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Ref.:	RWAB_Threshold_LCC_TP	(12 pages)
To:	**Chair & Members, Regional Watersheds Advisory Board, HRM**	
From:	S. M. Mandaville Post-Grad Dip., Professional Lake Manage. Chairman and Scientific Director	
Date:	November 03, 2013	
Subject:	**Phosphorus:- Details on Threshold/LCC values of lakes, and comparison with values chosen by the HRM**	

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. Written informally, hence may have typos. I provide web links where necessary as backup to my statements. I am providing this info in case you are all interested.

HRM's staff (and/or their paid consultants) has been setting incorrect Threshold/LCC TP values and are not following the federal CCME (2004) policy at all. HRM is basing their standards on the recent field data in contravention of the pre-cultural hindcast data as recommended in numerous scientific literature inclusive of the CCME. Recent paleolimnological literature suggests instead a compromise of selecting the diatom inference (DI) values of the pre-industrial era. In the HRM/Nova Scotia domain, it would be approximately the pre-1850's. These inference values can be also be used to set the maximum acceptable TP values as well. Our modelled TP, the DI (Diatom Inference) TP, suggestions on proper LCC's, as well as the HRM's threshold values are in the Tables on pages 8 to 11 incl..

No Government agency or university in Nova Scotia has ever conducted such necessary paleolimnological studies to our knowledge.

Important Note: At first glance, our recommended Threshold/LCC TP values may appear overly stringent. But, there are case histories in Canada and the USA where considerable effort is being expended to restore lakes to 1.5 times the pre-cultural values. Pragmatic action by `conscientious regulators' is preferable with stakeholder support.

Indeed, one of the active groups represented on your RWAB, the SRA (Sackville Rivers Association), had recommended restoration of all lakes in Nova Scotia to their `natural background values'. It was in their submission to the Province's WRMS. Mr. Walter Regan had emailed me their draft submission asking for my comments. I did not comment at all, but complimented the SRA on their submission a few years back.

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Lead scientists from Ontario carried out the first ever paleolimnology of select lakes across Nova Scotia. The NSERC (Natural Sciences and Engineering Research Council of Canada) awarded a major 5-year grant to them. Several government agencies as well as our scientific group (the SWCSMH) collaborated (access the URL, http://post.queensu.ca/~pearl/maritimes/partners.html for the list of partners).

One of the outcomes was the superb MSc thesis (2009) of Ms. Thiyake Rajaratnam of Queen's University, Ontario. Thiyake's thesis developed a paleolimnological approach to assess changes in diatom assemblages (class Bacillariophyceae) from present-day lake sediments in comparison to those deposited before significant human impact (*ca*. pre-1850) from 51 Halifax (Nova Scotia, Canada) region lakes in conjunction with regional diatom-based transfer functions for pH and total phosphorus (TP). Incidentally, Thiyake acclaimed the BIO in her thesis, and especially emphasized the contribution that one of your members from the BIO made to her, namely Mr. Pierre Clement.

Our recent overall submission to the HRM on TP did not provide a detailed discussion on the selection of the Threshold/LCC values nor did they show HRM's decisions; hence, the need for this submission for comparison purpose. That submission is in our web space (http://lakes.chebucto.org/DATA/TPcomparisons_HRM2013Oct.pdf).

I am including our team's modelled pre-cultural hindcast (+0.173 kg/ha.yr in precipitation) TP values for a selection of lakes and includes most of the 80 stations that the HRM chose for sampling during 2006-2011. I am including the precipitation in TP in our modelling since it may not be directly related to local land development projects, and may be long range transport. I do have values without the precipitation in my numerous modelling files.

We have completed certain research inclusive of predictive modelling of **TP** and **Ch*a*** of a massive two thousand (2,000) lakes/ponds within four (4) Nova Scotia counties. This submission is only on TP in order to focus on the primary limiting nutrient in our lakes (though TP is not the limiting nutrient in a few of the lakes per our research but to address that here will also be too unwieldy).

In addition, we are not including other data since this submission will become too unwieldy and time consuming for this purpose.

We have also not included the `biological inferences' of our studies of the phytoplankton, and of the zoobenthos either. We are also conducting studies of chironomid mentum deformities though the latter is progressing at a very slow pace. We do donate printed copies of final results to select local university libraries when time and funds permit.

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Caution: A few of the lakes are marked as highly coloured in the Table; hence our predictive modelling results may not be indicative of the true hindcast values in those few cases. Natural colour is a result of coloured humic acids which may result in higher background TP values even with no land development. Presently, certain research is ongoing at a leading Ontario university to more accurately predict the TP values of such lakes, and we have collaborated with them. We eagerly await the modelling methodology for such lakes.

In the following pages, I will provide evidence (i.e., scans) of a selection of the leading peer reviewed literature and of Government guidelines/standards.

The CCME-2004 guideline (http://documents.ccme.ca/download/en/205/) was indeed the result of extensive scientific consultations conducted across North America by Environment Canada's scientists over the early 2000's. But the `concept' has been known to many of us since approx. the early 1980's via peer reviewed literature.

In addition, there were numerous published papers in several peer reviewed journals relating to lake management dating as long back as the 1970's. Some examples of the peer reviewed journals are the Canadian Journal of Fisheries and Aquatic Sciences (CJFAS), the North Lake Management Society (NALMS) journals, Handbooks of the NALMS, and the Province of Quebec standards.

Following is a brief comparison of our model with the CWRS model as regards two significant lakes w/in the Papermill Lake watershed. Note how the values are the same:-

Lake and community	SWCSMH models	CWRS models, Dalhousie University
	Hindcast (+0.173 kg/ha.yr precipitation) TP in µg/l	Background TP in µg/l
Kearney (Halifax)	4.1	3.7
Papermill (Bedford)	4.6	4.0

(Note: The CWRS modelling data was supplied to us by Rick Scott, Research Associate, on November 12, 2010 for comparative purposes.)

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

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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2) This popular NALMS handbook is used worldwide (*cf.* Holdren, C., Jones, W., and Taggart, J. 2001. Managing Lakes and Reservoirs. N. Am. Lake Manage. Soc. And Terrene Inst., in coop. with Off. Water Assess. Watershed Prot. Div. U.S. Environ. Prot. Agency, Madison, WI. Xiv, 382 pp.) Excerpt inserted below; I am sorry that the scan did not come out too well but the info is clear there.-

Some typical restrictions include a certain percentage increase of phospho rus concentration above pre-development concentrations. The Ministry of th Environment in Ontario, Canada, proposes a factor of 1.5 increase above prehis toric annual average phosphorus concentrations as target values for its more tha 100,000 lakes on the Canadian Shield (Hutchinson et al. 1991). The Swedish gov ernment endorses a maximum of twice the background levels of phosphorus (an nitrogen) as a national target (Swedish EPA, 1994). Compliance with these target can be evaluated only by using phosphorus models in which current anthro pogenic sources are first included and used to verify the model and then remove to arrive at a pre-development phosphorus concentration.

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3) The Province of Quebec has strict standards (March, 2006) (http://lakes.chebucto.org/TPMODELS/Quebec/phosphore-eco-regions_selection.pdf). Their guidelines are in French but hopefully some of you may understand them. I am inserting only the most relevant parts of it below:-

"Les critères de qualité de l'eau actuellement en vigueur au Québec pour le phosphore sont exprimés en phosphore total et sont les suivants :

- dans les ruisseaux et les rivières ne s'écoulant pas vers un lac : 30 µg/l;
- dans les cours d'eau s'écoulant vers un lac dont le contexte environnemental n'est pas problématique : 20 µg/l;
- dans les lacs dont la concentration naturelle est ou était inférieure à 10 µg/l : 50 % d'augmentation par rapport à la concentration naturelle, sans dépasser un maximum de 10 µg/l afin d'éviter l'eutrophisation des lacs oligotrophes;
- dans les lacs dont la concentration naturelle se trouve ou se trouvait entre 10 et 20 µg/l : 50 % d'augmentation par rapport à la concentration naturelle, sans dépasser un maximum de 20 µg/l afin d'éviter l'eutrophisation des lacs.

Ces deux derniers critères s'appliquent à la période sans glace et, pour les lacs abritant des habitats sensibles (ex. : lacs à touladis), ils doivent être validés par des modèles du comportement de l'oxygène dissous dans l'hypolimnion (MENV, 2001).

Lorsqu'on alloue un nouvel apport de phosphore dans un plan d'eau, on vise à ce que la somme de cet apport et de la concentration déjà présente en amont ne dépasse pas ces critères. Comme valeur de la qualité amont, on utilise actuellement une estimation de la concentration naturelle, qui est de 17 µg/l pour l'Abitibi et de 11 µg/l pour le reste du Québec (Blais, 1997; MENV, 1996). Ces valeurs de qualité amont sont des équivalents simplifiés des valeurs de référence par éco-région conçues aux États-Unis et décrites plus loin."

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4) Leadership shown by the Kings County of Nova Scotia. 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.** Ch*a* is the most commonly used indicator of algal production in freshwaters. Incidentally, Dr. Joe Kerekes (Environment Canada) of the OECD (Organization for Economic Co-Operation and Development) repute, was an adviser to Kings County. I herewith insert a scan from their policy in our 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:

#	Lake and the community (other relevant info)	Deep station values (shallow zone values may differ considerably)				
		SWCSMH models	Queen's University Diatom Inference Model	Threshold/LCC TP	Threshold/LCC TP	HRM's threshold TP values
		Hindcast values (+0.173 kg/ha.yr precipitation)	Pre-1850's values (Bottom layer of core)	Based on CCME (2004) framework	Based on paleolimnological research	Objective - Early warning
		µg/l	µg/l	µg/l	µg/l	µg/l
1	Albro Big (Dartmouth)	2.8	4.90	4	5	---
2	Little Albro (Dartmouth)	---	3.80	---	4	---
3	Anderson (Bedford)	---	6.03	---	6	---
4	Banook (Dartmouth)	---	5.75	---	6	---
5	Barrett (Beaverbank)	4.6	---	7	---	<20 - 15
6	Bayers (Halifax)	5.6	4.47	8	4	---
7	Beaverbank	5.7	---	9	---	---
8	Bell (Dartmouth)	2.2	4.79	4	5	---
9	Bissett (Cole Harbour)	3.7	5.13	4 or 6	5	---
10	Black Duck Pd. (Lakeside)	4.3	---	6	---	---
11	Black Point Lake (high colour; Hubley)	5.3	---	High colour	---	---
12	Charles (Dartmouth)	4.7	4.79	7	5	<20 - 15
13	Chocolate (Halifax)	---	20.42	---	20	---
14	Cranberry (long history with eutrophication-Dartmouth)	3.3	9.33	4 or 5	9	<20 – 20
15	Drain (Middle Sackville)	4.8	---	7	---	---
16	Duck (coloured-Beaverbank)	4.0	---	High colour	---	---
17	Echo (Lake Echo)	4.3	---	6	---	---
18	Fenerty (Beaverbank)	4.7	---	7	---	22 – 22
19	First (Lower Sackville)	2.6	5.89	4	6	<20 – 15
20	First Chain (Halifax)	---	4.07	---	4	---

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#	Lake and the community (other relevant info)	Deep station data (shallow zone values may differ considerably)				
		SWCSMH models	Queens University Diatom Inference Model	Threshold/LCC TP	Threshold/LCC TP	HRM's threshold TP values
		Hindcast values (+0.173 kg/ha.yr precipitation)	Pre-1850's values (Bottom layer of core)	Based on CCME (2004) framework	Based on paleolimnological research	Objective - Early warning
		µg/l	µg/l	µg/l	µg/l	µg/l
21	Fish (Wellington)	5.0	---	8	---	---
22	Fletcher (Fall River)	3.6	2.09	4 or 5	2	<20 – 15
23	Fraser (Timberlea)	5.7	7.94	9	8	---
24	Frenchman (Dartmouth)	---	4.37	---	4	----
25	Frog (Jollimore)	-	4.90	---	5	---
26	Governor (Timberlea)	5.0	11.48	8	12	---
27	Half Mile (high colour; Timberlea)	5.4	---	High colour	---	---
28	Horseshoe (Beaverbank)	2.7	---	4	---	---
29	Hubley Big (high colour; Hubley)	4.2	---	High colour	---	---
30	Kearney (Halifax)	4.1	5.25	6	5	10
31	Kidston (high colour-Spryfield)	4.9	---	High colour	---	---
32	Kinsac (Windsor Jnctn.)	1.3	2.63	2	3	<20 – 15
33	Lewis (Shubie w/shed, Hants)	4.0	---	6	---	<10 - 9
34	Lamont (Dartmouth)	2.9	7.76	4	8	---
35	Little Springfield (Middle Sackville)	5.0	4.57	8	5	---
36	Lisle (Middle Sackville)	3.7	---	6	---	50
37	Long (high colour; Halifax)	4.7	5.37	High colour	5	---
38	Long Pd. (very high colour; Herring Cove)	5.5	---	High colour	---	---
39	Loon (Westphal)	2.5	7.94	4	8	<20 – 18
40	Lovett (Lakeside)	4.1	---	6	---	---

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#	Lake and the community (other relevant info)	Deep station data (shallow zone values may differ considerably)				
		SWCSMH models	Queens University Diatom Inference Model	Threshold/LCC TP	Threshold/LCC TP	HRM's threshold TP values
		Hindcast values (+0.173 kg/ha.yr precipitation)	Pre-1850's values (Bottom layer of core)	Based on CCME (2004) framework	Based on paleolimnological research	Objective - Early warning
		µg/l	µg/l	µg/l	µg/l	µg/l
41	Major (Preston)	---	4.79	---	5	---
42	Maynard (Dartmouth)	---	3.72	---	4	---
43	McCabe (very high colour; Lucasville)	6.3	6.03	High colour	6	---
44	MicMac (Dartmouth)	---	2.29	---	2	<20 – 15
45	Miller (Fall River)	4.2	7.94	6	8	---
46	Morris (Dartmouth)	3.4	3.89	4 or 5	4	15
47	Oathill (Dartmouth)	3.6	11.22	4 or 5	11	---
48	Papermill (Bedford)	4.6	4.37	7	4	10
49	Penhorn (Dartmouth)	2.3	5.37	3.4	5	---
50	Pockwock (Hammonds Plains)	3.2	2.29	4	2	---
51	Porters-Upper (very high colour)	5.6	--	High colour	---	---
52	Porters-Lower	4.6	---	7	---	---
53	Powder Mill (Waverley)	2.3	6.61	3.4	7	<20 - 15
54	Powers Pd. (Herring Cove)	5.5	5.89	8	6	---
55	Rocky (Bedford)	2.9	6.76	4	7	<20 – 18
56	Russell (Dartmouth)	4.7	23.44	7	23	15
57	Sandy (Bedford)	6.3	8.91	9	9	---
58	Sandy (Glen Arbour)	3.2	---	4 or 5	---	---
59	Second (Sackville/Windsor Jnct.)	4.3	7.24	6	7	<20 – 15
60	Second Chain	---	4.37	---	4	---

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#	Lake and the community (other relevant info)	Deep station data (shallow zone values may differ considerably)				
		SWCSMH models	Queens University Diatom Inference Model	Threshold/LCC TP	Threshold/LCC TP	HRM's threshold TP values
		Hindcast values (+0.173 kg/ha.yr precipitation)	Pre-1850's values (Bottom layer of core)	Based on CCME (2004) framework	Based on paleolimnological research	Objective - Early warning
		µg/l	µg/l	µg/l	µg/l	µg/l
61	Settle (Dartmouth)	3.2	7.94	4 or 5	8	---
62	Sheldrake (very high colour; Hubley)	4.7	4.68	High colour	5	---
63	Shubie Grand (Wellington)	3.1	5.50	4 or 5	6	<10 – 9
64	Soldier	4.2	6.61	6	7	---
65	Springfield (Middle Sackville)	3.1	5.01	4 or 5	5	<20 – 18
66	Stillwater (Hubley)	4.9	---	7	---	---
67	Third (Windsor Jnctn.)	3.0	12.02	4 or 5	12	<20 – 15
68	Thomas (Waverley)	3.9	3.39	4 or 6	3	<20 – 15
69	Three Mile (Waverley)	2.4	---	4	---	---
70	Topsail (Dartmouth)	2.5	4.79	4	5	--
71	Tucker (Beaverbank)	4.0	---	4 or 6	---	<20 – 15
72	Whimsical (Halifax)	---	13.80	---	14	---
73	William (Waverley)	3.5	8.51	4 or 5	8	<20 – 18
74	Williams (Jollimore)	3.9	4.07	4 or 6	4	---
75	Winder (North Preston)	5.7 (questionable due to its natural history of hyper eutrophy)	---	---	---	---

(Acronyms & brief explanation on next page)

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Acronyms & brief explanation of the aforesaid table

SWCSMH's predictive modelling- Computer modelling carried out by the Soil & Water Conservation Society of Metro Halifax over a decadal period
HRM- Halifax Regional Municipality
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)

HRM's has set the following Threshold/LCC values of TP:-

HRM had set 15 µg/l as the Threshold/LCC values for Lakes Morris and Russell, and 10 µg/l for Lakes Kearney and Papermill.

Scan from the HRM's Shubenacadie Lakes Sub-watershed Study Report d/September 20, 2013:-

Lake	Trophic State Objective	Numerical Objective	Early Warning	Evaluation
Grand, Lewis	Oligotrophic	< 10 µg/L	9 µg/L	Based on 3 year running average
Charles, Micmac, Banook, First, Second, Third, Thomas, Fletcher, Tucker, Kinsac, Barrett, and Powder Mill	Mesotrophic	< 20 µg/L	15 µg/L	
Loon, William, Rocky, Springfield	Mesotrophic	< 20 µg/L	18 µg/L	
Cranberry	Mesotrophic	< 20 µg/L	20 µg/L	
Fenerty	Meso-Eutrophic	22 µg/L	22 µg/L	Fenerty should be maintained at its current average phosphorus concentration of 22 µg/L.
Duck and Lisle	Both Duck (43 µg/L) and Lisle (50 µg/L) are eutrophic lakes. Water quality should not be allowed to deteriorate further and should be improved where feasible.			
Miller, Beaverbank, Fish and Beaver Pond	Insufficient data exist. More sampling is required to set WQO for these lakes.			