APPENDIX I

Forests and surface waters of Sandy Lake & Environs (Bedford, Nova Scotia)

http://versicolor.ca/sandylakebedford/lakes/

THE THREE LAKES

There are three lakes in the area encompassed by Sandy Lake and Environs:

Sandy Lake, a headwater lake for the Sackville River.

Marsh Lake, downstream from Sandy Lake via Peverill's Brook; it drains into the Sackville River. (Sandy Lake Watershed is a sub-watershed of the Sackville River Watershed.)

Jack Lake, on a separate watershed; it drains into Papermill Lake (outside of the proposed Sandy Lake Regional Park) and thence to the Bedford Basin.

Some morphometric water and chemistry data for the three lakes from the *Jack Lake CHMC/NSDH Report* (1986) are given below:

Summary of morphometric data for Sandy, Marsh and Jack Lakes. Ranges for temperature and dissolved oxygen are also given. From Jack Lake Environmental Evaluation Final Report. Canada Mortgage and Housing Corporation Nova Scotia Department of Housing, 1986

Lake	Elevation (m)	Surface area (ha)	Max depth (m)	Watershed Area (ha
Sandy Lake	30.5	74.0	20.0	1670
Marsh Lake	23.5	22.0	2.2	493
Jack Lake	75.0	2.75	7.0	32.8

Lake	Retention time (yrs)	Volume M3	Temperature Deg C	Dissolved O2 (mg/L)
Sandy Lake	0.34	5.1×10^6	2.5 - 11.5	9.9 – 11.7
Marsh Lake	0.01	7.4×10^5	5.0 – 9.2	10.1 – 11.2
Jack Lake	0.18	7.4×10^4	2.5 – 11.5	9.9 – 11.7

Selected water chemistry values for Sandy, Marsh and Jack Lakes in Nov/Dec 1984 (top values) and May 1985 (bottom).
From Jack Lake Environmental Evaluation Final Report. Canada Mortgage and Housing Corporation Nova Scotia Department of Housing, 1986.

Variable	Sandy Lake	Marsh Lake	Jack Lake
pH	6.14 5.44	6.10 5.30	4.63 4.50
Conductivity uS/cm	99.5 141	102 122	41.5 42.7
Calcium Mg/L	4.10 4.64	4.00 3.95	1.00 1.18

TEMPORAL TRENDS OF TOTAL P, pH and CONDUCTIVITY IN SANDY LAKE

Based on Total Phosphorus measurements, Sandy Lake has moved from an oligotrophic state in 1979 towards a mesotrophic state today.

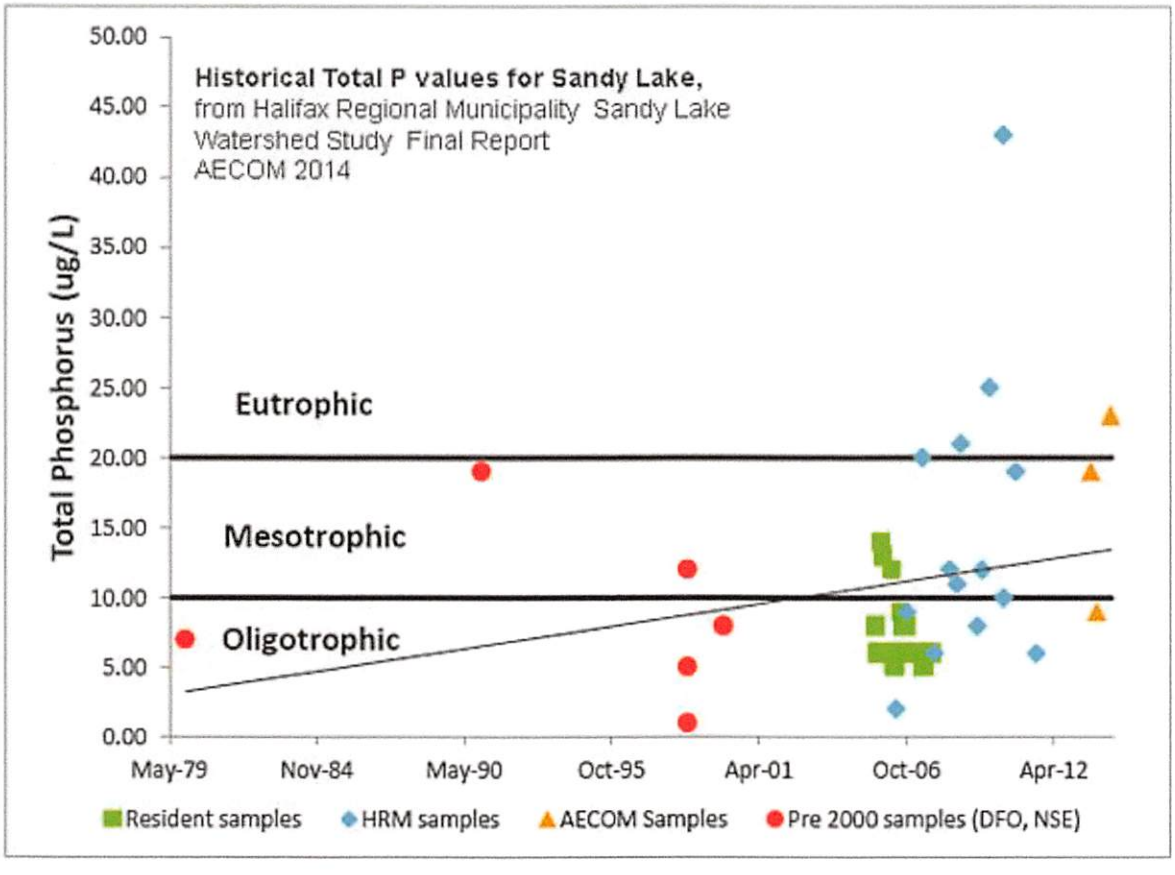


Figure 9: Sandy Lake Total Phosphorus - All Samples

pH and conductivity values have also increased since 1977-1980:

Some historical pH and conductivity values for Sandy Lake

Variable	1955	1971	1977	1980	1985	1991	2000	2010	2017
pH	5.10	-	4.57	4.90	5.44	5.29	5.65	7.56	6.70
EC (uS/cm)	40	37	100	58.9	141	113.7	133.0	167	168

2018: Oct 3, 2017. View this website> **Lakes>Limnological Profiles**

2010: from **HRM Water Quality Monitoring Program Results - Spring 2010**
http://www.region.halifax.ca/energy-environment/environment/documents/HRMLakesDeepstationSurveydata-Spring2010.pdf

1980-2000 from: **Synoptic Water Quality Survey Of Selected Halifax Regional Municipality Lakes On 28-29 March 2000** by P. Clement et al., 2007. Canadian Technical Report of Fisheries and Aquatic Sciences NNNN
https://novascotia.ca/nse/surface.water/docs/SynopticWaterQualitySurvey-MetroHalifaxLakes-2000.pdf

1985 (May 14-15) from: **JACK LAKE Environmental Evaluation Final Report,** Canada Mortgage and Housing Corporation Nova Scotia Department of Housing, 1986.

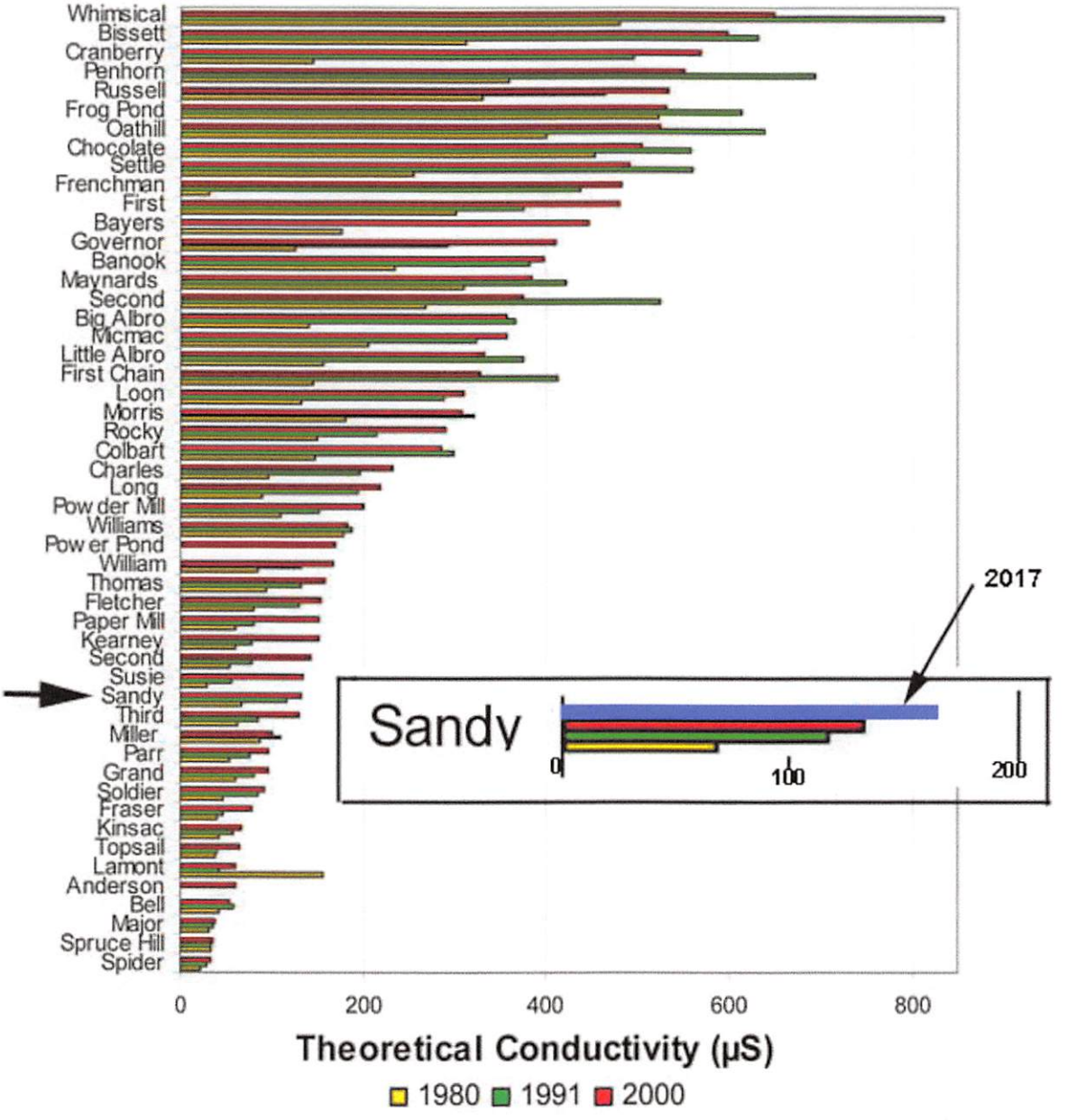
1977 from Watt, W.D. et al. 1979. **Acidification and other chemical changes in Halifax County lakes after 21 years.** Limnol. Oceanogr. 24: B 154 - % 16 1. Sampled in Jan 1977

1971: **Metropolitan Area Planning Committee 1971-1972: Water Quality Survey for Selected Metropolitan Area Lakes,** Feb 1972. Data for Lake 31 (Sandy Lake). All ec data: N. Inlet 57.0 S Inlet 57.0 Surface 37.0 59 feet 39.0 Outlet 39.0 Sampled Aug 30, 1971

1955 from: Gorham, E. 1957. **The chemical composition of lake waters in Halifax County, Nova Scotia.** *Limnol. Oceanogr.* 2: 12-21. Sampled in Dec 1977. pH avg of before and after aeration

The interpretation of pH changes is complicated by the influence of acid rain and the lack of values earlier than 1955. pH dropped about 1/2 unit between 1955 and 1977 which is attributable to acid rain; the values for 1977 and 1980 are below requirements for salmon (~5.0 and greater for adults, >5,4 for fry [1]), while the 1955 value is close to the lower limits for salmon. As salmon were in Sandy Lake historically, it seems that pH values favourable for Atlantic salmon must have existed in Sandy Lake prior to the era of increasing acid rain. That era occurred from the mid-1950's through to 1980s when average lake pH dropped 1-1.5 units.[2] Emission controls were implemented in the 1990s and reductions in stream acidity in northeastern NA began to be observed in the 2000s, although not in much of Nova Scotia on soils developed on slates and granite.[3] Increases in pH (less acidity) have been reported recently for the Pockwock and Lake Major water reservoirs.[4] As sugar maple, a calcium-demanding species [5], occurs on on the thick drumlins by Sandy Lake, it can be inferred that the forests/drumlins by Sandy Lake (also Marsh Lake) provide some watershed buffering of lake pH. (See AECOM 2014, Fig 5 for distribution of drumlins.)

Urbanization tends to increase stream pH values, also electrical conductivity (EC), a measure of salt content. In Nova Scotia, our liberal use of road salt is blamed for much of the trends of increase in conductivity in Halifax area lakes over the interval 1980-2000 as revealed in synoptic Lake studies:



Modified Fig 4 from **Synoptic Water Quality Survey Of Selected Halifax Regional Municipality Lakes On 28-29 March 2000.** P Clement et al. 2007. Canadian Technical Report of Fisheries and Aquatic Sciences NNNN

EC values in the area of 30-60 uS/cm are typical of pristine lakes in the Halifax region. [6] EC values for Sandy Lake were in that range in 1955 and 1971, and 1980 (not in 1977 however) but samples taken from 1985 onward were well above 100 with an overall upward trend. The low values in 1955 and 1971 suggest the lake was likely well below the mesotrophic range (re: figure above), i.e. it was oligotrophic in those earlier years.

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1. Also, pH in the range 4.5 to 5 is cited by White et.al 1981 for Sandy Lake in 1980; liming had only a transitory effect (White et.al 1981. On the feasibility of rehabilitating acidified Atlantic salmon habitat in Nova Scotia by the addition of lime. Fisheries Vol 9(1):1-3). Salmon fry are highly sensitive to ph 5.4 and below, adults to pH <5.0, but it depends on the

source of acidity, tolerance being less when the acidity is derived from sulphates in acid rain than from naturally occurring humic acids. Critical pH values for brook trout are cited as pH 4.7 to 5.2. Farmer, G. **Effects of low environmental pH on Atlantic salmon in Nova Scotia**. 2000. Canadian Stock Assessment Research Document 2000/050. Baldigo and Lawrence 2001. **Effects of stream acidification and habitat on fish populations of a North American river**. Aquat.Sci.63 (2001) 196–222.

2. Ginn et al. 2007. **Assessing pH changes since pre-industrial times in 51 low-alkalinity lakes in Nova Scotia, Canada** Can. J. Fish. Aquat. Sci. 64: 1043–1054.

3. Clair, T.A., Dennis, I.F., and Vet, R. 2011. **Water chemistry and dissolved organic carbon trends in lakes from Canada's Atlantic provinces: no recovery from acidification measured after 25 years of lake monitoring**. Can. J. Fish. Aquat. Sci. 68(4): 663–674.

4. L.E. Anderson et al., 2017.**Lake Recovery Through Reduced Sulfate Deposition: A New Paradigm for Drinking Water Treatment**. Environ. Sci. Technol., 2017, 51 (3), pp 1414–1422.

5. Long, R.P. et al. 2009. **Sugar maple growth in relation to nutrition and stress in the northeastern United States**. Ecol Appl. 2009 19:1454-66.

6.**Synoptic Water Quality Survey Of Selected Halifax Regional Municipality Lakes On 28-29 March 2000** by P. Clement et al. 2007. Canadian Technical Report of Fisheries and Aquatic Sciences NNNN. UPDATE May 10, 2019: 2011 data just published: Synoptic water quality survey of selected Halifax-area lakes : 2011 results and comparison with previous surveys / Pierre M. Clement and Donald C. Gordon.

OBSERVATIONS OF LIMNOLOGICAL VARIABLES IN 2017 and 2018

Four sets of data were obtained:

(i) I routinely carried a pocket conductivity meter and frequently a pocket pH meter (the latter borrowed from CBEM at St. Mary's University), and made measurements of water on surface waters as I encountered them.

(ii) On Aug 10, 2018, I paddled the perimeter of Sandy Lake and measured electrical conductivity (EC), occasionally pH at regular intervals.

These two sets of results are plotted on Google Maps. View EC & pH

pH values for Sandy Lake were in the range 6.6 to 7.2, while EC values were mostly in the range 170 to 180. Streams on the east side of Sandy Lake had EC values in the range 30-51 uS/cm, pH 4.9 to 5.8. EC values for 2 streams on the west side were 78 and 98 uS/cm (pH 4.8, 5.4) likely reflecting some input of solutes from developments in the Gatehouse run/Lucasville Road area within the watershed. The highest stream EC and pH values were for the major inlet at the southwest corner of the lake (EC 346, 348 uS/cm pH 7.4) where Johnsonn's Brook (sometimes known as Bob's Brook) enter the lake. These waters receive effluent originating from the Uplands Park Wastewater Treatment Facility serving approximately 170 people, which AECOM (2014) identified as a point source of pollutants.

A set of water quality observations on Sandy Lake in 1991* revealed an exceptionally low pH value of 3.38 for the "Northern Inlet". The same site sampled on Aug 21, 2017 had a pH value of 5.7. The low value in 1991 may have reflected peak acidification due to acid rain and/or exposure of acid slates in

the northwestern part of the watershed (see AECOM 2014, p 8) and the higher value now observed, reductions in acid rain-causing emissions, and possibly some urban influence of now established development.

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*__Sandy Lake Development Impact Assessment Final Report__ by D. Conrad et al. 2002 Biological Engineering Department, Dalhousie University

(iii) On Nov 8, 2018 I sampled 3 streams associated with Johnson's Brook and water entering the lake via the culverts at the SW corner of the lake (just down from the road to the dairy). There was very high-water flow at this time, but a clear salt signal was evident in two of the streams converging at "Murphy's Pit". One was the streams draining the Uplands Park wastewater treatment area (EC 125 uS/cm). Another was the stream draining the construction/trucking yard and community just to the SE of the Dairy Road (EC 410). Water at the latter site was very cloudy and full of particulate material. This stream does not seem to have been identified as a significant source of pollutants in the AECOM 2014 study and should be further investigated. Samples were taken again at this site on Dec 13, and through the winter by a volunteer (B. Sarty). These continued to show a salt signal. View details under http://versicolor.ca/sandylakebedford/lakes/ec-ph/

View EC & pH

(iv) A set of vertical profiles of temperature, oxygen, EC and pH were obtained for 3 sites on Sandy Lake ON Oct 3, 2017, using a Wet-pro Field kit borrowed from the Community Based Environmental Monitoring Network at St. Mary's University. I had wanted to do these measurements in August to view summer stratification at its peak, but the equipment was not available then. Hence measurements were made on Oct 3 when the water column was likely in the process of "de-stratifying". View Limnological Profiles for the results.

The oxygen values are of particular note. The phosphorus models in effect attempt to predict oxygen profiles which affect a wide range of life in lakes, but the oxygen profiles give a more direct and description of the state of the lake than total P values. The results from Oct 3 indicate oxygen values at depth are lower than values required for cold water fish, but there is not (yet) severe depletion of oxygen. This state is consistent with AECOM's conclusions based on Total Phosphorus measurements that the lake is moving from an oligotrophic (nutrient-poor) into a mesotrophic state.

(*Mesotrophic* lakes are richer in nutrients than nutrient-poor oligotrophic lakes but are not nutrient-rich *eutrophic* lakes in which oxygen is depleted in deeper layers.)

The only comparable historical data for Sandy Lake are apparently those reported for the surface and at 59 ft (18 m) on Aug 30, 1971:

Variable	1971 surface	1971 18 m	2017 surface	2017 17.5 m
Temp (° C)	21	-	17.1	5.7
Conductivity (uS/cm)	37	39	169	248
Oxygen (mg/L)	7.25	5.0	9.42	2.25

1971: from **Metropolitan Area Planning Committee 1971-1972: Water Quality Survey for Selected Metropolitan Area Lakes.** Sandy lake was sampled on Aug 30, 1971
2017: Sampled on Oct 3

So at peak stratification in 1971, the oxygen concentration at the bottom was twice the value in 2017. In 2018 the conductivity on the surface had increased about 4.6 fold and the bottom value was 79 uS/cm greater, compared to a difference of only 2 uS/cm in 1971. As differences in conductivity/salt content between surface and deeper water increase, they increase density stratification of water column and slow down and at some point eliminate seasonal turnover of the water column associated with temperature changes, and thus re-oxygenation of the deeper layers; in turn that can lead to permanently low or no oxygen in the deeper layers.

The current state of Sandy Lake and the worsening trend should be a matter of concern. While waters entering the major inlet are likely the major source of pollutants, I note also the apparent "salt signal" in streams draining land in the area of Gatehouse and Lucasville Roads; and that a large volume of clearcut debris entered the northwest side of the lake.

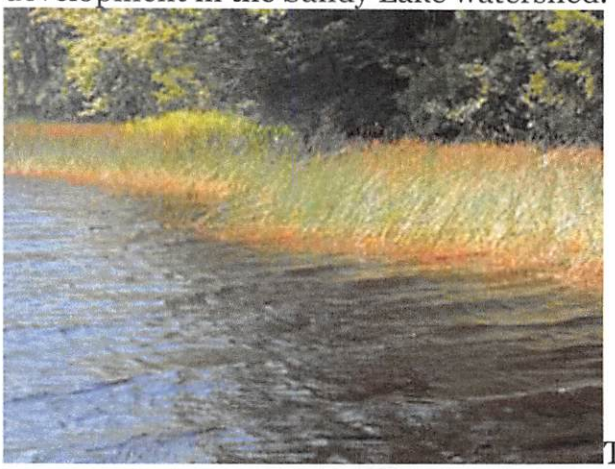
As noted in the SLCA Response to AECOM study rising temperatures add to the stresses, e.g. by reducing oxygen solubility.
AECOM has identified a number of measures to be taken to protect Sandy Lake even with further development in the watershed; stronger measures and less development were suggested by SLCA (see Recommendations in SLCA Response to AECOM study).
These recent observations suggest that the lake is currently in a precarious state.

In regard to Water Quality Monitoring, AECOM 2014 advised:

The Water Quality Monitoring Functional Plan identifies Sandy Lake as a Tier I waterbody or "High Vulnerability" to be sampled with a sampling program consisting of monthly collections during the ice free season (April – December) and at least one sample during the winter season...Temperature and dissolved oxygen profiles are recommended to be collected during each sampling event at 1 m intervals with profiling intervals increased to up to 3 m below the 20 m level. Water samples should be collected from 0.5 m below the lake surface, at mid-depth, and 1 m above the lake bottom.
Both discrete and volume-weighted samples from Sandy Lake are recommended to be analyzed. Total phosphorus and chlorophyll a testing must be performed on all discrete water samples. E. coli need only be measured for the 0.5 metre (top) water sample. Volume-weighted samples made up of top,

middle and bottom water samples are to be tested for the remaining grouped analytical parameters specified in Table 14.

The water quality monitoring program for Tier 1 lakes (Stantec 2009) is recommended as a suitably robust water quality monitoring plan for Sandy Lake that will allow for the identification of seasonal and long-term patterns in water quality and to evaluate how water quality may be impacted by development in the Sandy Lake watershed.



The observations reported here illustrate the paramount importance of routine monitoring of limnological profiles. In addition, they illustrate how measurements of conductivity of incoming waters through different seasons would be appropriate for monitoring. The equipment for such measurements is cheap and robust and such measurements could be conducted by a citizens group. Also, I suggest keeping a watchful eye on the lakeside wetlands. In the more open areas of the lake, those wetlands are now dominated by an emergent aquatic plant, the bayonet rush, which is characteristic of oligotrophic (nutrient-poor) lakes, thus change in that conditions towards species characteristic of mesotrophic/eutrophic conditions could be regarded as significant. *

I think its clear that Sandy Lake could and probably would degrade rapidly with further significant development in the watershed. The morphometrics of Sandy Lake and the degree of development around the lake are similar to those of Williams Lake on the Halifax south mainland. At Williams Lake, there was apparently no seasonal turnover in a recent winter*, and a program of alternatives to road salt on some adjacent streets has been re-introduced.

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*I have to report the detailed observations on aquatic plant species in Sandy Lake. Species more characteristic of higher nutrient levels occur closer to the major inlets.

-dp Jan 2, 2017

** View Water quality measurements on Williams Lake and Colpitt Lake (Halifax, N.S.) Dec 7-13, 2015 with reference to possible impacts of road salt by David Patriquin for the Williams Lake Conservation Company (2016)

Forests and surface waters of Sandy Lake & Environs (Bedford, Nova Scotia)