oxygen levels are affected by temperature and biological activity and can change diurnally. It is curious that the highest values occurred in the Nine Mile River Watershed. This may be due the fact that the lakes in the Kearney Run Watershed were sampled two to six days later and increasing water temperature would decrease the solubility of oxygen and increase biological activity, including respiration which consumes oxygen.

The lowest specific conductance values, less than 30 µS/cm, occurred in the more isolated lakes in the upper part of the Kearney Run Watershed (Table 8). These lakes are not subjected to development pressures and the readings represent nature levels of dissolved ions resulting from a combination of erosion and atmospheric input. The highest values, greater than 120 µS/cm, occurred in Susies, Quarry, Washmill and Kearney lakes. These clearly indicate pollution due to runoff from development in their immediate watersheds, beginning in Susies and increasing moving down the watershed. A major source of this pollution is road salt but other sources could include residential chemicals such as lime and fertilizers. The highest values in the Nine Mile River Watershed, 88-99 µS/cm, occurred in Coxs, Witherod and Cranberry lakes (Table 8), all of which have considerable residential development in their immediate watersheds. Unless corrective action is taken, these values are expected to increase as development continues. A recent study of nine HRM lakes indicated that once a watershed was 25% developed the concentrations of chloride, a major contributor to specific conductance, exceeded the CCME guideline for the protection of aquatic life (Scott et al. 2019).

Because of their geological setting and the presence of wetlands, the pH of lakes in the study area is naturally low and the lakes are quite acidic. The lowest values of pH observed in this study, less than 4, occurred in the more isolated lakes in the upper part of the Kearney Run Watershed (Table 9). These are lakes not subjected to development pressure. The highest values, on the order of 6, occurred in Coxs, Witherod and Cranberry lakes in the Nine Mile River Watershed. All three of these lakes have considerable residential development in their immediate watersheds and receive various residential pollutants.

With the exception of the anomalously high suspicious value observed in Flat Lake (2), the values of total phosphorus were low and ranged from 4 to 9 µg/l (Table 10). Values tended to be slightly higher in the Nine Mile River Watershed. There was no evidence of a relationship between total phosphorus and the degree of development in the immediate watersheds. For example, Kearney Lake, located at the lower end of its watershed and subjected to the greatest development pressure, was one of the three lakes with the lowest concentration at the time of sampling. This may also be related to flushing rate

Frasers, Susies and Kearney lakes have been included in the Metro Area Lakes Synoptic Survey program which has sampled the surface water of 51 lakes at approximately decadal intervals since 1980 (Clement and Gordon 2019). This program has consistently measured a large number of water quality variables including specific conductance, pH and total phosphorus and the results provide a look at temporal changes. The results from Frasers, Susies and Kearney lakes in this 2021 survey are compared to those from the 1980, 1991, 2000 and 2011 surveys in Table 11. Specific conductance has gradually increased over thirty years in all three lakes with the highest values occurring in 2011. However, values were lower in all three lakes in 2012. This is presumably due to the milder winters in recent years and the likely reduction in the use of road salt in the watersheds. Values for pH gradually increased over the first twenty years but have tended to drop since then. The initial increase was presumably due reduced acidic precipitation resulting from emission controls in the US and Canada but there is no obvious explanation for the apparent decrease in recent years. Concentrations of total phosphorus increased markedly in 1991 but these data are suspect for values decreased in later years and have since remained relatively constant.

Table 11. Decadal changes in specific conductance, pH and total phosphorus observed in Frasers, Susies and Kearney lakes. 1980, 1991, 2000 and 2011 data from Clement and Gordon (2019). 2021 data from this study. All values were measured in the spring just after the ice disappeared.

	1980	1991	2000	2011	2021
Specific Conductance (µS/cm)					
Frasers	~50	~60	~80	81	71
Susies	~40	~80	~150	285	128
Kearney	~60	~90	~160	231	208
pH					
Frasers	~4.8	~4.9	~5.6	5.70	5.36
Susies	~5.7	~5.7	~6.0	4.71	4.49
Kearney	~5.6	~5.7	~6.7	6.13	5.79
Total Phosphorus (µg/l)					
Frasers	3	16	11	7	8
Susies	1	12	8	5	7
Kearney	1	16	8	3	4

It is interesting to compare the values of specific conductance, pH and total phosphorus observed in this study to the range of values observed over the years in the synoptic surveys (Clement and Gordon 2019). Specific conductance in the synoptic surveys ranged from a low of 35 µS/cm in Spider Lake to a high of 1290 µS/cm in Frenchman's Lake while in this study values ranged from a low of 21 µS/cm in Ash Lake to a high of 208 µS/cm in Kearney Lake (Table 8). Clearly, values in the Blue Mountain-Birch Cove lakes fall into the lower range observed in Metro Area lakes as a whole. In general, this reflects their more isolated location and lower input of chemical pollutants, especially road salt. pH readings observed in the synoptic surveys ranged from a low of 4.28 in Lake Major to a high of 7.41 in Lake Micmac while in this study values ranged from a low of 3.49 in Flat Lake (2) to a high of 6.15 in Coxs Lake (Table 9). Therefore, values in the Blue Mountain-Birch Cove lakes are on average slightly lower than observed in Metro Area lakes. Again, this reflects their geological setting, more protected nature and perhaps measurement differences. Total phosphorus concentrations observed in the synoptic surveys ranged from a low of 1 µg/l in Kearney and Lamont lakes to over 20 µg/l in several lakes. As mentioned above, some of these higher values may be suspect. With the exception of the anomalously high value in Flat Lake (2), the values observed in this study ranged from a low of 4 µg/l in Ash, Charlies and Kearney lakes to a high of 9 µg/l in Coxs Lake and Big Horseshoe lakes (Table 10). Again, values in the Blue Mountain-Birch Cove lakes appear to fall well into range observed in Metro Area lakes as a whole.

It is also interesting to compare the values of other variables measured in the synoptic surveys in Frasers, Susies and Kearney lakes to the other forty-eight lakes sampled (Clement and Gordon 2019). Values of aluminum, dissolved organic carbon and colour were near the top of the range observed while those of alkalinity were near the bottom. Almost all of the trace metals measured were near the top of the range. These included iron, zinc, nickel, vanadium, cobalt, lead, cerium, cadmium, yttrium, uranium, gadolinium, Samarian, dysprosium, erbium, ytterbium, thallium, europium and holmium. These higher levels of trace metals reflect the bedrock geology (i.e. granite and slate) but do not pose any environmental concerns.

The significance of the values observed in this survey for specific conductance, pH and total phosphorus can be assessed by comparing them to established guidelines for the water quality of aquatic ecosystems, for example those developed by the Canadian Council of Ministers of the Environment (CCME) (CCME 1999). The accepted guidelines for the protection of freshwater aquatic life with respect to chloride, pH and total phosphorus are listed in Table 12. Using the relationship between chloride and specific conductance observed in the synoptic surveys (Clement and Gordon 2019), the chloride guideline of 120 mg/l is equivalent to a specific conductance reading of about 500 µS/cm. This is well above the maximum value of 208 µS/cm observed in this survey in Kearney Lake. However, the range of pH values observed in this survey (Table 9) fall well below the preferred range of 6.6 to 9.0. With regard to total phosphorus, the values fall well below the guidelines. Therefore, with the exception of pH, the CCME guidelines indicate that the existing water quality in the BMBC lakes with regard to conductivity and total phosphorus poses no threat to the protection of aquatic life.

Table 12. CCME water quality guidelines for the protection of freshwater aquatic life.

Variable	CCME Guideline
Chloride	120 mg/l
pH	6.6 to 9.0
Total phosphorus	50 µg/l

The low pH (high acidity) of Blue Mountain-Birch Cove lakes is of natural origin due to their geological setting. However, this natural acidity has been increased in recent decades due to wide spread acid precipitation in eastern Canada (Watt et al. 1979). This has had a severe impact on salmonid fish which can not successfully breed at pH values less than about 4.5. Recent monitoring data suggest that international controls on distant sulphate emissions are having a positive effect and that some Nova Scotian lakes, including Pockwock Lake and Lake Major, are beginning to show signs of recovery from this anthropogenic acidification (Clair et al. 2007, Anderson et al. (2017).

Due to the high level of development in recent years, several studies of total phosphorus have been made in the lower part of the Kearney Run Watershed, especially in Kearney and Papermill lakes (AECOM 2013, CWRS 2016). AECOM (2013) analyzed the extensive database collected during the monitoring program run by HRM from 2006 to 2011 and the mean concentrations of total phosphorus are listed in Table 13. The highest values, exceeding 10 µg/l, occurred in Big Horseshoe Lake, Black Duck Brook and McQuade Lake. The lowest values occurred in Three Finger, Charlies, Crane, Ash and Fox lakes. The high values in McQuade Lake and Black Duck Brook are not surprising since the immediate watershed has been subjected to considerable residential development in recent years but it is surprising to see the highest concentration in Big Horseshoe Lake which is well isolated from development. It is interesting to note that Big Horseshoe Lake is close to Flat Lake (2) where the anomalously high value of 97 µg/l was observed in this study (Table 10). Overall, these values have a slightly greater range than observed in this study (Table 10). The temporal variation in the total phosphorus concentrations observed in Kearney Lake between 2006 and 2011 is plotted in Fig. 18. A gradual trend of increasing concentration with time is evident and on two occasions exceeded 10 µg/l.

Lakes can be classified in regard to their trophic status using total phosphorus concentrations. Lakes with values below 4 µg/l are commonly classified as ultra-oligotrophic, lakes with values between 4 and 10 µg/l are classified as oligotrophic, lakes between 10 and 20/ µg/l are classified as mesotrophic, lakes with values between 20 and 35 µg/l are classified as meso-eutrophic, lakes with values between 35-100 ug/l are classified as eutrophic and lakes with values above 100 µg/l hyper-eutrophic.

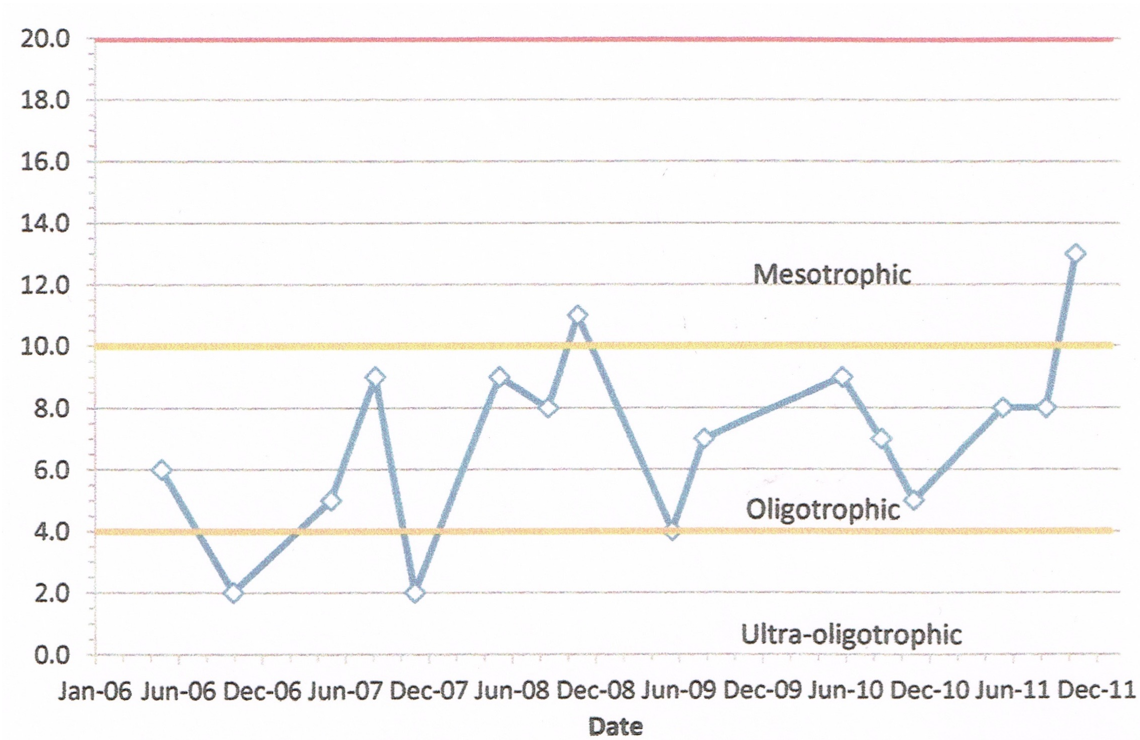
On the basis of this classification, with the exception of Flat Lake (2), all the Blue Mountain-Birch Cove lakes sampled in this survey had total phosphorus concentrations between 4 and 9 µg/l and therefore the lakes fall into the oligotrophic category (Table 10). The extremely high total phosphorus concentration of 97 µg/l observed in Flat Lake (2) puts it at the top of the eutrophic category. As mentioned before, this single high value is highly suspect and needs to be confirmed. With regard to the total phosphorus concentrations reported by AECOM (2023) (Table 13), Big Horseshoe Lake, Black Duck Brook and McQuade Lake all fell into the mesotrophic range while Crane, Ash and Fox fell into the ultra-oligotrophic range. The rest of the lakes all fell into the oligotrophic range as observed in this survey.

Table 13. Ranking of lakes by mean total phosphorus concentrations (µg/l) in surface samples collected from Blue Mountain-Birch Cove lakes between 2006 and 2011 during the HRM monitoring program (AECOM 2013) and the inferred trophic status.

Lake	Watershed	Total Phosphorus (µg/l)	Trophic Status
Big Horseshoe	Kearney Run	18	Mesotrophic
Black Duck Brook	Kearney Run	14	Mesotrophic
McQuade	Kearney Run	12	Mesotrophic
Big Cranberry	Kearney Run	9	Oligotrophic
Washmill	Kearney Run	8	Oligotrophic
Flat (2)	Kearney Run	7	Oligotrophic
Quarry	Kearney Run	7	Oligotrophic
Kearney	Kearney Run	7	Oligotrophic
Paper Mill	Kearney Run	7	Oligotrophic
Hobson	Kearney Run	7	Oligotrophic
Three Finger	Kearney Run	4	Oligotrophic
Charlies	Kearney Run	4	Oligotrophic
Crane	Kearney Run	3	Ultra-oligotrophic
Ash	Kearney Run	2	Ultra-oligotrophic
Fox	Kearney Run	2	Ultra-oligotrophic

More detailed information on total phosphorus in the Paper Mill Lake watershed is found in the desktop study conducted by the Centre for Water Resources Studies commissioned by HRM (CWRS 2016). This study was initiated in response to the realization that total phosphorus concentrations in Kearney and Paper Mill Lakes appeared to be gradually increasing with time and that on occasion exceeded the regulatory threshold adopted for lake management by HRM of 10 µg/l (Fig. 18). It focused on characterizing the sources of phosphorus loading and examining approaches for monitoring trophic state drivers and indicators within the watershed.

Figure 18. Temporal variation in the total phosphorus concentrations (μg/l) in surface waters of Kearney Lake between 2006 and 2011 (AECOM 2013).



Using accepted numerical models of phosphorus loading, it was found that upstream sources accounted for approximately 31% of the total phosphorus load in Kearney Lake. The remaining 69% came from the immediate watershed with the three largest sources in deceasing order of importance being septic systems, runoff from residential development and runoff from industrial development. Since the phosphorus export coefficients used in the models have a high level of uncertainty, it was not possible to identify any one source as the primary cause of the recent elevated levels of total phosphorus.

The possible release of phosphorus from lake sediments was also examined. This a process that can take place when bottom waters become devoid of oxygen, that is become anoxic. Oxygen profiles did indicate in July 2016 that a 1.5 m thick anoxic bottom layer did occur in the outlet basin of Kearney Lake near the dam where the maximum water depth is 7.4 m. However, it appeared that this anoxic event would have been a negligible source of phosphorus in the lake because of its short duration and limited spatial extent. However, because of the potential importance of this process in the future, it is important that future monitoring programs include vertical profiling of temperature, dissolved oxygen and total phosphorus.

The Centre for Water Resources Studies study (CWRS 2016) proposed that the most practical approach for evaluating more accurately the total phosphorus loading from the current Bedford West development would be to intensely monitor a select subset of catchment areas which represent dominant types of land use and management practices for a 2-4 year period.

With regard estimating the trophic state of lakes, the current water quality threshold used by HRM for lake management is a total phosphorus value of 10 µg/l which corresponds to the assumed transition from a state of oligotrophy to mesotrophy. However, it was recommended by CWRS (2016) that chlorophyll a is a better indicator of trophic state because it is a direct measurement of algal biomass while total phosphorus is only a key driver. A transition to mesotrophy would result in higher levels of phytoplankton growth and increased risk of harmful toxic blooms, including cyanobacteria. Nevertheless, it was recommended that total phosphorus should still be measured along with chlorophyll in future monitoring programs and remain a key parameter within any regulatory framework for lake watershed management. The study also made the point that when total phosphorus concentrations get too high and cause adverse effects in lake water, mitigation measures to reduce concentrations are seldom effective. As a result, a better approach is to combine water quality objectives with early warning alerts to evaluate evolving lake water quality rather than waiting for the specific total phosphorus water quality objective to be met or exceeded. If this approach was adopted, then action could be initiated when concentrations increased by an agreed percentage (e.g. 25 or 50%) above baseline levels.

The dissolved ions contributing to the conductivity readings come from many sources and increase the density of the water. One of the major sources in Metro lakes is road salt which contains approximately half chloride by weight. Recent studies in New York State Adirondack Park indicate that high concentrations of road salt (on the order of 50 mg/l and more) in the deep water of Mirror Lake have retarded the annual spring mixing (Wiltse et al. 2020). This has subsequently resulted in increased oxygen depletion (anoxia) in deep waters and a significant reduction in lake trout habitat. For temperate lakes receiving high levels of road salt, a chloride concentration of 50 mg/l is equivalent to a specific conductance reading of about 210 µS/cm. In this survey, the highest values observed were 200 and 208 µS/cm in Washmill and Kearney lakes and there was no evidence of stratification (Fig. 15). Nevertheless, based on the observations in Mirror Lake, it appears that current road salt loadings in these two lakes could be reaching levels capable of affecting the important spring turnover. Hence it is important to limit the input of road salt into the lakes and to continue monitoring water quality on a regular basis.

In nearby Sandy Lake, in recent years specific conductance in deep water has been on the order of 180 to 240 µS/cm and oxygen saturation levels were down to just 20%. As a result, there was concern that density stratification might interfere with the spring turnover and mixing. However, observations made in April 2021, using the same YSI multi-probe used in this study, confirmed that spring mixing had indeed taken place (David Patriquin, personal communication) and both specific conductance (~170 µS/cm) and oxygen saturation (~87%) were constant with depth. However, this situation should continue to be closely monitored. As an example of what could happen if mixing was prevented, anoxic conditions causing undesirable effects have been observed during the summer in recent years in the deep water of Oathill Lake in Dartmouth. This probably occurred naturally for many years but has increased more recently due to extensive residential development in the watershed. Under the lead of the Oathill Lake Conservation Society, this situation has been mitigated by installing a solar powered deep water aerating system which seems to be working well. A similar system has also been installed in nearby Penhorn Lake.

In conclusion, the Secchi depth observations of turbidity indicate that there are no serious siltation issues of concern at this time but this could change on relatively short notice. For example, there was heavy siltation in Black Duck Brook, which drains into Kearney Lake, during the winter of 2012 caused by erosion in the Brookline Park development. In the past, Kearney Lake received heavy siltation from a concrete plant that used to operate along Kearney Lake Road across from Maskwa and apparently significant silt deposits still exist.

No serious water quality problems were evident in the oxygen data. Saturation values were all above 80% and anoxic conditions in deep water were never observed. However, the low pH values of some lakes do have negative effects on salmonid fish such as trout and salmon. These are natural in origin and have been depressed further in recent years by acid precipitation but this problem is gradually being mitigated by the implementation of emission controls.

The major water quality issue identified in this study is specific conductance which is a measure of dissolved ions. Due to the geological setting, natural levels in the Blue Mountain-Birch Cove lakes are very low but can be increased substantially by the addition of various pollutants, in particularly road salt which is widely used in the watersheds. They increase the density of water and, if concentrations get too high, can interfere with the spring and fall turnovers which are important mixing events for maintaining water quality.

Existing concentrations of total phosphorus do not appear to pose serious problems. At this time, using total phosphorus as an indicator, the tropic state of all lakes appears to be oligotrophic. However, earlier studies indicate that concentrations appear to be increasing with time and that on some occasion certain lakes have crossed over into the mesotrophic category which is reason for concern.

The results of this study indicate that the lakes of most concern with regard to water quality at this time are Kearney, Washmill, Quarry and Susies, all in the lower part of the Kearney Run Watershed. This is due primarily to the elevated levels of specific conductance resulting from the widespread use of road salt in their watersheds. There also is continuing concern about Kearney Lake in regard to potential increases in total phosphorus because of the widespread development in its immediate watershed. The two large lakes subjected to development in the Nine Mile River Watershed, Coxs Lake and Frasers Lake, located on the periphery of the park, appear to have fewer water quality problems. The many lakes well within the park boundary appear to remain in a natural state and, with the exception of acid precipitation, have been unaffected by human activities.

Some water quality studies have also been carried out in the Nine Mile River Watershed on several occasions between 2014 and 2020 (Five Bridges Wildlife Heritage Trust 2021). A large number of water quality variable were measured including nutrients and trace metals at ten stream locations. There was no lake sampling. After reviewing the available data, it was concluded that at the present time there is no evidence of adverse effects on water quality from development in the upper reaches of the Nine Mile River Watershed, most of which lies within the conceptual boundary of the Blue Mountain-Birch Cove Regional Park.

This study measured only a limited suite of water quality variables. Important ones omitted, because of operational and financial constraints, include suspended sediment, nutrients and bacteria. More water quality information on these and additional variables will be forthcoming in the near future from the fifth 2021 synoptic survey which sampled Coxs, Long, Frasers, Ash, Quarry, Susies and Kearney lakes on 31 March under the lead of Rob Jamieson at Dalhousie University.

RECOMMENDATIONS

- Under the lead of HRM, with the participation of other agencies, universities, developers and volunteers, a formal long-term water quality monitoring program of lakes within the conceptual boundary of the Blue Mountain-Birch Cove Regional Park should be established. The results can used to manage residential and commercial development in the bordering watersheds and also guide the development and management of the park. Such a program could be incorporated into the proposed long-term HRM water quality program approved by the Environment and Sustainability Standing Committee on 3 June 2021 (Item No. 12.1.1).
- One component of this program should be seasonal water quality monitoring of those lakes under the heaviest development pressure, for example Susies, Quarry, Washmill and Kearney lakes. As a minimum, sampling should be carried at the time of the spring and fall turnovers as well as several times during the period of summer stratification. This program should include vertical profiling and, in addition to the variables measured in this survey, include suspended sediment, nutrients, chlorophyll and bacteria.
- A second component should be a general springtime water quality survey of all lakes in the park, very similar to this survey, conducted at an interval of at least once every five years. This survey should include vertical profiling and, in addition to the variables measured in this survey, include suspended sediment, nutrients, chlorophyll and bacteria. Such a less frequent but more extensive monitoring program would collect valuable information of potential changes in the more isolated lakes which are subjected to much less development pressure.

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