Sherbrooke Lake

Water Quality Report

2011

Diann Robar Photo

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LaHave River Watershed Committee

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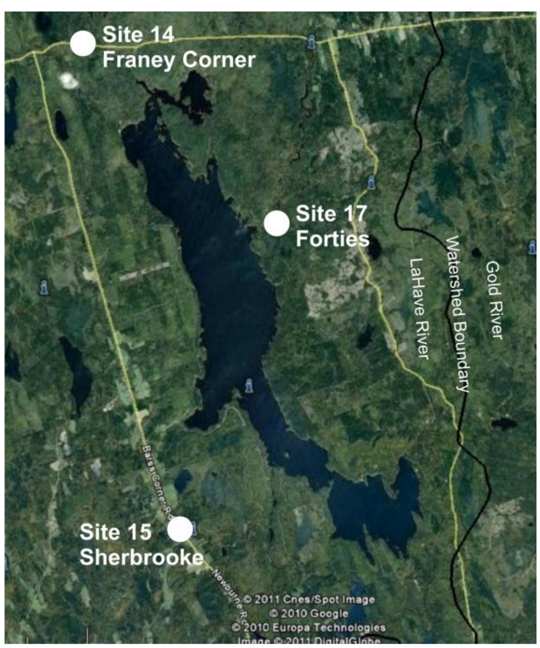
Introduction

Sherbrooke Lake is the largest body of water in the LaHave River watershed. It was scoured out of the bedrock by glaciers some 15,000 years ago, and is now the home of numerous species of aquatic and terrestrial life, including humans, all depending on the lake for sustenance of one kind or another. The lake receives drainage from small rivers and brooks mainly to the north, east, and south. The outlet (North Branch LaHave River) from the lake is located on the southwest side of the lake. The North Branch LaHave River is a main tributary of the LaHave River that eventually joins the main branch through Wentzell's Lake. This document is the second of a series of annual reports on the quality of water in the vicinity of Sherbrooke Lake. Last year's report is available at:
http://www.coastalaction.org/pages/projects/lrwp/field_reports/sherbrooke_lake_water_quality_report_2010-b.clarke.pdf

Water Quality Monitoring

In mid-2007, Bluenose Coastal Action Foundation (BCAF) (http://www.coastalaction.org/) of Lunenburg, Nova Scotia, began a program of water monitoring at 15 locations in the LaHave River watershed. Water sampling takes place every four weeks (13 times per year) and the water is analyzed at Maxxam Analytics (http://maxxam.ca/) at an annual cost of approximately $1850 per site per year. One of those sampling locations, Site 14, also known as Franey Corner, samples one input at the northern end of Sherbrooke Lake. Since January 2010, we have been analyzing the water at Site 15, also known as Sherbrooke, so that it would be possible to understand what happens to the quality of the water as it passes through the lake. This report is the second step in this process, and expands the investigation by including just one sample taken in August at Site 17 on the Forties River.



Locations of the three sampling sites relevant to Sherbrooke Lake.

Rationale for Sampling Sites 14 and 15

All regular LaHave River watershed sampling sites must be accessible throughout the year, including the Winter when secondary roads may be impassable; therefore, Sites 14 and 15 are at places where main roads intersect main water courses. Although Site 14 provides an excellent sample of the water entering Sherbrooke Lake, it is not the only input to the lake. Other inputs include the Forties River (Site 17), numerous brooks, surface runoff, direct precipitation of rain and snow, and groundwater. As shown in the previous report, Site 14 is among the most pristine water in the entire LaHave River watershed, thus it provides a good indication of water quality conditions from an area with minimal human activity, compared to further downstream locations which have more development and/or land-use activities (such as agriculture). Site 15 provides a good indication of the water quality leaving Sherbrooke Lake, because it includes all the additional inputs listed above plus the natural and human influences from Sherbrooke Lake, North Branch LaHave, and Texas Lake. Any differences between upstream Site 14 and downstream Site 15 output must reflect the combined total of these effects.

Sampling and Analytical Protocol

Maxxam Analytics, located in the Atlantic Acres Industrial Park on Kearney Lake Road, provides sterilized bottles for each sampling run. Samples are collected according to procedures described in the BCAF Baseline Report, are kept in coolers during the sampling run, and are delivered with chain-of-custody forms to Maxxam the same day. Analyses are done by accepted procedures, duplicates are run of some samples, and known standards are run at the same time to check for analytical accuracy. The laboratory is accredited by the Canadian Association for Laboratory Accreditation (www.cala.ca).

Water Quality Standards

Water quality standards for Nova Scotia are adopted from the Canadian Council of Ministers of the Environment (CCME) and depend on the uses for which that water is intended. Of principal interest to us on Sherbrooke Lake are the CCME standards for: drinking water (updated to 2011), recreational water (essentially not updated since 1992), and protection of aquatic life (updated to 2010), and they all appear at http://ceqe.ccme.ca/ Where relevant to our analytical package, these standards are included in the data at the back of this report.

Goals

Of interest to the residents of Sherbrooke Lake are the following on-going questions:

1. what are the absolute values of the various physical and chemical measurements at Sites 14 and 15?
2. where are those values in relation to the CCME water quality guidelines?
3. how does the quality of the water change from Site 14 to Site 15?
4. how does the quality of water change over the years (trends over time)?

Details of the Analyses

Measurements are of two kinds: field measurements using an electronic device known as a sonde, and Maxxam's laboratory measurements by various accredited analytical techniques. The complete analytical data set is in Appendix 1 at the end of this report. The data are organized to show the measurements for Sherbrooke Site 15 first, then Franey Corner Site 14 below, and finally the residuals obtained by subtracting Franey results from Sherbrooke results. A positive residual means that a measured parameter has increased as water passes through the lake (the lake adds that component and , therefore, may be a SOURCE); a negative residual means that parameter has decreased in the lake (the lake subtracts that component and, therefore, may be a SINK, and is shaded in blue on the data sheets). This section provides some explanation of each of the parameters measured.

The portable YSI 600QS electronic sonde used for measuring temperature, atmospheric pressure, pH, conductivity, and dissolved oxygen in naturally occurring surface water.

GENERAL PROPERTIES – essential general measurements

Temperature – in degrees Celsius, as measured in the field by the sonde

Barometric Pressure (BP) – in mm of mercury (Hg), as measured in the field by the sonde

pH – in obscure units ($\log_{10}$ x (1/aH$^+$)) that give values which range from 0 to 14, as measured in the field by the sonde (values lower than 7 are considered acidic) – the scale is logarithmic, so a pH of 4 is ten times more acidic than a pH of 5

SOLIDS – occur in the water in two forms, dissolved and suspended

Specific Conductance – in milliSiemens/centimetre (mS/cm), as measured by the sonde, is a measure of the ability of the water to conduct an electrical current, and that conductance is related to the amount of dissolved material in the water

Total Dissolved Solids (TDS Field) – in milligrams per litre (mg/L = parts per million (ppm)), as calculated by the sonde using the specific conductance measurements above (water is a universal solvent, meaning it can dissolve just about anything, and rivers carry away about 30 tonnes of dissolved material per square kilometer drained per year!)

Total Dissolved Solids (TDS Lab) – we no longer do this measurement in the interest of cost-saving

Total Suspended Solids (TSS) – in mg/L (ppm), as measured by Maxxam Analytics

SALINITY – salinity, is similar to TDS and is a measurement more commonly used for seawater

Salinity – in parts per thousand (ppt), as measured in the field by the sonde (for reference, seawater is about 35 ppt)

Choride – in mg/L (= ppm), as measured by Maxxam Analytics

OXYGEN – DO, DO%, and BOD are good measures of the health of the water, and many aquatic species, such a fish, use this dissolved oxygen to breathe

Dissolved Oxygen Concentration – in mg/L (= ppm) as measured in the field by the sonde

Dissolved Oxygen Percent – as calculated from DO Conc, Temperature, and Pressure by the sonde

Biological Oxygen Demand (BOD) – we no longer do this measurement in the interest of cost-saving

CRITICAL NUTRIENTS – as measured by Maxxam Analytics – all life needs nitrogen and phosphorus, but levels above CCME guidelines are undesirable and could lead to algal blooms in the lake – Sherbrooke Lake water is generally, and desirably, nutrient-poor

Nitrate and Nitrite – in mg/L (= ppm), expressed as nitrogen, are two forms of oxidized nitrogen; becomes toxic at > 2.9 mg/L

Ammonia – in mg/L (= ppm), expressed as nitrogen, is a reduced form of nitrogen, but we no longer do this measurement in the interest of cost-saving

Nitrogen – in mg/L (= ppm), is the total of all forms of nitrogen, including organic nitrogen forms

Phosphorus – in mg/L (= ppm) is normally the rate-limiting nutrient for algal growth in freshwater

BACTERIA – many species of bacteria inhabit natural waters, but fecal coliforms (including *E. coli*) are an indicator of the presence of wastes from warm-blooded animals (including humans)

Fecal Coliforms - in MPN/mL (Most Probable Number per mL), but note the units are per *millilitre*, so a value of 2/mL, which seems low, is really the same as 2000/L, which seems high!

METALLIC CHEMICAL COMPONENTS – here begins a long list of chemical components, collected only twice a year and reported in μg/L (micrograms per litre = parts per billion (ppb)) by Maxxam Analytics – all analyses where the concentrations in the water are below the lower limit of detection of the analytical method are shaded in green – the values reported are the sum of dissolved and suspended material – note that, for every component above the lower limit of analytical detection, Sherbrooke Lake appears to be a sink, meaning that these metals are accumulating in the lake mainly as normal sedimentary deposits as a result of decreased flow velocities, and chemical precipitates probably related to increasing pH – for reference, a periodic table of the chemical elements appears on the next page.

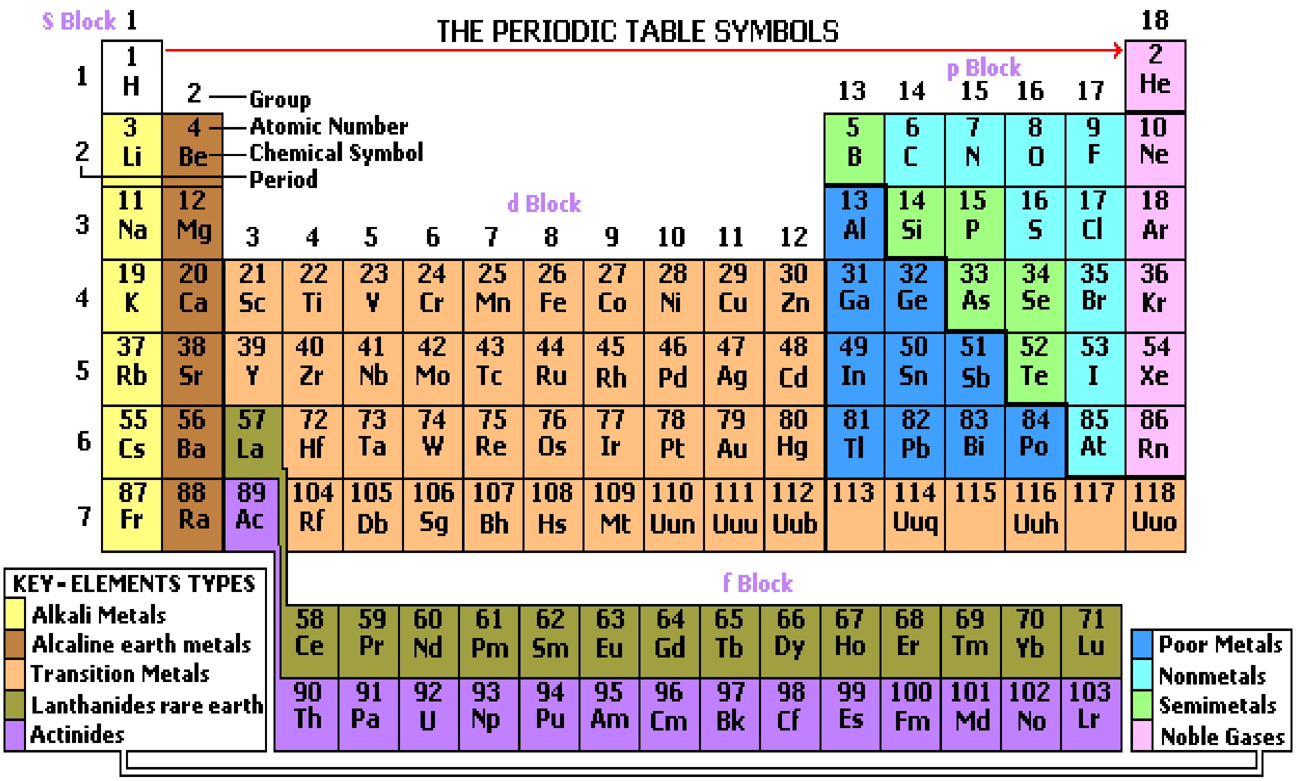
LIGHT ELEMENTS – aluminum and magnesium are probably present mainly in suspended clays, whereas beryllium and boron may be mainly dissolved, but very minor, constituents

ALKALI AND ALKALI EARTH ELEMENTS – sodium, potassium, and calcium are elements readily leached out of rocks and soil; potassium and calcium are both essential nutrients for plant and animal life – clear-cutting of forests results in a depletion of calcium that can negatively affect the aquatic food chain in the region (a reference is: Jeziorski, A. et al. 2008. The widespread threat of calcium decline in fresh waters. Science 322: 1374-1377)

FIRST TRANSITION SERIES – represents a chemically related group of metals, the only ones of which with concentrations well above the lower limit of detection are iron and manganese – there are some old manganese mines northeast of New Ross, but they drain into the Gold River, not the LaHave watershed; the movie "Erin Brokovich" was all about the occurrence of hexavalent chromium in water, but no such highly oxidized species of chromium occurs in natural waters

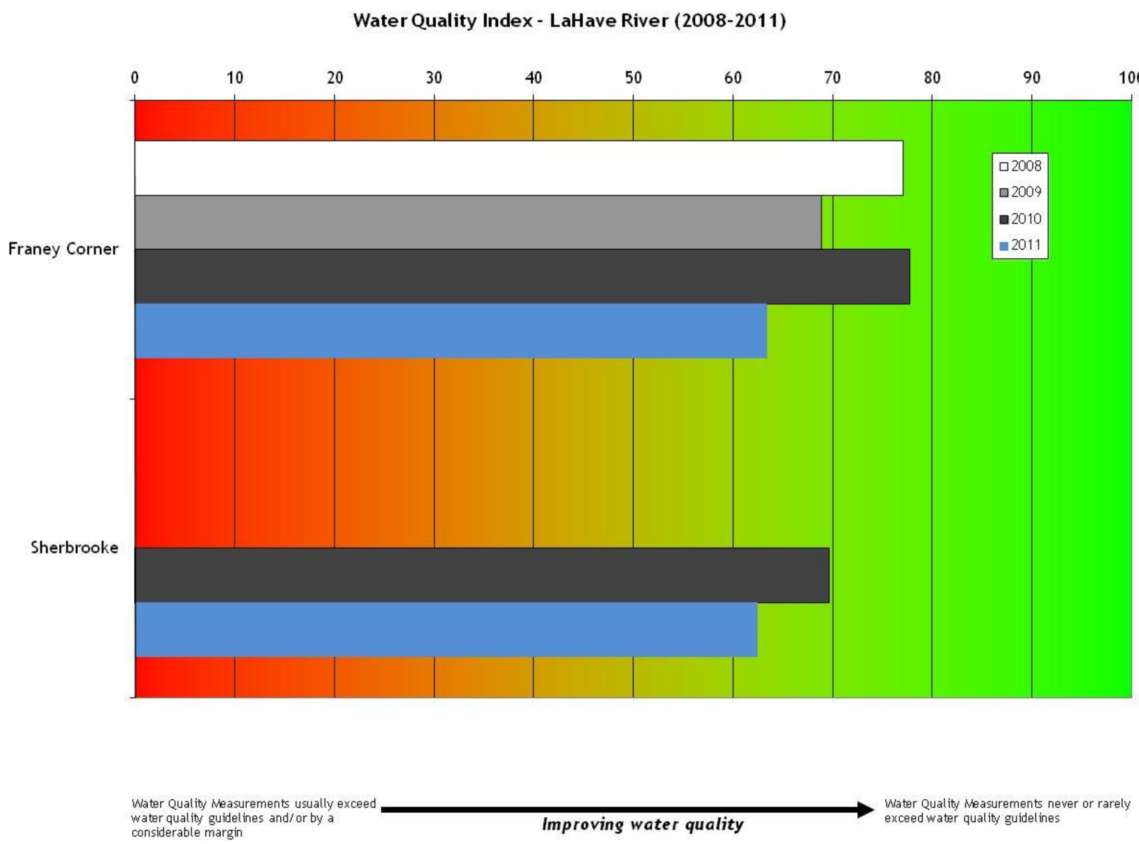
SECOND TRANSITION SERIES – another chemically related group of metals, of more concern than the First Transition Series, especially cadmium – if new mining were ever to take place in our watershed, at least some of these elements would risk being released into the hydrosphere

ASSORTED OTHER ELEMENTS – except perhaps for barium and strontium, a rather undesirable and toxic group of elements, particularly arsenic, lead, and uranium, requiring close monitoring



Water Quality Index (WQI)

The Canadian Council of Ministers of the Environment (CCME) has developed a water quality index (WQI) as a communication tool to summarize complex water quality data into a single measure. The CCME scale of WQIs ranges from 0 (worst) to 100 (best). WQIs for the entire LaHave watershed for 2011 are not yet available, but last year's Sherbrooke Lake report noted that sampling Sites 14 and 15 were among the best in the entire watershed, and we might reasonably expect that ranking to continue in 2011. Instead, this report contains WQI data for Sites 14 and 15 only. Three considerations are of note: (i) the reported WQIs are measured against the guidelines for aquatic life and recreational use (fecal coliforms only); (ii) because we no longer analyze water for ammonia, in this report we have substituted combined nitrate + nitrite and recalculated all the WQIs for 2008-2011 inclusive, so the results are comparable with each other, but not precisely with previous reports; and (iii) the significant drop in WQI at Sites 14 and 15 this year is attributable mainly to the sampling run on August 25th (just after a heavy rainfall), and this drop will undoubtedly be mirrored in similar drops in WQI in the rest of the watershed when those calculations are done. (The drop in WQI won't be just us!)



A bar graph showing WQIs for Franey Corner (Site 14) for four years (2008-2011), and Sherbrooke (Site 15) for the two years we have been sampling it (2010-2011). Note that in both 2010 and 2011, the WQI is lower at Sherbrooke than at Franey Corner.

If the apparent medium-term decline in the WQI at Site 14 is true, it would be alarming and might require further investigation and remedial action. Alternatively, the *apparent* downward trend in WQI may just reflect natural variation and, if so, we might reasonably expect the WQI to be higher in 2012. This uncertainty constitutes good reason for continuing the water monitoring program until we know whether real longitudinal trends exist.

Sampling the Forties River

Although most lakes, including Sherbrooke Lake, have only one output, they have many inputs (rivers, streams, direct precipitation in the form of rain or snow, and groundwater). Sampling Site 14 (Franey Corner) is only one of these inputs, albeit a very important one because of its volume and relative freedom from human influences. This year we decided to do a spot check on the Forties River, and this sampling took place on the same day (August 25, 2011) as the rest of the sampling in the LaHave watershed was being done. The location was just upstream from the bridge on North Fork Road (44^{o} 41.436' North Latitude, 64^{o} 35.760' West Longitude). The table below enables a comparison of the Franey Corner and Forties River inputs with each other, and with the Sherbrooke Site 15 output.

BCAF technicians sampling the Forties River. Photo courtesy of Rob Fensome

Comparison of Forties, Franey, and Sherbrooke Sampling Sites (August 25, 2011)

	Units	Forties (INPUT)	Franey (INPUT)	Sherbrooke (OUTPUT)
Field Measurements				
Temperature	^{o}C	19.94	20.04	21.40
pH	$[H^{+}]^{-14}$	5.54	5.72	5.90
TDS	mg/L	0.022	0.019	0.017
Dissolved Oxygen (DO)	mg/L	8.38	8.99	8.69
DO%		92.1	99.0	98.2
Sp Cond	mS/cm	0.033	0.029	0.026
Lab Measurements				
Chloride	mg/L	5	5	4
Nitrate+Nitrite	mg/L	ND	ND	ND
Phosphorus	mg/L	0.014	0.027	0.014
Suspended Solids	mg/L	ND	1	1
Total Nitrogen	mg/L	0.57	0.49	0.24
Fecal Coliforms	**MPN/mL**	**10**	**3**	**12**
Metals				
Al	µg/L	446	373	199
Sb	µg/L	ND	ND	ND
As	µg/L	ND	1.1	ND
Ba	µg/L	5.6	4.5	3.3
Be	µg/L	ND	ND	ND
Bi	µg/L	ND	ND	ND
B	µg/L	ND	ND	ND
Cd	µg/L	0.022	0.052	ND
Ca	µg/L	2060	1720	1260
Cr	µg/L	ND	ND	ND
Co	µg/L	ND	ND	ND
Cu	µg/L	ND	ND	ND
Fe	µg/L	614	538	207
Pb	µg/L	ND	ND	ND
Mg	µg/L	693	540	469
Mn	µg/L	20.9	27.7	27.0
Mo	µg/L	ND	ND	ND
Ni	µg/L	ND	ND	ND
K	µg/L	511	377	340

Se	μg/L	ND	ND	ND
Ag	μg/L	ND	ND	ND
Na	μg/L	3550	3430	3000
Sr	μg/L	8.5	6.5	5.1
Tl	μg/L	ND	ND	ND
Sn	μg/L	ND	ND	ND
Ti	μg/L	6	4.3	2.9
U	μg/L	0.22	0.18	ND
V	μg/L	ND	ND	ND
Zn	μg/L	5.9	ND	5.4

With the caveat that any single sample must be treated with great caution, some notable points of comparison between the Franey Corner input (little upstream human influence) and Forties input (more upstream human influence) to Sherbrooke Lake are highlighted in red:

1. Both the dissolved oxygen and percentage oxygen are noticeably lower in the Forties River, possibly attributable to a higher organic content and increased biological oxygen demand (BOD, a parameter we no longer analyze for in the interest of cost-saving), i.e., organic material that needs to be oxidized.

2. Fecal coliform counts are significantly higher in the Forties River than in the Franey Corner input, consistent with human and agricultural activity upstream in Forties Settlement. First note that fecal coliform counts were high everywhere in the LaHave watershed on that sampling day, and second note that the output from Sherbrooke Lake was even higher than the Forties input, suggesting addition of fecal coliform bacteria in the lake itself, or somewhere between the lake and sampling Site 15.

3. Given the agricultural activity upstream in the Forties River, the levels of NPK (nitrogen, phosphorus, potassium) are of some interest. Potassium is anomalously high, total nitrogen is slightly high, and phosphorus is unexpectedly lower in the Forties River compared with the Franey Corner input.

We have committed to sample the Forties River one more time in the Spring of 2012.

Measuring the Mean Residence Time for Water in Sherbrooke Lake

One of the future questions identified in last year's report was that of mean residence time for water in Sherbrooke Lake. The mean residence time is the average time that a molecule of H_2O spends in the lake. To determine the mean residence time, all one needs is the volume of the lake (V in m^3), and the rate of outflow from the lake (R in m^3/year). Mean residence time RT = V/R (in years). Nick White of the College of Geographic Sciences in Lawrencetown used the bathmetric map of Sherbrooke Lake (http://www.gov.ns.ca/fish/sportfishing/lakesurvey/3-L-sherbrooke.pdf) to calculate V = 141,360,000

m^3. To put that volume in perspective, the lake contains about 14% of a cubic kilometer of water. On August 23, 2011, Barrie Clarke and Jennifer McKinnon of BCAF measured the flow rate in the outlet river as R = ~ 5 m^3/second, or 153,066,704 m^3/year (data and calculations are in Appendix ll). So, the mean residence time RT = V/R = 0.92 years or about 11 months. The problem with this measurement is that it is done on one day only, and unless the flow rate of the outlet river was exactly average on that day, the resulting RT will be too large or too small. Denis Parent of Environment Canada used the flow monitors at Northfield to determine that, on August 23rd , the flow rate in the entire LaHave watershed system was about 55% below mean average discharge rate, in other words, our field measurement of about ~ 5 m^3/second for the discharge from Sherbrooke Lake should have been more like 10.6m^3/second. This revision results in an RT = 0.42 years or about 5 months.

What does a residence time of 5 months mean for Sherbrooke Lake? It means that the average time a drop of water spends in the lake is 5 months. That average time includes a raindrop that falls into the lake just beside the outlet river and spends a few seconds in the lake, and a molecule of water that enters the lake from a stream in the southern end, goes to the deep bottom and stays there for years or decades. Overall, though, the residence time is short, meaning that *on average* the lake flushes itself about twice a year. At least this means that dissolved pollutants will tend to build up more slowly than in a lake with a longer residence time. (For comparison, the mean residence time for Lake Erie is 2.6 years, Lake Ontario is 6 years, Lake Okanagan in BC is 53 years, Lake Superior is 191 years, and Lake Vostok in Antarctica is 13,300 years!) But even Lake Winnipeg with an RT of only 3.5 years has become highly polluted. It all depends on the type and intensity of human activity in the catchment area.

Summary of Principal Findings in 2011

The findings below are *in addition to* the seven findings in the report for 2010.

1. On average, Sherbrooke Lake flushes itself about twice a year. This is good news because pollutants cannot as easily accumulate, but it is no reason to be complacent. There are pockets of deep water and geographic areas of more restricted circulation of water where the flushing rate will be much slower.
2. For two years running, fecal coliform bacteria have been at, or have exceeded, recreational water guidelines in the Summer. These high levels seem to have correlated with high water temperatures and/or high rainfall. The Summer is also the time when most people go swimming. It would be reasonable to predict that high temperatures and/or high rainfall in future would also create conditions for high fecal coliform counts.
3. A single sample of the Forties River in August suggests that its water quality is noticeably less than the quality of the water entering at the north end of the lake. It is a situation that may require more careful monitoring in future.
4. As noted last year, concentrations of most chemical parameters are lower at the Sherbrooke monitoring station compared with the Franey Corner monitoring station. These decreases

indicate that processes within the lake, and influence from other sources, are reducing the concentrations by some combination of dilution by rain and snow, mechanical deposition in the lake as sediments, chemical precipitation as a consequence of increasing pH, or biological consumption within the lake.

5. The Water Quality Index at Site 14 shows is markedly lower in 2011 than in previous years. This low value is a problem if it represents a long-term decline, but is not a problem if it represents natural variation about some higher mean value. Only continued monitoring can answer this question.
6. Although the WQIs at Sites 14 and 15 have been (are probably still are) among the highest in the LaHave River watershed, at least the first two years of sampling at Site 15 suggests that the WQI decreases as water passes through Sherbrooke Lake. The most probable causes are the Forties River, the human activity on the lake itself, and/or human activity between Sherbrooke Lake and Site 15.
7. The water quality reports for 2010 and 2011 represent the beginning of an important baseline against any future upstream agricultural, forestry, mining, or other development that could potentially have a negative impact on the water quality in Sherbrooke Lake. Sampling for 2012 is already under way.

The Importance and Cost of Ongoing Monitoring

This report presents a measure of water quality in the Sherbrooke Lake watershed for one year (2011), and in combination with the report for 2010, begins to tell us how water quality changes as a function of time. Any such change is an important question for all of us who, at some point in the future, plan either to sell our properties or to will them to our families. However and whenever that transfer of property takes place, all parties will want those properties to be of the highest value possible. That value will depend to some significant extent on the health of the lake. Only a program of ongoing monitoring will allow us to detect trends, and allow us to take remedial action before any crisis develops, as has already happened to some recreational lakes in Ontario.

The total costs for this sampling year (2011) were $1857, distributed as follows:
Highlanding Road Association $95
Sherbrooke Forest Homeowners Association $1112
Wil-Dor Park Homeowners Association $650
We encourage each association on the lake to contribute to the costs for 2012 and into the future. If everyone around the lake were to contribute to this program of annual water quality monitoring , the cost would be about $10 per year per property. It’s a small investment to ensure that our lake remains as good as it is.

Future Questions and Suggestions

Once we have a complete set of data for 2012, we can begin to look for longitudinal trends, for instance, is the water becoming more or less acidic with time, or does the water contain more or less uranium with each passing year? The longer the period of sampling, the better we can confidently answer these kinds of questions. Also, following on from the first principal finding on page 13, this Summer we might turn our attention to the question of hydrodynamics in the lake. With a suitable platform, we could lower the sonde into the lake to do some vertical profiling to see if the lake becomes thermally stratified (which would inhibit mixing of the lake). Also, it would be useful to see if the two deeper basins shown on page 22, especially the one in the southern end of the lake, experience any decrease in oxygen with depth during the Summer months.

Now that this water monitoring program is well under way, we should try again to form a Sherbrooke Lake Water Monitoring Committee, with one member from each property owners' association. That member could be the contact person for matters concerning this program, including communication, decision-making, and fund-raising. Please put this topic on the agenda for your 2012 annual meeting, which I would be glad to attend if you want, and contact me with your decision at: clarke@dal.ca

Acknowledgements

This report constitutes a small part of the work being done in the whole watershed by the LaHave River Watershed Committee, under the auspices of the Bluenose Coastal Action Foundation. Thanks are due to Bluenose Coastal Action for funding the sampling at Site 14. Many thanks to Andrew Breen and all others who worked faithfully to sample the river 52 times over the last four years. Thanks also to Denis Parent for valuable advice and for assistance with the updated WQI calculations, and for reviewing this report before its release. Otherwise, the author is solely responsible for any errors of commission or omission in this report.

Appendix 1 – The Analytical Data for 2011

Explanatory Notes

1. The upper part of the tables gives the values for downstream Site 15 (Sherbrooke), the middle part gives the measurements for upstream Site 14 (Franey Corner), and the lower part gives the residuals from subtracting the upstream value from the downstream value. Let's say the upstream value is 25 mg/L and the downstream value is 5 mg/L. The residual value is then: 5 - 25 = -20 mg/L. The *negative* number signifies that the concentration of the element has *decreased* as the water passed through the lake, suggesting that the lake is SINK for that element. Conversely, *positive* residual values signify that the concentrations are *increasing* in the lake, suggesting somehow that the lake is a SOURCE for that element. Note that residuals close to zero probably mean that there is no analytically detectable difference between inflow and outflow.
2. However, because there are so many other variables at play, all these residual values may be only an **apparent** Sherbrooke Lake effect. For example, if some component increased from upstream Site 14 to downstream Site 15, the SOURCE might indeed be Sherbrooke Lake, but it could alternatively be in the Forties River, or take place between Sherbrooke Lake and the Site 15 sampling site. Such are the limitations of the current sampling regime. Better resolution would require more sites and more expense.
3. For this report, the tables still contain columns for ammonia, TDS (lab), and biological oxygen demand (BOD), but we no longer analyze for these parameters in order to reduce costs, and these columns will disappear in future reports.

SHERBROOKE SITE 15 (DOWNSTREAM)			GENERAL PROPERTIES			TOTAL DISSOLVED/SUSPENDED SOLIDS				SALINITY	
Site Number	Site Name	Date Time	Temp	BP	pH	SpCond	TDS Field	TDS Lab	TSS	Salinity	Chloride
Units			°C	mmHg	$[H^+]^{-14}$	mS/cm	g/L	mg/L	mg/L	permil (‰)	mg/L
15	Sherbrooke	Jan-06-2011 14:29	1.01	740.4	4.87	0.015	0.018		<1	0.01	5
15	Sherbrooke	Feb-10-2011 09:11	0.56	745.9	4.64	0.016	0.02		1	0.01	5
15	Sherbrooke	Mar-10-2011 08:53	0.98	767.5	5.2	0.016	0.019		<1	0.01	16
15	Sherbrooke	Apr-07-2011 09:37	2.80	749.1	4.82	0.026	0.017		1	0.01	5
15	Sherbrooke	May-05-2011 13:55	10.61	747.2	5.05	0.026	0.017		2	0.01	5
15	Sherbrooke	Jun-02-2011 13:27	16.61	741.5	5.10	0.025	0.016		1	0.01	4
15	Sherbrooke	Jun-29-2011 12:47	20.77	749.6	5.05	0.025	0.017		1	0.01	4
15	Sherbrooke	Jul-28-2011 12:13	20.11	751.9	5.46	0.025	0.016		2	0.01	5
15	Sherbrooke	Aug-25-2011 13:30	21.40	754.5	5.90	0.026	0.017		1	0.01	4
15	Sherbrooke	Sept-21-2011 09:05	17.13	756	6.07	0.026	0.017		<2	0.01	4
15	Sherbrooke	Oct-20-2011 08:38	13.13	745.1	5.94	0.027	0.018		18	0.01	70
15	Sherbrooke	Nov-17-2011 08:30	9.35	741.5	5.45	0.025	0.016		<1	0.01	4
15	Sherbrooke	Dec-15-2011 13:38	4.59	753.5	5.43	0.024	0.015		<2	0.01	4
CCME Drinking (2011)		http://ceqg-rcqe.ccme.ca/	<15.00		6.50-8.50			500			250
CCME Recreation (1992)		http://ceqg-rcqe.ccme.ca/	αt		5.00-9.00						
CCME Aquatic Life (2010)		http://ceqg-rcqe.ccme.ca/									

FRANEY CORNER SITE 14 (UPSTREAM)			GENERAL PROPERTIES			TOTAL DISSOLVED/SUSPENDED SOLIDS				SALINITY	
Site Number	Site Name	Date Time	Temp	BP	pH	SpCond	TDS Field	TDS Lab	TSS	Salinity	Chloride
Units			°C	mmHg	$[H^+]^{-14}$	mS/cm	g/L	mg/L	mg/L	permil (‰)	mg/L
14	Franey Corner	Jan-06-2011 13:39	0.21	737.1	4.9	0.016	0.019		<1	0.01	6
14	Franey Corner	Feb-10-2011 09:55	0.04	741.6	4.32	0.015	0.019		<1	0.01	5
14	Franey Corner	Mar-10-2011 09:35	0.13	763.9	4.33	0.014	0.017		<1	0.01	7
14	Franey Corner	Apr-07-2011 10:03	3.33	746	4.68	0.024	0.016		1	0.01	4
14	Franey Corner	May-05-2011 13:26	12.42	744	5.13	0.023	0.015		1	0.01	4
14	Franey Corner	Jun-02-2011 13:03	20.68	738.6	5.44	0.025	0.016		<1	0.01	4
14	Franey Corner	Jun-29-2011 12:22	20.78	746.4	5.04	0.025	0.016		<2	0.01	4
14	Franey Corner	Jul-28-2011 11:26	19.41	748.7	6.08	0.03	0.019		1	0.01	6
14	Franey Corner	Aug-25-2011 11:54	20.04	750.9	5.72	0.029	0.019		1	0.01	5
14	Franey Corner	Sept-21-2011 09:31	15.78	753	6.12	0.03	0.02		<2	0.01	5
14	Franey Corner	Oct-20-2011 09:06	11.36	741.9	4.98	0.029	0.019		2	0.01	4
14	Franey Corner	Nov-17-2011 09:01	8.79	738.6	4.86	0.023	0.015		<1	0.01	3
14	Franey Corner	Dec-15-2011 13:18	2.38	750.3	5.18	0.021	0.014		<2	0.01	3
CCME Drinking (2011)			<15.00		6.50-8.50			500			250
CCME Recreation (1992)			αt		5.00-9.00						
CCME Aquatic Life (2010)											

RESIDUALS (DOWNSTREAM SITE 15 - UPSTREAM SITE 14)			GENERAL PROPERTIES			TOTAL DISSOLVED/SUSPENDED SOLIDS				SALINITY	
Site Number	Site Name	Date Time	Temp	BP	pH	SpCond	TDS Field	TDS Lab	TSS	Salinity	Chloride
Units			°C	mmHg	$[H^+]^{-14}$	mS/cm	mg/L	mg/L	mg/L	permil (‰)	mg/L
15-14	S-F	Jan-06-2011	0.80		-0.03	-0.001	-0.001			*	-1
15-14	S-F	Feb-10-2011	*		0.32	*	0.001			*	0
15-14	S-F	Mar-10-2011	0.85		0.87	0.002	0.002			0.000	9
15-14	S-F	Apr-07-2011	-0.53		0.14	0.002	0.001		0.000	0.000	1
15-14	S-F	May-05-2011	-1.81		-0.08	0.003	0.002			0.000	1
15-14	S-F	Jun-02-2011	-4.07		-0.34	0.000	0.000			0.000	0
15-14	S-F	Jun-29-2011	-0.01		0.01	0.000	0.001			0.000	0
15-14	S-F	Jul-28-2011	0.70		-0.62	-0.005	-0.003		1.000	0.000	-1
15-14	S-F	Aug-25-2011	1.36		0.18	-0.003	-0.002			0.000	-1
15-14	S-F	Sept-21-2011	1.35		-0.05	-0.004	-0.003			0.000	-1
15-14	S-F	Oct-20-2011	1.77		0.96	-0.002	-0.001			0.000	66
15-14	S-F	Nov-17-2011	0.56		0.59	0.002	0.001			0.000	1
15-14	S-F	Dec-15-2011	2.21		0.25	0.003	0.001			0.000	1
Mean 15-14			**0.265**		**0.17**	**0.000**	**-0.0001**			**0.000**	**5.77**
SHERBROOKE LAKE SOURCE OR SINK			SOURCE		SOURCE	NEITHER	SINK				"SOURCE"

Additional Notes:

1. The atmospheric pressure (BP), as measured in the field by the sonde, is not a property of the water, but is used by the sonde to determine dissolved oxygen percentage (DO%).
2. The "αt" symbol for temperature recreational guidelines means that the temperature is a function of time (t) – the colder the water, the shorter the time you can swim safely.
3. The chloride results are skewed by one anomalously high value at Sherbrooke on October 20th that might be the result of turnover in the Autumn (chloride was also high in the Spring).

SHERBROOKE SITE 15 (DOWNSTREAM)			OXYGEN			CRITICAL NUTRIENTS				BACTERIA
Site Number	Site Name	Date Time	DO Conc	DO%	BOD	Nitrate+Nitrite	Ammonia	Nitrogen	Phosphorus	Fecal Coliform
Units			mg/L	%sat	mg/L	mg/L	mg/L	mg/L	mg/L	MPN/mL
15	Sherbrooke	Jan-06-2011 14:29	14.94	105.9		<0.05		0.25	0.012	<1
15	Sherbrooke	Feb-10-2011 09:11	16.95	118.8		0.05	<0.05	0.34	0.018	<1
15	Sherbrooke	Mar-10-2011 08:53	14.14	99.6		<0.05		0.27	0.014	<1
15	Sherbrooke	Apr-07-2011 09:37	13.82	102.0		0.05		0.21	0.011	<1
15	Sherbrooke	May-05-2011 13:55	11.13	100.0		<0.05		0.23	0.011	<1
15	Sherbrooke	Jun-02-2011 13:27	9.91	101.7		<0.05		0.23	0.013	<1
15	Sherbrooke	Jun-29-2011 12:47	8.54	95.3		<0.05		0.26	0.02	1
15	Sherbrooke	Jul-28-2011 12:13	8.71	96.2		<0.05		0.21	0.015	1
15	Sherbrooke	Aug-25-2011 13:30	8.69	98.2		<0.05		0.24	0.014	12
15	Sherbrooke	Sept-21-2011 09:05	9.62	99.8		<0.05		0.19	0.012	2
15	Sherbrooke	Oct-20-2011 08:38	10.09	96.0		<0.05		0.29	0.047	8
15	Sherbrooke	Nov-17-2011 08:30	11.23	97.9		<0.05	<0.05	0.34	0.014	<1
15	Sherbrooke	Dec-15-2011 13:38	11.88	92.1		<0.05	0.04	0.27	0.015	<1
CCME Drinking (2011)		http://ceqg-rcqe.ccme.ca/				45				0
CCME Recreation (1992)		http://ceqg-rcqe.ccme.ca/								2
CCME Aquatic Life (2010)		http://ceqg-rcqe.ccme.ca/						13		

FRANEY CORNER SITE 14 (UPSTREAM)			OXYGEN			CRITICAL NUTRIENTS				BACTERIA
Site Number	Site Name	Date Time	DO Conc	DO%	BOD	Nitrate+Nitrite	Ammonia	Nitrogen	Phosphorus	Fecal Coliform
Units			mg/L	%sat	mg/L	mg/L	mg/L	mg/L	mg/L	MPN/mL
14	Franey Corner	Jan-06-2011 13:39	15.19	105.2		<0.05		0.21	0.011	<1
14	Franey Corner	Feb-10-2011 09:55	14.14	97.1		0.06	<0.05	0.28	0.018	<1
14	Franey Corner	Mar-10-2011 09:35	15.05	103.4		<0.05		0.24	0.021	<1
14	Franey Corner	Apr-07-2011 10:03	14.68	110.3		<0.05		0.21	0.018	<1
14	Franey Corner	May-05-2011 13:26	10.51	98.4		<0.05		0.29	0.017	<1
14	Franey Corner	Jun-02-2011 13:03	8.73	97.4		<0.05		0.37	0.027	<1
14	Franey Corner	Jun-29-2011 12:22	8.98	100.3		<0.05		0.42	0.031	<1
14	Franey Corner	Jul-28-2011 11:26	9.00	98.1		<0.05		0.39	0.024	2
14	Franey Corner	Aug-25-2011 11:54	8.99	99.0		<0.05		0.49	0.027	3
14	Franey Corner	Sept-21-2011 09:31	10.06	101.4		<0.05		0.39	0.024	1
14	Franey Corner	Oct-20-2011 09:06	11.02	100.7		<0.05		0.37	0.017	1
14	Franey Corner	Nov-17-2011 09:01	11.66	100.3		<0.05	<0.05	0.35	0.019	<1
14	Franey Corner	Dec-15-2011 13:18	12.58	91.8		<0.05	0.04	0.27	0.024	<1
CCME Drinking (2011)						45				0
CCME Recreation (1992)										2
CCME Aquatic Life (2010)								13		

RESIDUALS (DOWNSTREAM SITE 15 - UPSTREAM SITE 14)			OXYGEN			CRITICAL NUTRIENTS				BACTERIA
Site Number	Site Name	Date Time	DO Conc	DO%	BOD	Nitrate+Nitrite	Ammonia	Nitrogen	Phosphorus	Fecal Coliform
Units			mg/L	%sat	mg/L	mg/L	mg/L	mg/L	mg/L	MPN/mL
15-14	S-F	Jan-06-2011 13:39	-0.25	0.70		*		0.04	0.00	*
15-14	S-F	Feb-10-2011 09:55	2.81	21.70		-0.01	*	0.06	0.00	*
15-14	S-F	Mar-10-2011 09:35	-0.91	-3.80		*		0.03	-0.01	*
15-14	S-F	Apr-07-2011 10:03	-0.86	-8.30		*		0.00	-0.01	*
15-14	S-F	May-05-2011 13:26	0.62	1.60		*		-0.06	-0.01	*
15-14	S-F	Jun-02-2011 13:03	1.18	4.30		*		-0.14	-0.01	*
15-14	S-F	Jun-29-2011 12:22	-0.44	-5.00		*		-0.16	-0.01	*
15-14	S-F	Jul-28-2011 11:26	-0.29	-1.90		*		-0.18	-0.01	-1
15-14	S-F	Aug-25-2011 11:54	-0.30	-0.80		*		-0.25	-0.01	9
15-14	S-F	Sept-21-2011 09:31	-0.44	-1.60		*		-0.20	-0.01	1
15-14	S-F	Oct-20-2011 09:06	-0.93	-4.70		*		-0.08	0.03	7
15-14	S-F	Nov-17-2011 09:01	-0.43	-2.40		*		-0.01	-0.01	*
15-14	S-F	Dec-15-2011 13:18	-0.70	0.30		*		0.00	-0.01	*
Mean 15-14			**-0.07**	**0.01**		*	*	**-0.073**	**-0.005**	**1.23**
SHERBROOKE LAKE SOURCE OR SINK			SINK	"SOURCE"				SINK	SINK	"SOURCE"

Note that fecal coliform counts were at, or exceeded, recreational guidelines at the Sherbrooke Site 15 in August, September, and October, and at the Franey Corner Site 14 in August and October.

SHERBROOKE SITE 15 (DOWNSTREAM)				LIGHT ELEMENTS					ALKALI/ALKALI EARTH ELEMENTS		
Site Number	Site Name	Date Time		Aluminum	Beryllium	Boron	Magnesium		Sodium	Potassium	Calcium
Units				µg/L	µg/L	µg/L	µg/L		µg/L	µg/L	µg/L
15	Sherbrooke	Jan-06-2011 14:29									
15	Sherbrooke	Feb-10-2011 09:11									
15	Sherbrooke	Mar-10-2011 08:53									
15	Sherbrooke	Apr-07-2011 09:37									
15	Sherbrooke	May-05-2011 13:55		240	<1	<50	433		3110	326	1180
15	Sherbrooke	Jun-02-2011 13:27									
15	Sherbrooke	Jun-29-2011 12:47									
15	Sherbrooke	Jul-28-2011 12:13									
15	Sherbrooke	Aug-25-2011 13:30		199	<1	<50	469		3000	340	1260
15	Sherbrooke	Sept-21-2011 09:05									
15	Sherbrooke	Oct-20-2011 08:38									
15	Sherbrooke	Nov-17-2011 08:30									
15	Sherbrooke	Dec-15-2011 13:38									
CCME Drinking (2011)		http://ceqg-rcqe.ccme.ca/		100	*	5000			<200000	*	*
CCME Recreation (1992)		http://ceqg-rcqe.ccme.ca/							*	*	*
CCME Aquatic Life (2010)		http://ceqg-rcqe.ccme.ca/				1.5			*	*	*

FRANEY CORNER SITE 14 (UPSTREAM)				LIGHT ELEMENTS					ALKALI/ALKALI EARTH ELEMENTS		
Site Number	Site Name	Date Time		Aluminum	Beryllium	Boron	Magnesium		Sodium	Potassium	Calcium
Units				µg/L	µg/L	µg/L	µg/L		µg/L	µg/L	µg/L
14	Franey Corner	Jan-06-2011 13:39									
14	Franey Corner	Feb-10-2011 09:55									
14	Franey Corner	Mar-10-2011 09:35									
14	Franey Corner	Apr-07-2011 10:03									
14	Franey Corner	May-05-2011 13:26		261	<1	<50	332		3040	320	1030
14	Franey Corner	Jun-02-2011 13:03									
14	Franey Corner	Jun-29-2011 12:22									
14	Franey Corner	Jul-28-2011 11:26									
14	Franey Corner	Aug-25-2011 11:54		373	<1	<50	540		3430	377	1720
14	Franey Corner	Sept-21-2011 09:31									
14	Franey Corner	Oct-20-2011 09:06									
14	Franey Corner	Nov-17-2011 09:01									
14	Franey Corner	Dec-15-2011 13:18									
CCME Drinking (2011)				100	*	5000			<200000	*	*
CCME Recreation (1992)									*	*	*
CCME Aquatic Life (2010)						1.5			*	*	*

RESIDUALS (DOWNSTREAM SITE 15 - UPSTREAM SITE 14)				LIGHT ELEMENTS					ALKALI/ALKALI EARTH ELEMENTS		
Site Number	Site Name	Date Time		Aluminum	Beryllium	Boron	Magnesium		Sodium	Potassium	Calcium
Units				µg/L	µg/L	µg/L	µg/L		µg/L	µg/L	µg/L
15-14	S-F	Jan-06-2011									
15-14	S-F	Feb-10-2011									
15-14	S-F	Mar-10-2011									
15-14	S-F	Apr-07-2011									
15-14	S-F	May-05-2011		-21	*	*	101		70	6	150
15-14	S-F	Jun-02-2011									
15-14	S-F	Jun-29-2011									
15-14	S-F	Jul-28-2011									
15-14	S-F	Aug-25-2011		-174	*	*	-71		-430	-37	-460
15-14	S-F	Sept-21-2011									
15-14	S-F	Oct-20-2011									
15-14	S-F	Nov-17-2011									
15-14	S-F	Dec-15-2011									
Mean 15-14				**-97.5**	*	*	**15**		**-180**	**-15.5**	**-155**
SHERBROOKE LAKE SOURCE OR SINK				SINK			SOURCE*		SINK*	SINK*	SINK*
	SINK* - large seasonal fluctuations - with only two samples, designation as SINK may not be an accurate assessment										

SHERBROOKE SITE 15 (DOWNSTREAM)				FIRST TRANSITION SERIES ELEMENTS								
Site Number	Site Name	Date Time		Titanium	Vanadium	Chromium	Manganese	Iron	Cobalt	Nickel	Copper	Zinc
Units				µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
15	Sherbrooke	Jan-06-2011 14:29										
15	Sherbrooke	Feb-10-2011 09:11										
15	Sherbrooke	Mar-10-2011 08:53										
15	Sherbrooke	Apr-07-2011 09:37										
15	Sherbrooke	May-05-2011 13:55		3.3	<2	<1	24	201	<0.4	<2	<2	<5
15	Sherbrooke	Jun-02-2011 13:27										
15	Sherbrooke	Jun-29-2011 12:47										
15	Sherbrooke	Jul-28-2011 12:13										
15	Sherbrooke	Aug-25-2011 13:30		2.9	<2	<1	27	207	<0.4	<2	<2	5.4
15	Sherbrooke	Sept-21-2011 09:05										
15	Sherbrooke	Oct-20-2011 08:38										
15	Sherbrooke	Nov-17-2011 08:30										
15	Sherbrooke	Dec-15-2011 13:38										
CCME Drinking (2011)		http://ceqg-rcqe.ccme.ca/		*	*	50	50	300	*	*	1000	5000
CCME Recreation (1992)		http://ceqg-rcqe.ccme.ca/										
CCME Aquatic Life (2010)		http://ceqg-rcqe.ccme.ca/						300				30

FRANEY CORNER SITE 14 (UPSTREAM)				FIRST TRANSITION SERIES ELEMENTS								
Site Number	Site Name	Date Time		Titanium	Vanadium	Chromium	Manganese	Iron	Cobalt	Nickel	Copper	Zinc
Units				µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
14	Franey Corner	Jan-06-2011 13:39										
14	Franey Corner	Feb-10-2011 09:55										
14	Franey Corner	Mar-10-2011 09:35										
14	Franey Corner	Apr-07-2011 10:03										
14	Franey Corner	May-05-2011 13:26		3.8	<2	<1	15.4	257	<0.4	<2	<2	<5
14	Franey Corner	Jun-02-2011 13:03										
14	Franey Corner	Jun-29-2011 12:22										
14	Franey Corner	Jul-28-2011 11:26										
14	Franey Corner	Aug-25-2011 11:54		4.3	<2	<1	27.7	538	<0.4	<2	<2	<5
14	Franey Corner	Sept-21-2011 09:31										
14	Franey Corner	Oct-20-2011 09:06										
14	Franey Corner	Nov-17-2011 09:01										
14	Franey Corner	Dec-15-2011 13:18										
CCME Drinking (2011)				*	*	50	50	300	*	*	1000	5000
CCME Recreation (1992)												
CCME Aquatic Life (2010)								300				30

RESIDUALS (DOWNSTREAM SITE 15 - UPSTREAM SITE 14)				FIRST TRANSITION SERIES ELEMENTS								
Site Number	Site Name	Date Time		Titanium	Vanadium	Chromium	Manganese	Iron	Cobalt	Nickel	Copper	Zinc
Units				µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
15-14	S-F	Jan-06-2011										
15-14	S-F	Feb-10-2011										
15-14	S-F	Mar-10-2011										
15-14	S-F	Apr-07-2011										
15-14	S-F	May-05-2011		-0.5	*	*	8.6	-56	*	*	*	*
15-14	S-F	Jun-02-2011										
15-14	S-F	Jun-29-2011										
15-14	S-F	Jul-28-2011										
15-14	S-F	Aug-25-2011		-1.4	*	*	-0.7	-331	*	*	*	*
15-14	S-F	Sept-21-2011										
15-14	S-F	Oct-20-2011										
15-14	S-F	Nov-17-2011										
15-14	S-F	Dec-15-2011										
Mean 15-14				**-0.95**	*	*	**3.95**	**-194**	*	*	*	*
SHERBROOKE LAKE SOURCE OR SINK				SINK			SOURCE	SINK				
	SINK* - large seasonal fluctuations - with only two samples, designation as SINK may not be an accurate assessment											

SHERBROOKE SITE 15 (DOWNSTREAM)				SECOND TRANSITION SERIES ELEMENTS						ASSORTED OTHER ELEMENTS							
Site Number	Site Name	Date Time		Molybdenum	Silver	Cadmium	Tin	Antimony		Arsenic	Barium	Bismuth	Lead	Selenium	Strontium	Thallium	Uranium
Units				µg/L	µg/L	µg/L	µg/L	µg/L		µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
15	Sherbrooke	Jan-06-2011 14:29															
15	Sherbrooke	Feb-10-2011 09:11															
15	Sherbrooke	Mar-10-2011 08:53															
15	Sherbrooke	Apr-07-2011 09:37															
15	Sherbrooke	May-05-2011 13:55		<2	<0.1	<0.017	<2	<1		<1	3.8	<2	<0.5	<1	5.7	<0.1	0.11
15	Sherbrooke	Jun-02-2011 13:27															
15	Sherbrooke	Jun-29-2011 12:47															
15	Sherbrooke	Jul-28-2011 12:13															
15	Sherbrooke	Aug-25-2011 13:30		<2	<0.1	<0.017	<2	<1		<1	3.3	<2	<0.5	<1	5.1	<0.1	<0.1
15	Sherbrooke	Sept-21-2011 09:05															
15	Sherbrooke	Oct-20-2011 08:38															
15	Sherbrooke	Nov-17-2011 08:30															
15	Sherbrooke	Dec-15-2011 13:38															
CCME Drinking (2011)		http://ceqg-rcqe.ccme.ca/		*	*	5	*	6		10	1000	*	10	10	*	*	20
CCME Recreation (1992)		http://ceqg-rcqe.ccme.ca/															
CCME Aquatic Life (2010)		http://ceqg-rcqe.ccme.ca/		73	0.1					5				1		0.8	15

FRANEY CORNER SITE 14 (UPSTREAM)				SECOND TRANSITION SERIES ELEMENTS						ASSORTED OTHER ELEMENTS							
Site Number	Site Name	Date Time		Molybdenum	Silver	Cadmium	Tin	Antimony		Arsenic	Barium	Bismuth	Lead	Selenium	Strontium	Thallium	Uranium
Units				µg/L	µg/L	µg/L	µg/L	µg/L		µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
14	Franey Corner	Jan-06-2011 13:39															
14	Franey Corner	Feb-10-2011 09:55															
14	Franey Corner	Mar-10-2011 09:35															
14	Franey Corner	Apr-07-2011 10:03															
14	Franey Corner	May-05-2011 13:26		<2	<0.1	<0.017	<2	<1		<1	3.5	<2	<0.5	<1	4.4	<0.1	0.11
14	Franey Corner	Jun-02-2011 13:03															
14	Franey Corner	Jun-29-2011 12:22															
14	Franey Corner	Jul-28-2011 11:26															
14	Franey Corner	Aug-25-2011 11:54		<2	<0.1	0.052	<2	<1		1.1	4.5	<2	<0.5	<1	6.5	<0.1	0.18
14	Franey Corner	Sept-21-2011 09:31															
14	Franey Corner	Oct-20-2011 09:06															
14	Franey Corner	Nov-17-2011 09:01															
14	Franey Corner	Dec-15-2011 13:18															
CCME Drinking (2011)				*	*	5	*	6		10	1000	*	10	10	*	*	20
CCME Recreation (1992)																	
CCME Aquatic Life (2010)				73	0.1					5				1		0.8	15

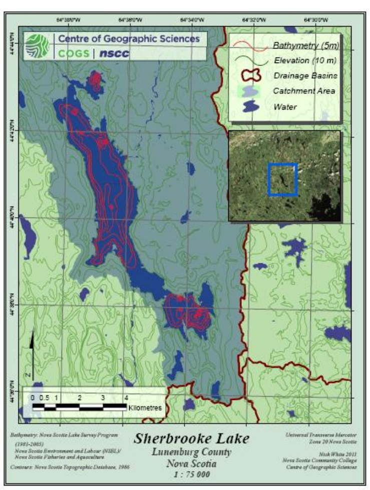
RESIDUALS (DOWNSTREAM SITE 15 - UPSTREAM SITE 14)				SECOND TRANSITION SERIES ELEMENTS						ASSORTED OTHER ELEMENTS							
Site Number	Site Name	Date Time		Molybdenum	Silver	Cadmium	Tin	Antimony		Arsenic	Barium	Bismuth	Lead	Selenium	Strontium	Thallium	Uranium
Units				µg/L	µg/L	µg/L	µg/L	µg/L		µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
15-14	S-F	Jan-06-2011															
15-14	S-F	Feb-10-2011															
15-14	S-F	Mar-10-2011															
15-14	S-F	Apr-07-2011															
15-14	S-F	May-05-2011		*	*	*	*	*		*	0.3	*	*	*	1.3	*	0
15-14	S-F	Jun-02-2011															
15-14	S-F	Jun-29-2011															
15-14	S-F	Jul-28-2011															
15-14	S-F	Aug-25-2011		*	*	*	*	*		*	-1.2	*	*	*	-1.4	*	*
15-14	S-F	Sept-21-2011															
15-14	S-F	Oct-20-2011															
15-14	S-F	Nov-17-2011															
15-14	S-F	Dec-15-2011															
Mean 15-14				*	*	*	*	*		*	**-0.45**	*	*	*	**-0.05**	*	*
SL SOURCE OR SINK											SINK*				SINK*		

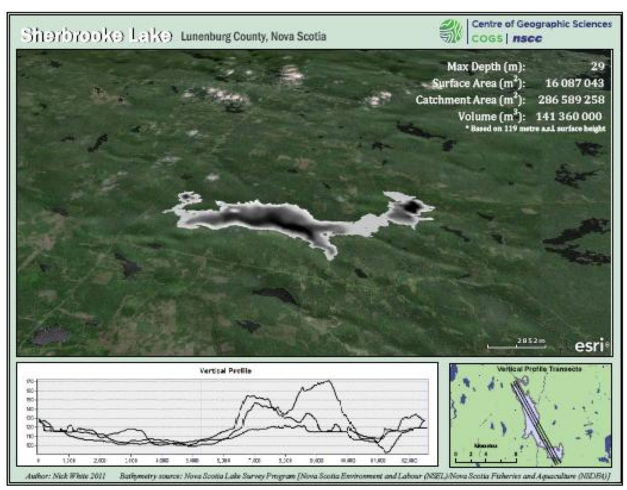
Appendix 2 – Calculation of the Mean Residence Time of Sherbrooke Lake

To calculate the mean residence time for any body of water, all we need to know are two parameters: 1. the volume of the body of water; and 2. the flow rate into, or out, of the body of water. The formula for mean residence time (RT) = Volume (m^3)/Flow Rate (m^3/y), and cancelling out the m^3s, the answer comes out in units of years. A bath tub analogy might be useful here. Half fill the tub and put a line on the side of the tub to mark the water level. Open the drain and turn on the tap. Adjust the flow rate in the tap so the water level stays at the marked line. Now, just like our lake with a more or less constant level, inflow equals outflow, and the system is in dynamic equilibrium. You can measure the volume of water in the tub (length x width x depth), and you can measure the flow rate from the tap by collecting water in a bucket for, say, ten seconds and dividing the collected volume of water by ten to give you volume per second. Then divide the bath tub volume (m^3) by the flow rate (m^3/s) to give you the <u>mean</u> residence time of water in the tub in seconds. Obviously, some water at the tap and drain end of the tub spends less than the mean residence time in the tub, and water at the far end of the tub spends longer than the mean residence time in the tub. A little bit like Sherbrooke Lake.

1. The Volume of Sherbrooke Lake

Nick White, of COGS and BCAF, used a satellite image of the lake and the bathymetric map of the lake to calculate the volume of water in the lake.





The volume of 141 million cubic metres is equivalent to the amount of water it would take to cover 1 km^2 to a depth of 141 metres (about 14% of a cubic kilometre). The volume of a 50x25x2.5 m Olympic swimming pool is about 3000m^3, so our lake is about 47,000 Olympic swimming pools in volume.

2. The Flow-Rate Out of Sherbrooke Lake

To measure the flow rate of the outlet river, one needs the cross-sectional area of the river (A = width of river times its depth, measured in m^2), and the rate of flow (R) past that place where you measured the area, measured in m/s. The flow rate is A x R and the units are m^3/s (cubic metres per second). We measured the cross-sectional area by measuring the depth every metre across the river, and we measured the flow rate by measuring the velocity of floating popcorn every metre across the river. The river flows fastest in the centre and slowest along its banks, so ideally the velocities have to be worked out for individual "cells", but the average flow rate and average depth tend to give about the same answers (the cell method gives 5.27 m^3/s whereas the average method gives 4.85 m^3/s. The spreadsheet on the next page contains all of the calculations.

As explained in the main part of this report, this measured flow rate was for one day (August 23, 2011). Was that an average flow in the river, or was it more or less? Environment Canada has a continuous flow rate monitor in the LaHave River farther downstream at Northfield. On the day we did our measurement of the outflow from Sherbrooke Lake, the monitor indicated that the flow rate in the river system was about 58% lower than mean annual discharge, and that the mean flow in the outlet river should be closer to 10.6 m^3/s. With this higher average flow rate, the lake will have a lower mean residence time of about 5 months. In round terms, it means that, on average, Sherbrooke Lake flushes itself about twice a year.

Thanks are due to Bob and Janet Stewart who gave us access from their property to do these flow-rate measurements. Thanks also to Nick White for doing the volume measurement, Jennifer McKinnon for accompanying me in the field, and Denis Parent and Rick Gagné for checking the calculations.

North Branch LaHave - Outflow Measurement

Measured by Barrie Clarke and Jennifer McKinnon
Date: August 23, 2011, the day after significant rainfall (~10 mm in Hfx)

Average Method			Popcorn Travel Time for 15.5 m				Cell Method by Denis Parent			
Station	**distance (m)**	**depth (m)**	**Time 1 (s)**	**Time 2 (s)**	**Time 3 (s)**	**Mean Time (s)**	**Velocity (m/sec)**	**Segment Width (m)**	**Depth at mid-segment (m)**	**Discharge in Segment (m3/sec)**
North Bank	1.2	0.00								
1	**2.0**	0.70								
2	**3.0**	0.26	41.7	52.1	39.1	44.30	0.349887133	3.0	0.26	0.272911964
3	**4.0**	0.54	37.8	47.7	39.5	41.67	0.372	2.0	0.54	0.40176
4	**5.0**	0.49								
5	**6.0**	0.36	36.0	37.6	28.3	33.97	0.456329735	2.0	0.36	0.328557409
6	**7.0**	0.47								
7	**8.0**	0.29	31.1	29.4	26.9	29.13	0.532036613	2.0	0.29	0.308581236
8	**9.0**	0.31								
9	**10.0**	0.30	28.8	28.8	25.2	27.60	0.561594203	2.0	0.30	0.336956522
10	**11.0**	0.43								
11	**12.0**	0.37	10.3	10.9	10.1	10.43	1.485623003	2.0	0.37	1.099361022
12	**13.0**	0.49								
13	**14.0**	0.46	11.2	11.5	11.2	11.30	1.371681416	2.0	0.46	1.261946903
14	**15.0**	0.32								
15	**16.0**	0.30	12.4	12.7	12.8	12.63	1.226912929	2.0	0.30	0.736147757
16	**17.0**	0.22								
17	**18.0**	0.33	19.6	20.0	21.9	19.47	0.796232877	2.0	0.33	0.525513699
18	**19.0**	0.34	17.5	20.6	17.2					
19	**20.0**	0.19								
South Bank	20.5	0.00								
Mean River Depth		0.38	m							
Mean Travel Time for 15.5m						23.28 s			**Total Discharge**	**5.272**
Mean Water Velocity	0.67	m/s								

River Cross-Sectional Area = River Width x Mean Depth = 7.28 m^2

Flow Volume = **4.85** m^3/s

Flow Volume = 153066704 m^3/y

Sherbrooke Lake Volume = 141360000 m^3
(measured by Nick White of COGS)

Residence Time (RT) = **0.92** **y**
or about 11 months

QUICK CHECK
Ballpark Sherbrooke Lake
Volume = 140000000 m^3
i.e., (14km x 1km x 0.01km)
or (14000m x 1000m x 10m)
(Nick White's measurement seems reasonable)