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Ref.:	SandyLake_Bedford2013	(7 pages)
To:	**Chair & Members, North West Community Council, HRM**	
From:	S. M. Mandaville Post-Grad Dip., Professional Lake Manage. Chairman and Scientific Director	
Date:	October 30, 2013	
Subject:	SANDY LAKE, Bedford:- Accelerated eutrophication signs, and suggested restoration parameters	

(*cf.* http://lakes.chebucto.org/WATERSHEDS/SACKVILLER/SANDY2/sandy2.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).

Of specific interest are the Ch*a* (chlorophyll*a*) values which are representative of the `algal production'. HRM's Ch*a* data ranged 0.32–12.95 µg/l during the years 2006 to 2011 (analyzed at private labs). Compare that with our data of 1990 which ranged 0.65-2.01 µg/l (lab work at the CWRS, TUNS), and Paul Mandell's grad thesis data of 1991-92 which ranged 0.71–1.25 µg/l (lab work at the provincial QEII labs).

The TP (total phosphorus) values which are usually the `limiting nutrients':- HRM's TP data ranged 6-43 µg/l during the years 2006 to 2011 (analyzed at private labs) is of considerable concern. Compare that with the 1980's-200o's data from miscellaneous sources of 5-18 µg/l. Our modelled pre-cultural hindcast (+0.173 kg/ha.yr precipitation) value is 6.3 µg/, and the Queen's University pre-industrial (i.e., pre-1850's) diatom inference value is 8.91 µg/l.

I include the predictive phosphorus modelling conducted by my team some years back (results updated in page-5, and the pictorial model in page-7). The enrichment has already occurred (see page-3 on suggested action by the NWCC).

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	~~Max~~ 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	2~~7~~5-75	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 Ch*a* values in the low range of 2.5 µg/l 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.

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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 enrichment of 50% increase over the hindcast value of TP, and to not exceed the trigger range. The hindcast cultural (+0.173 kg/ha.yr precipitation) value is 6.3 µg/l, hence the trigger range is 4-10 µg/l. 50% increase results in a conc. of 9.4 µg/l. Hence, the goal of restoration should be a maximum deep station TP of 9 µg/l.

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.

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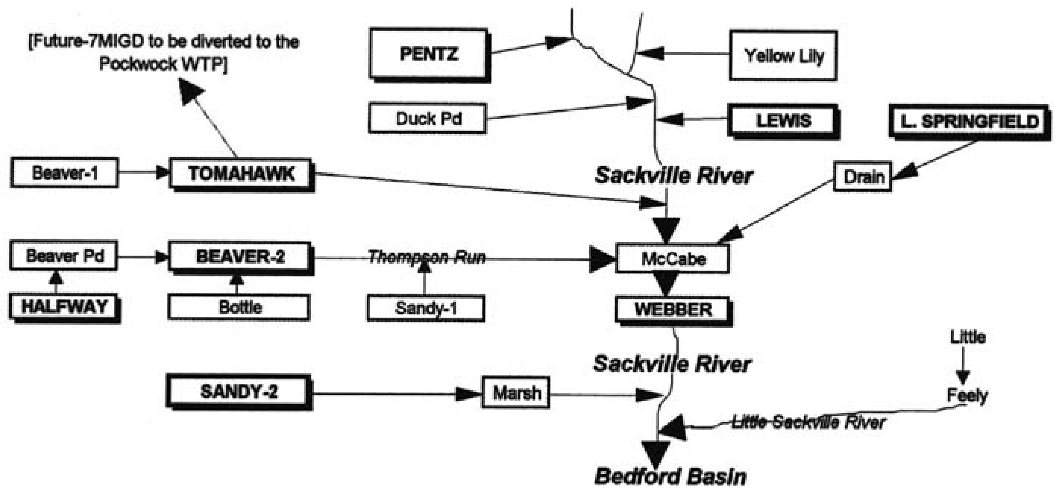
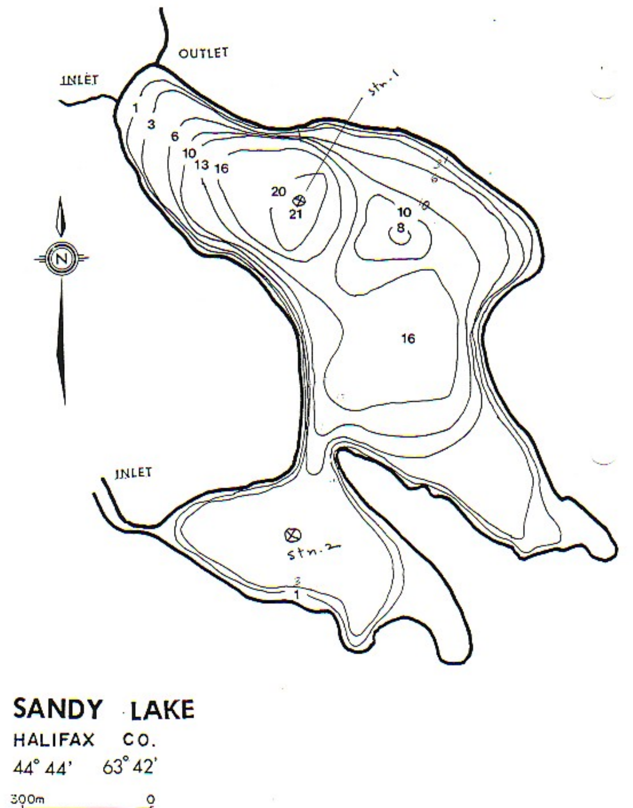
The Sackville River flow chart developed by us (Sandy, Bedford is denoted as Sandy-2)



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



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Data (deep station) archives

Source of field data	Date(s) of sampling	#s of sampling events and type of sampling	TP (µg/l)		Cha (µg/l)	
		Deep stn.	mean	range	mean	range
BIO	Apr. 1980	1# (surf.)	7	-	-	-
SWCSMH	May-Oct. 1990	3#s (arms depth)	10.9	8 - 14.8	1.42	0.65 - 2.01
BIO	Apr. 1991	1# (surf.)	18	-	0.926	-
SWCSMH's Predictive Modelling (also see graph on page 7)		Pre-cultural (+0.173 kg/ha.yr precipitation)	6.3	-	-	-
		Based on 1991 land use stats	11.2	-	-	-
Mandell	1991-92	4#s (surf.)	9	5 - 14	0.99	0.71 – 1.25
BIO	March, 2000	2#s (surf.)	8	-	0.751	-
SNC-Lavalin	Sept. 2000	2#s (surf.)	10	8 - 12	1.25	0.9 – 1.6
HRM	Oct. 2006	1# (1 m.)	9	-	8.85	-
HRM	2007	2#s (1 m.)	13	6 – 20	1.16	0.32 – 2.0
HRM	2008	3#s (1 m.)	14.7	11 – 21	6.42	1.12 – 10.43
HRM	2009	3#s (1 m.)	15.0	8 – 25	7.58	3.56 – 12.95
HRM	2010	3#s (1 m.)	24.0	10 – 43	5.45	2.94 – 9.23
HRM	2011	3#s (1 m.)	8.0	6 – 17	3.66	1.49 – 7.96
Thiyake's Paleo Inference Model	Pre-1850's (Bottom layer of core)	Queen's University Diatom Inference Model	8.91	-	-	-
	2005-2006		5.62	-	-	-

(Acronyms & brief explanation on next page)

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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
SNC-Lavalin- Consultants to the HRM
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= 7 km
- Surface area= 78 ha
- maximum depth= 19 m; mean depth= 7 m
- volume= $6x10^6$ cu.m.
- watershed (headwater lake)= 1,770 ha
- Flushing rate= 3 times/yr (approx.)
- In-lake TP retention= 0.34

- Zr , Relative depth= 2 % ………. (for most lakes, Zr < 2%. Deep lakes with small surface areas exhibit greater resistance to mixing and usually have Zr > 4%).
- DL, Shoreline dev.= 2 …………. (DL is important because it reflects the potential for development of littoral communities which are usually of high biological productivity).
- Dv, Deve. of volume= 1 ………….. (For the majority of lakes, Dv will be greater than 1 (i.e. a conical depression).
- Index of Basin Permanence (IBP)=1 $x10^6$ 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).

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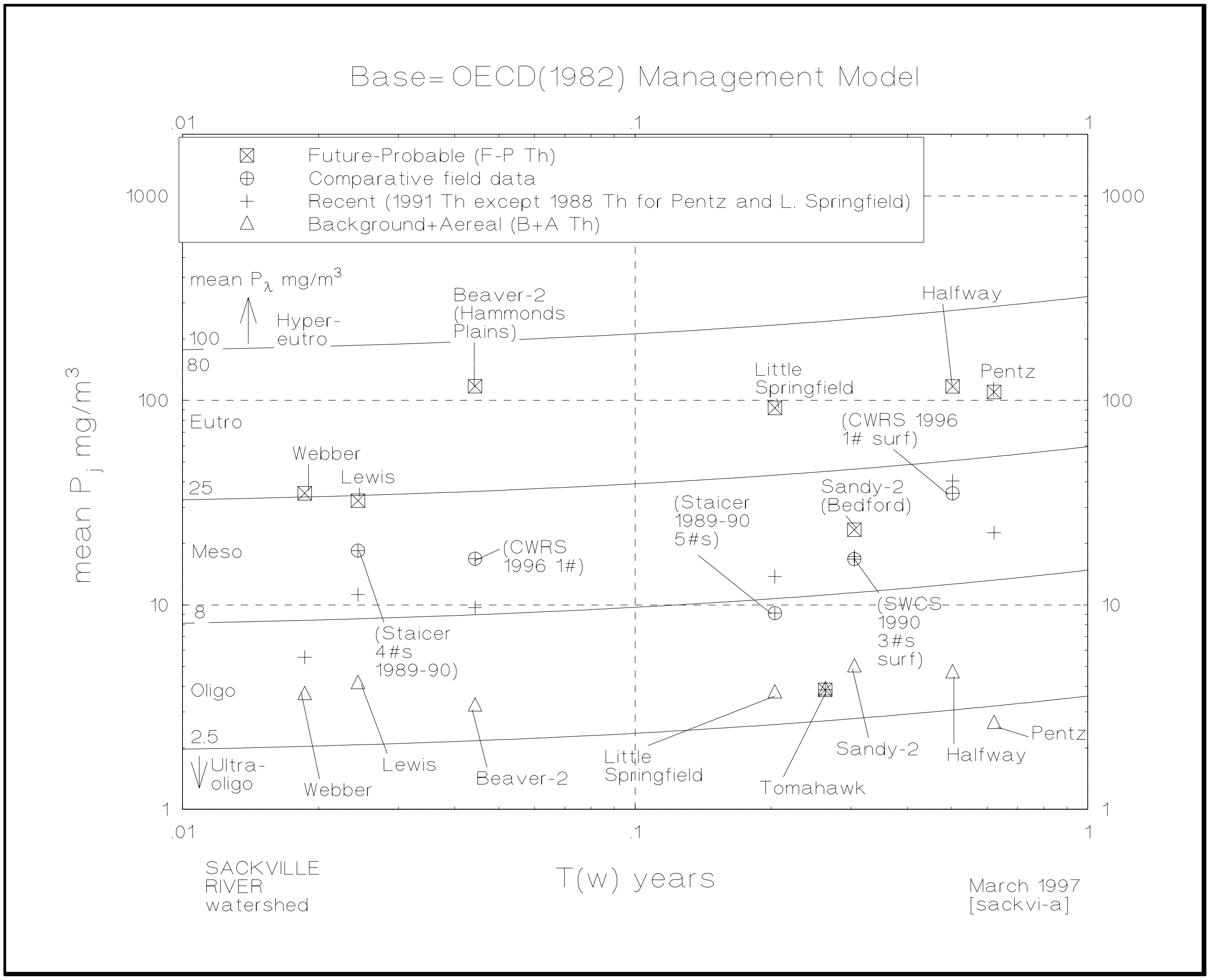
<u>Our predictive model utilizing the 18-country OECD (Organization for Economic Co-Operation and Development) peer consensus base models</u>



<u>Notes for the log-log graph above</u>:-
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.