Soil & Water Conservation Society of Metro Halifax (SWCSMH)
310-4 Lakefront Road, Dartmouth, NS, Canada B2Y 3C4
Email: limnes@chebucto.ns.ca Tel: (902) 463-7777
Master Homepage: http://lakes.chebucto.org

Ref.:	RockyLake_Bedford&Waverley2013	(7 pages)
To:	**Chair & Members, North West Community Council (NWCC), HRM**	
From:	S. M. Mandaville Post-Grad Dip., Professional Lake Manage. Chairman and Scientific Director	
Date:	October 30, 2013	
Subject:	ROCKY LAKE, Bedford&Waverley:- is enriched per HRM's synoptic data of 2006-2011, and suggested restoration parameters	

(*cf.* http://lakes.chebucto.org/WATERSHEDS/SHUBIER/ROCKY/rocky.html)

Please feel free to ask me any questions, and I will endeavour my level best to respond either via emails and/or in person at one of your meetings, if invited to do so.

Restoration parameters for consideration by the NWCC are suggested on page-3.

I have provided a synopsis of the relevant data from various known sources referenced appropriately (see page-5. These are all deep station values (shallow zone values may differ considerably). I have also not included our inference values of phytoplankton or zoobenthos.

Of specific interest are the TP (total phosphorus), the primary limiting nutrient, and Ch*a* (chlorophyll*a*) which is representative of the algal production.

HRM's TP data varied widely, 3-50 µg/l, with a mean of means of 15.6 µg/l during the years 2006-2011. That is an unexpected and alarming range, and high compared with the historical mean of means of 6.1 µg/l (range=2-<10 µg/), and the modelled hindcast (pre-cultural+0.173 kg/ha.yr precipitation) value of 2.9 µg/l, and the pre-industrial (pre-1850's) value of 6.76 µg/l. Prior to HRM's data, data from other sources was mostly in the same magnitude as that of the pre-1850's value.

HRM's Ch*a* data had a wide range as well, 1.60- 28.83 µg/l during the years 2006 to 2011 with a mean of means of 8.16 µg/l. It is also alarming when compared with the historical mean of means of 0.99 µg/l (range=0.2-1.39 µg/l).

……../2

I also include the predictive phosphorus modelling conducted by my team some years back (results updated in page-5, and the pictorial model in page-7).

Environment Canada (2004) published a table which was derived from the 18-country OECD peer consensus (http://lakes.chebucto.org/TPMODELS/OECD/oecd.html) which I reproduce below:-

Table 4.1 Trophic classifications of lakes, with their corresponding phosphorus and chlorophyll concentrations and transparency (Secchi depth) (sources: Wetzel 2001; Vollenweider and Kerekes 1982).

Trophic level	Total Phosphorus ($\mu g \cdot L^{-1}$)		Chlorophyll *a* ($\mu g \cdot L^{-1}$)		Secchi depth (m)	
	Wetzel (2001)	Vollenweider and Kerekes (1982)	Vollenweider and Kerekes (1982)		Vollenweider and Kerekes (1982)	
			Mean	Max	Mean	Min.
Ultra-oligotrophic	< 5	< 4	< 1	< 2.5	> 12	> 6
Oligo-mesotrophic	5-10	4-10	< 2.5	< 8	> 6	> 3
Meso-eutrophic	10-30	10-35	2.5-8	8-25	6-3	3-1.5
Eutrophic	30-100	35-100	8-25	25-75	3-1.5	1.5-0.7
Hypereutrophic	> 100	> 100	> 25	> 75	< 1.5	< 0.7

To further understand the relevance of Ch*a* values, kindly note that the Kings County of Nova Scotia set a maximum objective <u>Ch*a* values in the low range of 2.5 µg/l</u> for 18 lakes. I herewith insert a scan from their policy in my archives:-

Kings County adopted water quality objectives for 18 lakes in the county, through amendment of MPS and LUB. The maximum objective value of chlorophyll-a for most of these lakes is 2.5 µgm/L. Seven of the lakes' objectives were set below the level of 2.5. Based on predictive modelling, the estimated maximum number of dwellings that could be added to the contributing area without exceeding the threshold value was established. This number of dwellings was set as a limit for development in the LUB. Policy in the MPS enables application for a permit with a development having "near-zero impact" through site standards or performance standards. Primarily this condition is expected to be met with septic field fill with a 20 year phosphorus input retention and a requirement to replace the fill every 20 years. A condition in adopting these limits was implementation of an annual monitoring program for a minimum of six years. The sampling required was to be completed by volunteers.

Page 9-12

……../3

Suggested deliberation for restoration by the community council:

(i) See the CCME's fact sheet (2004) for the phosphorus guidance framework (http://documents.ccme.ca/download/en/205/).

(ii) The CCME's framework recommends a maximum increase of 50% over the hindcast value of TP, and to not exceed its trigger range. The hindcast value (+0.173 kg/ha.yr precipitation) is 2.9 µg/l, hence the relevant trigger range is the very stringent <4 µg/l.

(iii) Since the aforesaid restoration goal is not practical, one could aim for 50% increase which results in 4.4 µg/l. This would place it in the second tier of the CCME trigger range of 4-10 µg/l. But 4.4 µg/l is also hard to achieve. Hence the goal could be 1.5 x pre-cultural=1.5x6.76=13.52 µg/l, but it exceeds the upper value of the second tier, i.e., 10 µg/l. Hence, 10 µg/l should be the ultimate goal. Any higher value may result in severe degradation as exemplified in the CCME document.

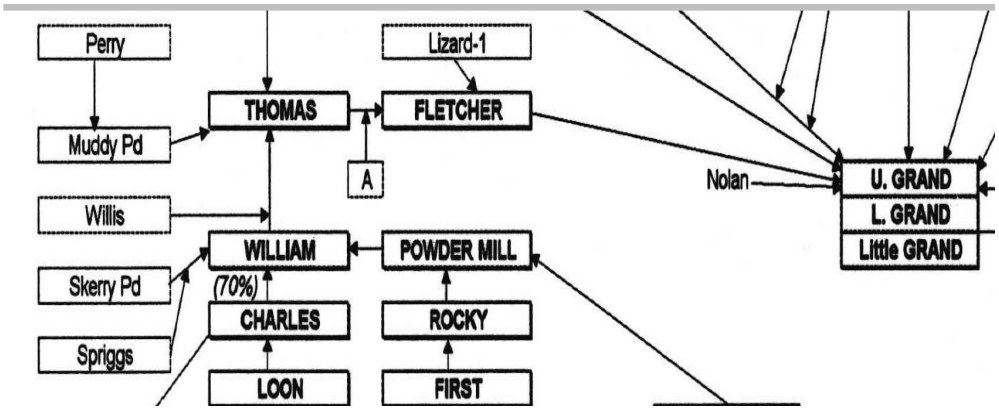
Total phosphorus (TP) trigger ranges for Canadian lakes and rivers (CCME, 2004)

Trophic status	TP (µg/l)
Ultra-oligotrophic	< 4
Oligotrophic	4-10
Mesotrophic	10-20
Meso-eutrophic	20-35
Eutrophic	35-100
Hyper-eutrophic	> 10

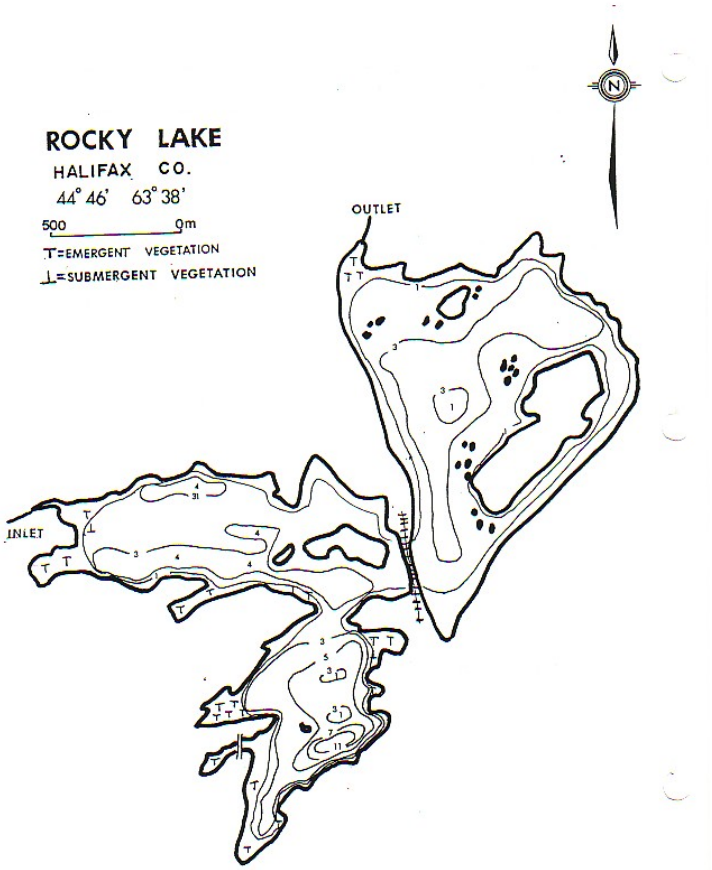
Per the CCME (2004), the framework offers a tiered approach where phosphorus concentrations should not (i) exceed predefined 'trigger ranges'; and (ii) increase more than 50% over the baseline (reference) levels. The trigger ranges are based on the range of phosphorus concentrations in water that define the reference trophic status for a site (i.e., hindcast values). If the upper limit of the range is exceeded, or is likely to be exceeded, further assessment is required. When assessment suggests the likelihood of undesired change in the system, a management decision must be made.

……../4

Partial flow chart developed by us of the Shubie River headwaters



Lake bathymetry (as supplied by the NS. Dept. of Fisheries)



……../5

Data (deep station) archives

Source of field data	Date(s) of sampling	#s of sampling events and type of sampling	TP (µg/l)		Ch*a* (µg/l)	
		Deep stn.	mean	range	mean	range
Environment Canada	June-Sept. 1974	7#s (surf.)	<10	<5 – 10	0.51	0.2 – 1.2
BIO	Apr. 1980	1# (surf.)	2	---	---	---
SWCSMH	July & Oct. 1990	2#s (arms depth)	7.7	6.7 – 8.7	0.83	0.73 – 0.92
BIO	Apr. 1991	1# (surf.)	8	---	1.39	---
SWCSMH's Predictive Modelling (our updated values)		Pre-cultural (+0.173 kg/ha.yr precipitation)	2.9	---	---	---
		Based on 1988 land use stats	10.9	---	---	---
Mandell	1991-92	4#s (surf.)	5	4 – 6	0.85	0.53 – 1.10
BIO	March, 2000	2#s (surf.)	8	---	1.383	---
HRM	2006	2#s (1 m.)	3	---	8.22	4.81 – 11.62
HRM	2007	3#s (1 m.)	12	8 – 17	6.93	1.66 – 10.39
HRM	2008	3#s (1 m.)	20.3	18 – 25	9.15	5.16 – 12.81
HRM	2009	3#s (1 m.)	22.0	12 – 30	3.08	1.92 – 4.84
HRM	2010	3#s (1 m.)	26.0	11 – 50	5.18	1.60 – 8.74
HRM	2011	3#s (1 m.)	10.3	8 – 15	16.39	9.55 – 28.83
Thiyake's Paleo Inference Model	Pre-1850's (Bottom layer of core)	Queen's University Diatom Inference Model	6.76	---	---	---
	Early 2000's (Top layer of core)		6.61	---	---	---

(Acronyms & brief explanation on next page)

……../6

Acronyms & brief explanation of the aforesaid table

arms depth.= sampling at arms depth
surf.= surface samples
1 m.= 1 metre depth sampling

BIO- Bedford Institute of Oceanography
SWCSMH- Soil & Water Conservation Society of Metro Halifax's research
SWCSMH's predictive modelling- Computer modelling carried out by the Soil & Water Conservation Society of Metro Halifax
Mandell- Paul Mandell's MSc thesis (1994) at Dalhousie University
HRM- Halifax Regional Municipality (2006 to 2011; the Ch*a* values are means of the 2 methodologies reported)
Thiyake- Thiyake Rajaratnam's MSc thesis (2009) at the Queen's University in Kingston, Ontario under a major NSERC grant. The grant was for the first ever paleolimnology conducted on lakes across Nova Scotia (I calculated the antilog values from her reported log values based on the diatom inference model)

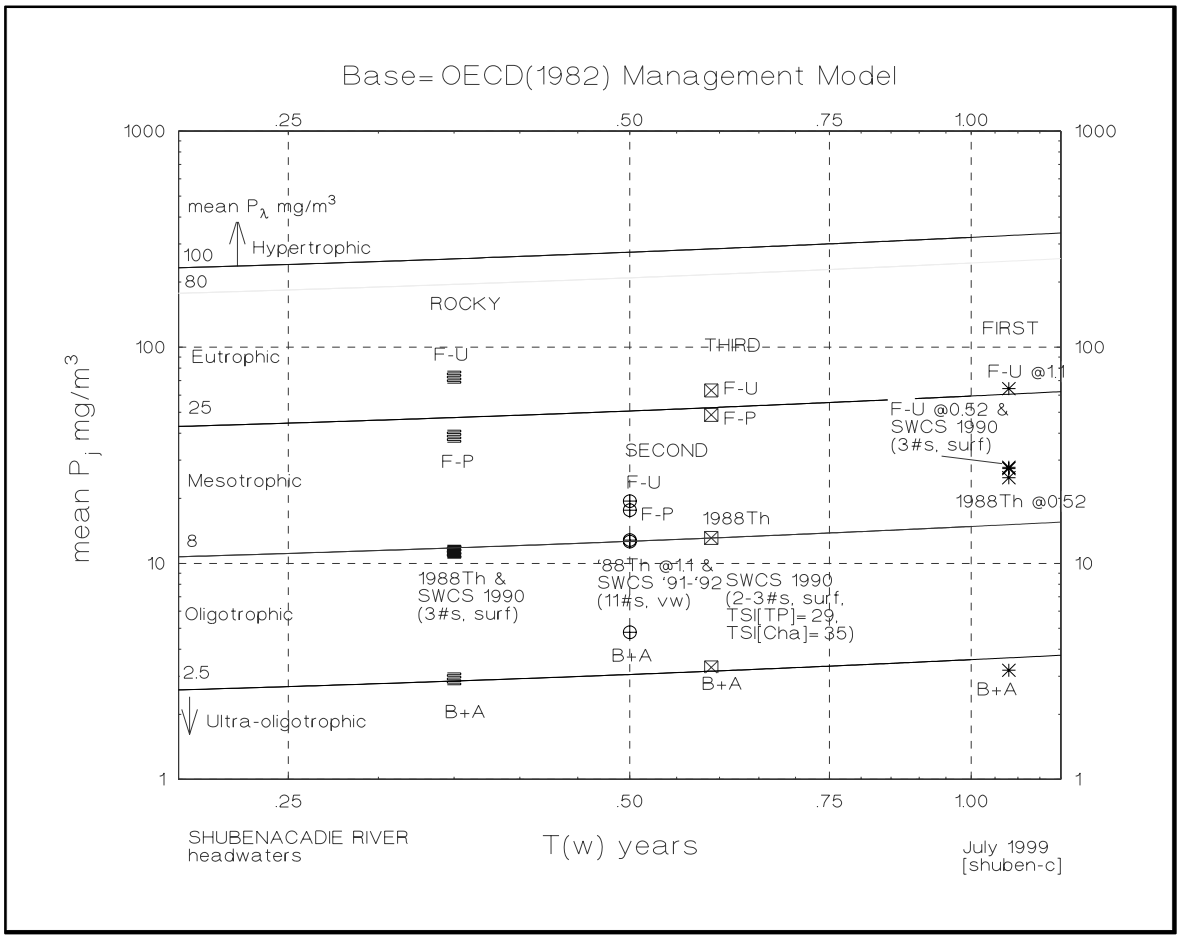
Basic Morphometric and Hydrologic data
(computed by us from bathymetric maps supplied by the Provincial Fisheries Dept.)

- Shoreline length= 15.252 km
- Surface area= 144.1 ha
- maximum depth= 11.0 m; mean depth= 3.0 m
- volume= 4.14×10^6 cu.m.
- watershed (local)= 707 ha, watershed (total)=1082.2 ha
- Flushing rate= 2.9 times/yr (approx.)
- In-lake TP retention= 0.60

- Zr , Relative depth= 0.8 % ……. (for most lakes, Zr < 2%. Deep lakes with small surface areas exhibit greater resistance to mixing and usually have Zr > 4%).
- DL, Shoreline dev.= 3.6 ……. (DL is important because it reflects the potential for development of littoral communities which are usually of high biological productivity).
- Dv, Deve. of volume= 0.8 …….. (For the majority of lakes, Dv will be greater than 1 (i.e. a conical depression).
- Index of Basin Permanence (IBP)=0.36×10^6 cu.m/km …… (The IBP is a morphometric index that reflects the littoral effect on basin volume. Lakes within the Atlantic National Parks (IBP < 0.1) are dominated by rooted aquatic plants and indicate senescence (excessive shallowness, high water color and high TP).

……../7

Our original predictive model utilizing the 18-country OECD (Organization for Economic Co-Operation and Development) peer consensus base models



Notes for our log-log graph above:-

The X-axis is the water retention time. The Y-axis is the inflow TP concentration. The pelagic (i.e., open water) phosphorus concentrations are shown as curved lines with values of 2.5, 8, 25, 80, and 100 µg/l expressed as total phosphorus (TP)) delineating the OECD management model categories of nutrient enrichment. Chlorophyll*a* values have not been plotted though they can be with some more work. We have also not updated the model with the latter field data of various sources inclusive of HRM's from the Table since it will get cluttered.

B+A= Background+Aereal TP
1988 Th= TP Based on the 1980 land use stats
F-P= Future-Probable TP conc.
F-U= Future-Ultimate TP conc.