Soil & Water Conservation Society of Metro Halifax (`SWCSMH')
310-4 Lakefront Road, Dartmouth, NS, Canada B2Y 3C4
lakescience@outlook.com Tel: (902) 463-7777 http://lakes.chebucto.org, and
data in https://1drv.ms/f/s!Au0xeIA-MCofgT6hH_HmNC5EW7Oe

Ref.:	RP+10#1	(3 pages)
To:	Regional Policy Program, Planning & Development, Halifax	
From:	S. M. Mandaville Post-Grad Dips. Scientific Director	
Date:	June 17, 2020	
Subject:	1st submission to the 2nd five-year review of the Regional Plan (RP)	

<u>Preamble</u>: We had made numerous submissions to the Regional Plan as well as to the RP+5 of Halifax. We had also supplied a DVD+R disk with extensive limnological info to the RP. Prior to that, we had made submissions to the former Halifax County plan reviews dating back to the 1990's. During this 2nd five-year RP review, our submissions will be simpler and as concise as possible keeping in mind what a municipality can achieve on a pragmatic level.

To introduce ourselves briefly, we are a scientific society with focus in the field of limnology (i.e., scientific specialty of freshwaters), and we have received select world acclaim for some of our work. We had lodged select printed reports of ours with the university libraries of Dalhousie University (Killam and Sexton), and with the St. Mary's University (Patrick Power library). Of late, we have also made some of our research, data, related documents, and reports from other sources available at no cost or obligations via our OneDrive with the URL, https://1drv.ms/f/s%21Au0xeIA-MCofgT6hH_HmNC5EW7Oe.

<u>Recommendation #1</u>: Consultant reports, especially of watershed studies:

We found significant shortcomings in numerous reports contracted out by Halifax and by the previous municipal units at considerable public cost.

The reports have failed to compare field/modelled data with the pre-cultural TP (total phosphorus) values although that is a fundamental requirement in any authentic watershed study.

As a cooperative venture, we herewith commit to supply you with the pre-cultural TP data of approximately one thousand (1,000) lakes/ponds over 1 ha in size within Halifax, at no cost to you. Our models were based primarily on the natural export coefficients developed by various authorities in Nova Scotia. Nova Scotia Environment (NSE) department had accepted many of the export coefficients over the years; indeed, they were funded by Provincial/Federal programs.

We can also supply you with the pre-industrial DI (Diatom Inference) values of approx. 60 lakes. These values were not our work but developed by the world reknown Paleolimnology Department of Queen's University, Ontario.

TP has long been accepted as the primary nutrient of concern although other variables also have negative impacts on water quality. The resultant increase in the fertility of affected lakes, reservoirs, slow-flowing rivers and certain coastal waters causes symptoms such as algal blooms (with potential toxicity in cases), heavy growth of rooted aquatic plants (macrophytes), algal mats, deoxygenation and, in some cases, unpleasant odour, which often affects most of the vital uses of the water such as water supply, recreation, fisheries (both commercial and recreational), or aesthetics.

Potential sources of phosphorus:- Phosphorus has been reduced or eliminated in most laundry detergents but there are several other sources as follows:- fertilizers (farm, golf course, residential); animal, pet and bird feces; wastewater treatment plant discharges (WWTP's do not remove all phosphorus, and the discharge is highly biologically available more so than other sources); overflows/bypasses from WWTPs and pumping stations; high concentration of septic systems within 300 metres of lakes and/or failures; cross connections between sanitary and storm sewer laterals; certain industrial discharges; and high sedimentation. In some lakes, there could be internal loading, i.e., re-suspension, from bottom sediments as well.

Recommendation #2: Lake Carrying Capacities (LCCs) based on total phosphorus (TP) for pragmatic protection, in perpetuity:

The year-2004 CCME phosphorus policy (http://lakes.chebucto.org/DATA/PARAMETERS/TP/ccmefactsheet.pdf) clearly states that the development capacities be based on the pre-cultural TP values (i.e., hindcasting) in order to protect the lakes in perpetuity. Halifax never implemented this.

There was nothing original in the CCME (2004) policy. The concept had been published in numerous peer reviewed journals dating back to the 1970's.

Halifax did set the LCCs for Lakes Morris (15 µg/l) of Dartmouth, Russell (15 µg/l) of Dartmouth, Papermill (10 µg/l) of Bedford, and Kearney (10 µg/l) of Halifax. These values were not based on sound limnological principles.

Our pre-cultural values for these lakes were: Morris (3.4 µg/l), Russell (4.7 µg/l), Papermill (4.6), and Kearney (4.1 µg/l).

The pre-industrial (DI) values from the Queen's University were: Morris (3.89 µg/l), Russell (23.44 µg/l), Papermill (4.37 µg/l), and Kearney (5.25 µg/l).

<u>Recommendation #3</u>: Compare the parametre values with those of the 3 protected lakes in two of the Atlantic Canada National Parks, as applicable:

A similar recommendation was also enshrined in the aforementioned CCME TP policy (2004).

Mandell, P.R. 1994. The Effects of Land Use Changes on Water Quality of Urban Lakes in the Halifax/Dartmouth Region. M. Sc. Thesis, Dalhousie Univ., Halifax. xii, 171p.

The fecal coliform counts in the below table relate to other drinking water lakes obtained from the Nova Scotia Health Authority by Mandell. The data of the protected lakes can be used as a baseline comparison with lakes across Nova Scotia, perhaps all across Atlantic Canada.

Table 1 Reference lake types used as indicator thresholds for anthropogenic stressors of urban lakes

	Type 1	*Type 2*	*Type 3*
	Beaverskin Lake	*Bluehill Pond South*	*Pebblelogitch*
	thin till	*thick till*	*dystrophic*
pH	5.40	6.92	4.30
conductivity (µsiemens)	24	35	34
colour (Hazen units)	5	22	87
alkalinity (µeq/l)	2.0	5.6	-25.5
total phosphorus (mg/l)	0.003	0.004	0.013
total nitrogen (mg/l)	0.23	0.23	0.32
sodium (mg/l)	2.59	2.90	2.80
chloride (mg/l)	4.24	4.90	3.90
sulphate (mg/l)	1.92	3.20	2.20
calcium (mg/l)	0.33	2.80	0.39
magnesium (mg/l)	0.34	0.50	0.37
potassium (mg/l)	0.23	0.60	0.27
turbidity (JTUs)	0.30	0.30	0.63
chlorophyll-a (mg/m^3)	1.38	1.20	1.80
DOC (mg/l)	2.0	2.0	11.9
fecal coliform (count/100ml)	18	18	18

Note: The data in the table were mostly taken from the Environment Canada's data base by Mandell (1994).

<u>Recommendation #4</u>: Severe controls have to be placed on new developments in order to achieve the aforementioned goals, though in most areas, the lake carrying capacities (LCCs) had exceeded over decadal time scales; e.g., the ongoing issues with Lakes Banook, MicMac, Morris, all of Dartmouth as an example (though there are examples all over Halifax).

Alternately, no further development should be allowed in the watersheds of lakes where the LCCs have exceeded unless pragmatic pre-restoration is carried out to restore the LCCs per the CCME-2004 TP policy prior to further development.

Kindly pardon any typos/grammar.

PS: Future submissions will have pragmatic suggestions on lake restoration and related topics. We realize `lake restoration' is not considered as the primary function of a municipality. But the municipalities do allow developments without any regard to consequences as proven over the decades.

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Ref.:	RP+10#2	(2 pages)
To:	Regional Policy Program, Planning & Development, Halifax	
From:	S. M. Mandaville Post-Grad Dips. Scientific Director	
Date:	June 18, 2020	
Subject:	2nd submission to the 2nd five-year review of the Regional Plan (RP)	

The Recommendation #s are a continuation from our 1st submission, RP+10#1.

<u>Recommendation #5</u>: The LCCs (lake carrying capacities) based on TP (total phosphorus) can be set at approximately 50% over the pre-cultural, i.e., the modelled hindcast values. The latter were explained in our 1st submission, RP+10#1. Such a recce is also in the CCME (2004) TP policy, http://lakes.chebucto.org/DATA/PARAMETERS/TP/ccmefactsheet.pdf (6 pages).

This *modus operandi* is expected to preserve the ecosystem to a considerable degree. Kindly also refer to the background report (2004) of Environment Canada with the URL, http://lakes.chebucto.org/DATA/PARAMETERS/TP/ccme.pdf (133 pages).

Significant number of lakes within Halifax have already exceeded the limit of 50% over their pre-cultural TP values.

<u>Recommendation #6</u>: No new serviced developments should be allowed where pumping stations are required. In other words, all serviced developments should be designed using gravity sewerage only. Otherwise, they are not `sustainable'.

Although Halifax Water does its utmost in the monitoring, maintenance, and upgrading of the sewage pumping stations, their efforts have not been foolproof.

<u>Recommendation #7</u>: Perpetual stormwater treatment (SWT) to minimize the input of the inevitable post-development stressors to our lakes/rivers:- We are aware that neither the Halifax Water nor the previous municipal engineering departments allow(ed) advanced SWT within their easements. Hence, unlike in our past submissions to the RP and RP+5, we will not recommend such aspects now.

An economic (partial) solution in new serviced as well as unserviced developments could be perpetual spreading of stormwater over protected forest land of sufficient depth and area as advised by Prof. Dr. Gordon Ogden IIIrd., Jr., when he was still with the Dalhousie University Biology Dept., Halifax and prior to that with the Yale University, CT, USA. Prof. Ogden (deceased) was one of our founding members during the 1980's. Click on the URL or his photo to watch a 2:18 minute video on YouTube, http://www.youtube.com/watch?v=rwP5x4Boryg

PS: Kindly pardon any typos/grammar.

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Ref.:	RP+10#3	(4 pages)
To:	Regional Policy Program, Planning & Development, Halifax	
From:	S. M. Mandaville Post-Grad Dips. Scientific Director	
Date:	June 20, 2020	
Subject:	3rd submission to the 2nd five-year review of the Regional Plan (RP)	

The Recommendation #s are a continuation from our 1st and 2nd submissions, RP+10#s 1 & 2.

<u>**Recommendation #8**</u>**: New large subdivisions should be planned with the public transit in mind, and urban sprawl discouraged whenever possible. Vehicular traffic should be discouraged. Halifax already supports this concept based on its web pages on "HalifACT 2050: Acting on Climate Together" (as accessed now).**

While HalifACT 2050 focuses on the effects of climate change, this submission of ours focuses on the negative impacts of highways and road traffic on the water quality of lakes/rivers. The data below is only a bird's eye view from literature, and while it is somewhat dated, is still applicable to a considerable extent.

Mean pollutant concentrations (µg/l) in runoff from urban and rural highways (some pollutant concentrations below may have been reduced now due to North American regulations):

(Drapper *et al* [Source: Driscoll, E., Shelley, P.E., and Strecker, E.W. 1990. Pollutant Loadings and Impacts from Highway Stormwater Runoff. Volumes I-IV. FHWA/RD-88-006-9, Federal Highway Administration, Woodward-Clyde Consultants, Oakland, CA])

Pollutant	**Urban (ADT> 30,000) (µg/l)**	**Rural (ADT< 30,000) (µg/l)**
TSS (Total Suspended Solids)	142,000	41,000
VSS (Volatile Suspended Solids)	39,000	12,000
TOC (Total Organic Carbon)	25,000	8,000
COD (Chemical Oxygen Demand)	114,000	49,000
NO_3/NO_2 (Nitrate + Nitrite)	760	570
TKN (Total Kjeldahl Nitrogen)	1,830	870
Phosphorus as PO_4	400	160
Cu (Total Copper)	54	22
Pb (Total Lead)	400	80
Zn (Total Zinc)	329	80

Common road runoff pollutants and sources:

(Drapper *et al* [Source: Kobringer, N.P. 1984. Volume I. Sources and Migration of Highway Runoff Pollutants-Executive Summary. FHWA/RD-84/057. Federal Highway Administration, Rexnord, EnviroEnergy Technology Center, Milwaukee, WI])

* No mineral asbestos has been identified in runoff, however some breakdown products of asbestos have been measured

Constituent	Primary Sources
Particulates	Pavement wear, vehicles, atmosphere, maintenance, snow/ice abrasives, sediment disturbance
Nitrogen, Phosphorus	Atmosphere, roadside fertiliser use, sediments
Lead	Leaded gasoline, tire wear, lubricating oil and grease, bearing wear, atmospheric fallout
Zinc	Tire wear, motor oil, grease
Iron	Auto body rust, steel highway structures, engine parts
Copper	Metal plating, bearing wear, engine parts, brake lining wear, fungicides and insecticides use
Cadmium	Tire wear, insecticide application
Chromium	Metal plating, engine parts, brake lining wear
Nickel	Diesel fuel and gasoline, lubricating oil, metal plating, brake lining wear, asphalt paving
Manganese	Engine parts
Bromide	Exhaust
Cyanide	Anticake compound used to keep deicing salt granular
Sodium, Calcium	De-icing slats, grease
Chloride	De-icing salts
Sulphate	Roadway beds, fuel, de-icing salts
Petroleum	Spills, leaks, blow-by motor lubricants, antifreeze, hydraulic fluids, asphalt surface leachate
PCBs, pesticides	Spraying of highway right of ways, atmospheric deposition, PCB catalyst in synthetic tires
Pathogenic bacteria	Soil litter, bird droppings, trucks hauling livestock/stockyard waste
Rubber	Tire wear
Asbestos*	Clutch and brake lining wear

The following was research carried out by the former academia of the NS Technical College followed by the TUNS.

[L] (Ref.: Waller and Hart 1985)
Hypothesized sources of Total Phosphorus in Surface Runoff (kg/ha-yr) based on impervious areas

Source	Residential Vegetation Low Traffic	Commercial No Vegetation High Traffic	Commercial Vegetation Moderately High Traffic	Institutional No Vegetation Low Traffic
Vehicles	0.003	2.00	0.74	0.10
Animals	0.30	0.20	0.90	0.20
Vegetation	5.94	---	4.00	---
Atmosphere	0.12	0.12	0.12	0.12
Less Sweeping	0.90	0.30	0.10	---
Less Leaf Re-moval	3.60	---	1.70	---
Net Total	1.86	2.02	3.98	0.42
Measured Mean First Flush Con-centration (mg/l)	0.88	1.29	2.87	0.30

[M] (Ref.: Waller and Hart 1985)
Effect of Vegetation on Phosphorus in Surface Runoff.
First Flush Conc. of TP (mg/l)

Land Use	Vegetation	No Vegetation
Residential	0.88	0.68
Commercial	2.87	1.29
Institutional	0.97	0.30

The potential significance of vegetation is supported by information about leaching of phosphorus from vegetation.

Reported TP content of tree leaves and seeds	1.6- 11 mg/g
Leaching from fresh leaves	0.08 mg/g
Leaching from tree canopies	0.1- 0.3 kg/ha-yr
Leaching from leaves (decomposed) collected from gutters	0.2- 0.3 mg/g
Concentrations in puddles containing leaves	5.3 mg/l

cf.

Waller, D.H., and Hart, W.C. 1985. Solids, Nutrients, and Chlorides in Urban Runoff. Procs. NATO Advanced Research Workshop, France, Aug.1985. NATO ASI Series, Vol. G10, Springer-Verlag. 1986. 59-85.

Waller, D.H. 1977. Effects of urbanization on phosphorus flows in a residential system. Procs. Amsterdam Symposium, Effects of urbanization and industrialization on the hydrological regime and on water quality, Oct. 1977. UNESCO. IAHS-AISH Publn. 123:52-58.

PS: Kindly pardon any typos/grammar.

Soil & Water Conservation Society of Metro Halifax (`SWCSMH')
310-4 Lakefront Road, Dartmouth, NS, Canada B2Y 3C4
lakescience@outlook.com Tel: (902) 463-7777 http://lakes.chebucto.org, and
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Ref.:	RP+10#4	(2 pages)
To:	Regional Policy Program, Planning & Development, Halifax	
From:	S. M. Mandaville Post-Grad Dips. Scientific Director	
Date:	June 20, 2020	
Subject:	4th submission to the 2nd five-year review of the Regional Plan (RP)	

The Recommendation #s are a continuation from our 1st, 2nd, and 3rd submissions, RP+10#s 1, 2, & 3.

Recommendation #9: Enforce the former Halifax County's Topsoil Removal Bylaw of only allowing a maximum 50 mg/l of suspended solids in any grab sample at the outlets of all new developments which should include residential developments as well.

The sampling has to be conducted at the stormwater outlets prior to discharge into lakes and streams, and not in the watercourses themselves where they are dispersed but may harm the ecosystem some years down the road.

This should cover all areas of Halifax region.

Halifax may consider imposing restorative penalties as a deterrent.

Recommendation #10: Larger buffers should be enforced along rivers and lakes as far as possible. Attached below is a recce that we received from Environment Canada some time back from a senior manager. The buffers should be owned by the municipality, and not by private interests.

This should apply to all areas, urban, suburban, and rural.

Environment Canada Environnement Canada

Environmental Conservation Branch
45 Alderney Drive, 16th Floor
Dartmouth, Nova Scotia
B2Y 2N6

March 13, 2003

Mr. Shalom Mandaville
Chairman and Scientific Director
Soil & Water Conservation Society of Metro Halifax
310-4 Lakefront Road
Dartmouth, Nova Scotia
B2Y 3C4

Dear Mr. Mandaville:

In response to your request with regards to some past work on nutrient impacts of land use activities near to aquatic systems, I am providing you with the following information.

A number of years ago, I undertook a small Geographic Information System based study to investigate the geospatial relationship between land use and river nutrient concentrations in Prince Edward Island. This work subdivided the drainage basins of a number of streams into a series of corridors around the stream channel (100m, 250m, 500m, 1Km) and then used the GIS to calculate land use characteristics within each of these corridors. The land use mapping employed was based on 1:50,000 scale land cover characteristics (21 classes) derived from Landsat images collected circa 1987. The twenty-one classes were roll into a "protected" layer (cover types expected to control nutrient supply to aquatic systems) and a "delivery" layer (cover types provide limited nutrient supply protection to aquatic systems) and a subsequent "supply index" (Delivery/Protected) was calculated for each corridor. Regression analysis between the supply index and average nitrogen concentration in the stream indicated a significant relationship for the 100m and 250m corridors based on approximately 30 streams. No correlation was observed for the supply index and total phosphorus concentration.

Although this work provided some interesting preliminary insights into the potential importance of 100m and 250m buffer strips in controlling nutrient supply to aquatic systems, it was not completed and has not been adequately peer reviewed. As such, the work provides an indication of the importance of buffer strip protection, but would require more detailed analysis to provide definitive evidence on the optimal buffer strip width.

Through the Model Forest Program and in particular the Fundy Model Forest, there have been on-going studies to investigate different harvesting practices on water quality. Some of this work has been published, while other studies are still underway. I would suggest that you contact the Fundy Model Forest office to get information on their work.

Yours sincerely,

Geoff Howell
Manager, Ecosystem Science and Information Division

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310-4 Lakefront Road, Dartmouth, NS, Canada B2Y 3C4
lakescience@outlook.comTel: (902) 463-7777 http://lakes.chebucto.org, and
Data in https://1drv.ms/f/s!Au0xeIA-MCofgT6hH_HmNC5EW7Oe

Ref.:	RP+10#5	(4 pages)
To:	Regional Policy Program, Planning & Development, Halifax	
From:	S. M. Mandaville Post-Grad Dips. Scientific Director	
Date:	July 01, 2020	
Subject:	5th submission to the 2nd five-year review of the Regional Plan (RP)- Stormwater treatment (SWT) and the rationale	

The Recommendation #s are a continuation from our 1st, 2nd, 3rd, and 4th submissions, RP+10#s 1, 2, 3, & 4.

<u>**Recommendation #11**</u>**: Stormwater treatment (SWT) to be considered in existing as well as proposed significant developments since it would be uneconomic to implement in smaller developments. We are including SWT here notwithstanding what we had stated in Recommendation #7 of our 2nd submission d/June 18, 2020:**

We have been made aware of the SWT recces in the massive 305-page plan of Halifax titled, "HalifACT 2050: Acting on Climate Together" with the URL of https://www.halifax.ca/sites/default/files/documents/city-hall/regional-council/200623rc916.pdf that was approved by the RC (Regional Council) in June 2020.

☞ We congratulate Halifax's professionals for planning to institute SWT as described on page-17 of the above report. Hopefully, it will be carried out effectively and in a timely manner. Note from limnological literature that once a lake has undergone enrichment as compared with the pre-cultural values (especially of phosphorus, TP), it can take decade(s) of treatment before it is restored to its natural background state, if at all possible.

<u>Caution</u>: Nothing stated below should be taken as personal criticisms, but is a technical critique only.

Until now we were left with the impression that neither Halifax nor its previous municipal units were interested in centralized SWT. As one key example, kindly view the relevant pages of the HRM's staff comments dated February 14, 2006 in https://1drv.ms/b/s!Au0xeIA-MCofgmihH_HmNC5EW7Oe. On page 31, Item# 4, HRM's staff at that time did not show any pragmatic interest.

We are inserting the relevant scan from the Regional Planning staff's report of year-2006 which went to the former Regional Planning Advisory Committee (RPAC):

4. Total Stormwater Treatment

Issue/Concern

Mandate total stormwater treatment systems capable of removing the myriad of post-development stressors, not silt/soils alone, in new major developments (Section 10 in SWCSMH submission). Use constructed wetlands for stormwater treatment (Subsection 10.1 in SWCSMH submission).

Discussion/Options

The issues raised in the recommendations by the Soil and Water Conservation Society will be addressed in a more holistic manner under future watershed studies. These studies will look at the density and form of development in conjunction with best management practises to minimze the impact on lakes and rivers. Best management practises may include treatment systems like engineered wetlands and total treatment systems, but more importantly will first look at what can be done to prevent the need for these treatment systems in the first place.

Even the $100,000± WRMS 2002/2003 study did not fully address the SWT needed to remove **small particle sizes as well as the soluble stressors**, in perpetuity. Detention pond examples in the fact sheets of the WRMS cannot remove these stressors efficiently. HRM's consultants, Dillon Inc., did approach us directly, probably on the request of John Sheppard P.Eng., Manager of the HRM's former EMS Dept., at which time we did supply select literature as well as web links to them.

The myriad of `stressors' that can exist in typical stormwater runoff are listed in our web page, http://lakes.chebucto.org/SWT/pollutants.html,which is an overview of numerous published literature inclusive of considerable excerpts from the U.S. Environmental Protection Agency (USEPA).

We take the liberty of inserting only 2 scans from the above web page:-

(USEPA, 1976 [Source: Sartor and Boyd, 1972])

Measured Pollutant	Particle size				
	<43μ		43μ - 246μ		>246μ
	(% by weight)				
TS	5.9		37.5		56.5
BOD_5	24.3		32.5		43.2
COD	22.7		57.4		19.9
VS	25.6		34.0		40.4
Phosphates	56.2		36.0		7.8
Nitrates	31.9		45.1		23.0
Kjeldahl Nitrogen	18.7		39.8		41.5
All heavy metals		51.2		48.7	
All pesticides		73		27	
PCB		34		66	

(Herr and Harper [Source: Harper, H.H. 1988. Effects of Stormwater Management Systems on Groundwater Quality. Final Report for Project SM 190, submitted to the Florida Department of Environmental Regulation.])

Parameter	Typical Distribution (%)	
	Dissolved	Particulate
Total N	40	60
Total P	50	50
TSS	0	100
BOD	60	40
Total Cd	70	30
Total Cr	65	35
Total Cu	70	30
Total Ni	70	30
Total Pb	25	75
Total Zn	35	65

Note that a significant amount of post-development stressors are below 43 microns in size, and many more are in dissolved form. These are difficult to remove effectively in detention ponds unless they are followed with tertiary treatment.

Tertiary treatment of stormwater has been published in several handbooks easily available to the HRM. We are unaware of any extensive SWT systems across Halifax.

We had listed various treatment technologies used elsewhere in North America inclusive of by the mammoth USEPA in another web page, http://lakes.chebucto.org/SWT/treatment.html

Select municipalities in Ontario are allegedly implementing advanced SWT to not only remove some stressors but also treat for fecal pollution in stormwater outfalls; one example is the municipality of Nepean.

An interesting design example is from Australia (*cf.* Wong, T.H.F., Breen, P.F., Somes, N.L.G., and Lloyd, S.D. 1999. Managing Urban Stormwater Using Constructed Wetlands. Industry Report 98/7, Second Ed., 1999. CRC for Catchment Hydrology and the CRC for Freshwater Ecology, Monash University, Victoria, Australia. 50pp). Maintenance would be required. We can supply the handbook in PDF to you. The regression curves in the handbook may have to be modified to take into account our local rainfall/runoff characteristics.

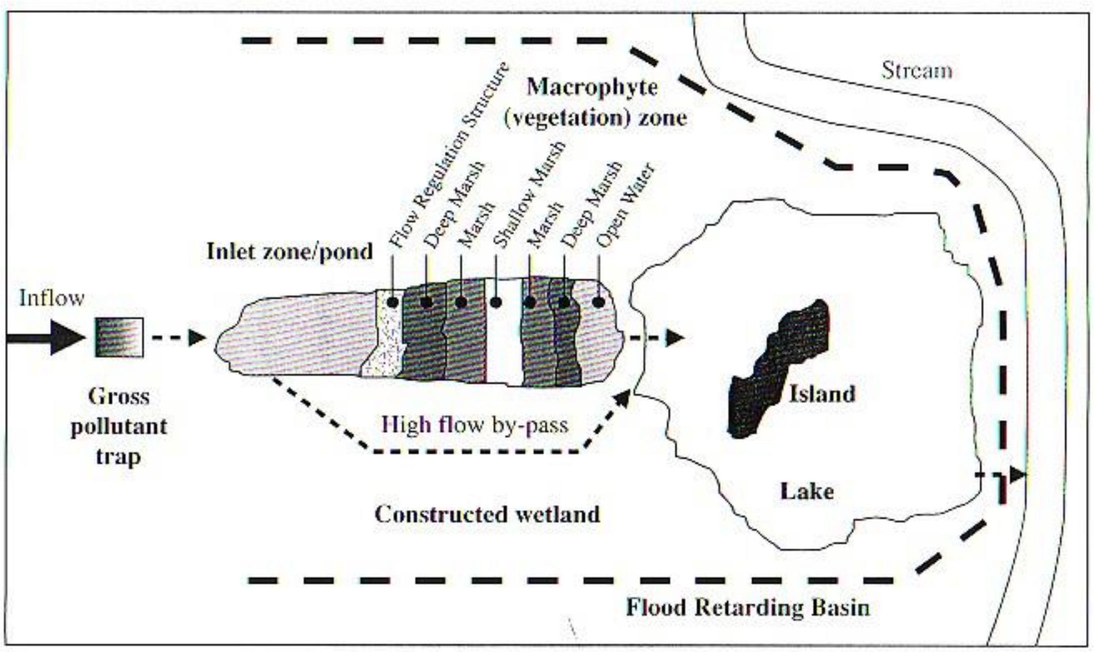

Figure 1: Modular elements in an integrated stormwater management system

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Ref.:	RP+10#6	(18 pages)
To:	Regional Policy Program, Planning & Development, Halifax	
From:	S. M. Mandaville Post-Grad Dips. Scientific Director	
Date:	July 01, 2020	
Subject:	6th submission to the 2nd five-year review of the Regional Plan (RP)- **Implement the 18-country OECD's recommendations**	

The Recommendation #s are a continuation from our 1st, 2nd, 3rd, 4th, and 5th submissions, RP+10#s 1, 2, 3, 4, & 5. This is a lengthy submission. This is intended to be a basis of scientific assessment of pre- and post-development conditions, and is in addition to comparing with pre-cultural TP values embellished in our 1st and 2nd submissions.

Recommendation #12: Follow the OECD's recommendations since their 15-year research was conducted by approximately 80 of the world's leading limnologists with doctoral and post-doctoral accreditations, working at 50 research institutes in 18 of the western countries. Of specific significance are the OECD Probability Distributions explained below.

Unfortunately, several studies have not been applying the OECD research resulting in lake management issues which are costly, if not impossible, to ameliorate.

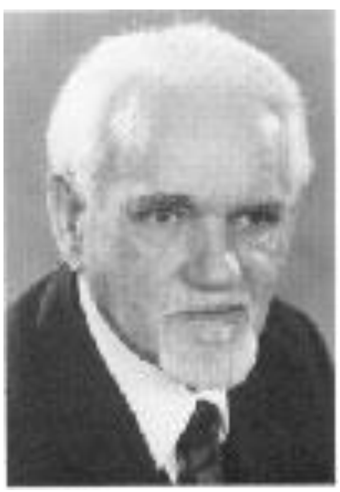
The final OECD report is a synthesis of the main results of the Cooperative Programme on Eutrophication under the Chairman of the Technical Bureau, Dr. Richard Vollenweider (*cf.* Vollenweider, R.A., and Kerekes, J. 1982. Eutrophication of waters. Monitoring, assessment and control. OECD Cooperative programme on monitoring of inland waters (Eutrophication control), Environment Directorate, OECD, Paris. 154 p.). This report can also be downloaded from our OneDrive, https://1drv.ms/b/s!Au0xeIA-MCofgkqhH_HmNC5EW7Oe

Shortcomings of the Fixed Boundary approach

What emerged from the assessment of all information available, however, led to the conclusion that there is no possibility of defining strict boundary values between trophic categories. Whilst the progression from oligo- to eutrophy is a gliding one- as has been stressed many times in literature- any one combination of trophic factors, in terms of trophic category allocation, can only be used in a probabilistic sense. Objective reasons exist for the uncertainty of classifying a given lake in different categories by two or more investigators depending on the management of that body of water.

Average conditions, expressed by "average nutrient concentrations", "average biomass values", "average transparency" do not necessarily express the degree of variability, particularly with regard to peak levels, frequency of their occurence, and their qualitative nature (type of phytoplankton).

From the management viewpoint, such situations and their frequency are as important as average conditions. For this reason, prediction uncertainties must be accounted for. The resulting probability distributions are given in Figures 3 to 6 below for the main components: average lake phosphorus, average and peak chlorophyll *a* concentrations, and average yearly Secchi disk transparency.



Click on the 4-minute .wav sound file (https://1drv.ms/u/s!Au0xeIA-MCofijShH_HmNC5EW7Oe) to listen to Dr. Richard Vollenweider explaining the rationale behind the OECD Probability Distribution Diagrams relating to the scientifically credible methodology of ascertaining trophic states which can be achieved only in a `probabilistic sense'.

Dr. Vollenweider (deceased) of Environment Canada has also been the first Canadian to have ever received the top international medal in limnology, the Naumann-Thienemann medal (1986/7), in addition to many other international awards.

Figure-3: Probability distribution curve for the average phosphorus:

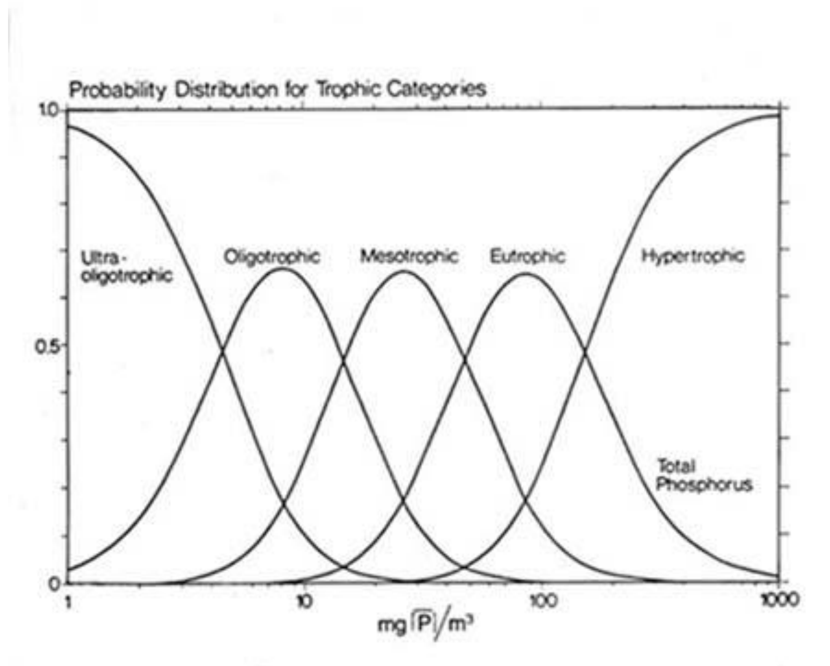


Figure-4: Probability distribution curve for the average chlorophyll *a*:

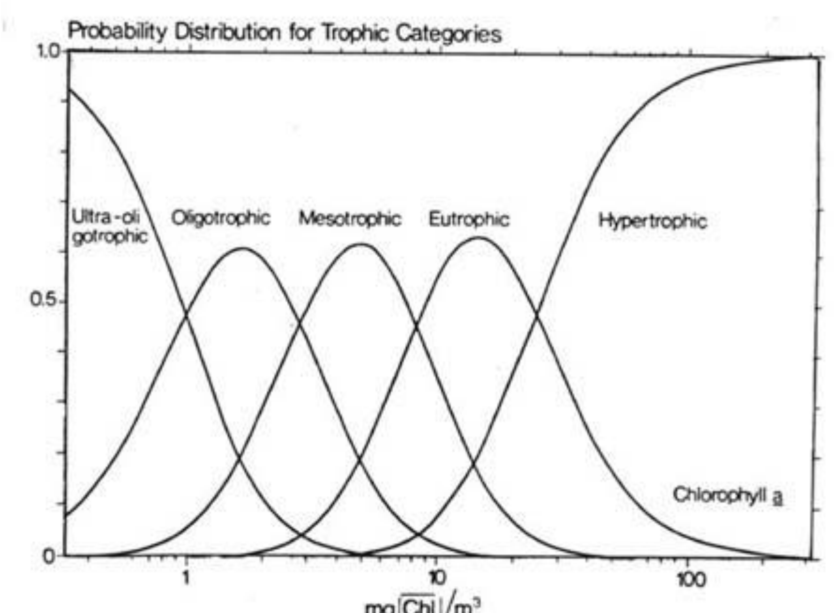


Figure-5: Probability distribution curve for the peak <u>chlorophyll *a*</u>:

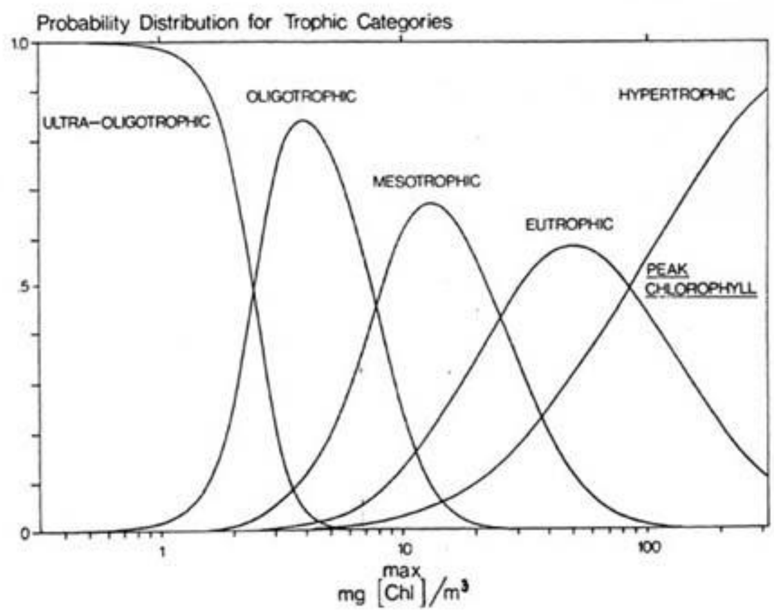
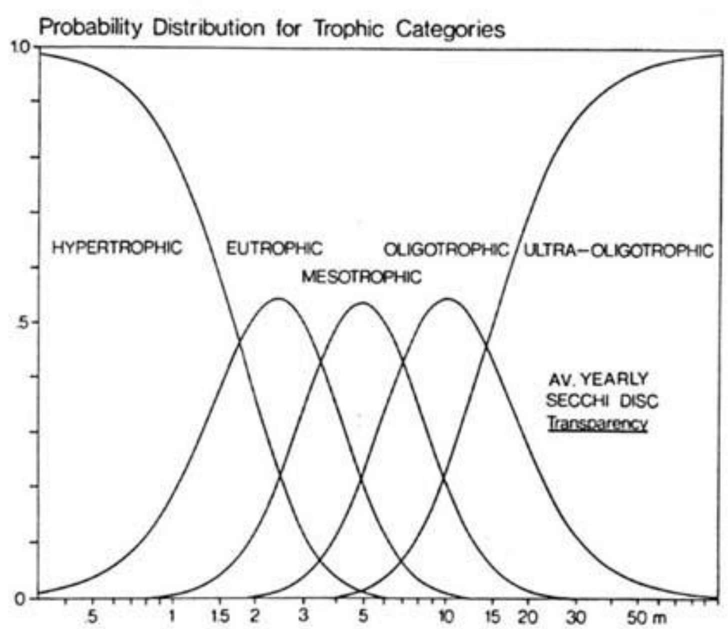


Figure-6: Probability distribution curve for the average <u>Secchi disk</u> transparency:



One example of an application of the OECD Probability Distribution Diagrams for lakes in Halifax, Nova Scotia (*cf.* Soil & Water Conservation Society of Metro Halifax. 1991. Limnological study of twenty seven Halifax Metro lakes. 136p.: ill., maps.)

(Since the field data of the 27 lakes below was only seasonal, i.e., three samples per year in most cases, peak chlorophyll *a* was not considered. One needs extensive yearly data to confidently ascertain peak chlorophyll *a*.)

Percentage Probability Classification of 1990 lake trophic states based on the "OECD" probability distribution curves. Classifications based on yearly averages for total phosphorus, chlorophyll a and Secchi disc readings. UO= Ultraoligotrophic, O= Oligotrophic, M= Mesotrophic, E= Eutrophic and HE= Hypereutrophic.

	Percentage Probability Classification														
	Based on Total Phosphorus					Based on Chlorophyll a					Based on Secchi Disc				
Lake	UO	O	M	E	HE	UO	O	M	E	HE	UO	O	M	E	HE
1 Albro	5%	55%	36%	4%	0%	51%	44%	5%	0%	0%	3%	34%	50%	11%	2%
2 Banook	14	66	18	2	0	59	38	3	0	0	0	12	50	35	3
3 Beaverbank	2	37	55	6	0	22	61	17	0	0	0	4	37	51	8
4 Bell	32	61	7	0	0	74	24	2	0	0	2	27	53	16	2
5 Bissett	0	17	65	18	0	0	14	62	24	0	0	0	4	38	58
6 Chocolate	35	60	5	0	0	93	7	0	0	0	32	54	14	0	0
7 First	4	46	46	4	0	0	19	63	18	0	0	0	13	52	35
8 Hubley Big	4	47	45	4	0	8	55	34	3	0	0	3	33	51	13
9 Kearney	22	65	13	0	0	93	7	0	0	0	2	31	51	13	3
10 Kinsac	4	46	46	4	0	8	55	34	3	0	0	8	45	40	7
11 Loon	22	65	13	0	0	82	18	0	0	0	-	-	-	-	-
12 Maynard	17	65	15	3	0	21	61	18	0	0	2	31	51	13	3
13 MicMac	4	47	45	4	0	5	50	42	3	0	2	19	53	24	2
14 Miller	22	65	13	0	0	63	34	3	0	0	0	8	45	40	7
15 Morris	4	46	46	4	0	22	61	17	0	0	0	3	33	51	13
16 Nicholson	14	66	18	2	0	34	56	10	0	0	-	-	-	-	-
17 Oathill	2	43	51	4	0	3	33	56	8	0	0	12	50	33	5
18 Papermill	19	65	14	2	0	22	61	17	0	0	0	8	45	40	7
19 Portuguese Cove	2	43	51	4	0	20	60	20	0	0	0	0	13	52	35
20 Rocky	17	65	15	3	0	59	38	3	0	0	6	44	44	6	0
21 Sandy	5	55	38	2	0	25	60	15	0	0	0	12	50	33	5
22 Second	5	55	36	4	0	20	60	20	0	0	2	19	53	24	2
23 Settle	0	20	65	15	0	0	11	58	29	2	0	0	4	38	58
24 Springfield	4	54	39	3	0	22	61	17	0	0	0	8	45	40	7
25 Third	35	60	5	0	0	20	60	20	0	0	0	12	50	35	3
26 Tucker	10	63	26	1	0	3	33	56	8	0	0	3	35	51	11
27 Williams	17	65	15	3	0	20	60	20	0	0	6	44	44	6	0

Note: We had continued to follow this methodology in other assessments. We were pleased that several of the lake problems in Nova Scotia were explained on a scientific basis since these events spanning several decades could not be rationalized utilizing simpler metrics.

A superb example of utilization of the OECD research was the following published paper of Dr. Joe Kerekes wherein an assessment was carried out prior to a planned installation of a package sewage treatment plant in Cape Breton (*cf.* Kerekes, J. 1983. Predicting Trophic Response to Phosphorus Addition in a Cape Breton Island Lake. Proc. N.S. Inst. Sci. 33:7-18.).

Note: The same methodology could be utilized to `predict' the ecological impacts of nutrients (post-development) from residential and/or commercial/industrial developments. Our research group had used parts of that methodology in urban and suburban areas of Halifax.

(Since scans from the paper are inserted below, they may not be of the best visual appearance)

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PREDICTING TROPHIC RESPONSE TO PHOSPHORUS ADDITION IN A CAPE BRETON ISLAND LAKE

JOSEPH KEREKES
Environment Canada
Canadian Wildlife Service
c/o Biology Department
Dalhousie University
Halifax, N.S. B3H 4J1

Freshwater Lake in Cape Breton Island is characterized by clear water (2-8 Hazen u), and high water temperature (10-12°C) and low oxygen levels (0-20% air saturation) in the hypolimnion in late summer. The lake receives ca. 27 mgP/m²/y from developments and sea spray in addition to the natural, edaphic phosphorus load of 106 mgP/m²/y. The lake is considered oligo-mesotrophic based on transparency (Secchi depth 7 m), total phosphorus (7.6 mg/m³), annual mean and peak chlorophyll (2.5 and 6.4 mg/m³, respectively), low hypolimnetic oxygen levels and relatively dense growth of macrophytes in shallow areas. A proposed development would increase the phosphorus load by ca. 5 mgP/m² during the summer which would increase the epilimnetic total phosphorus concentration to 8.6 mg/m³ and peak chlorophyll to 9.8 mg/m³, assuming an average lake response. These changes would place the lake into the mesotrophic category. Close to the outflow of the secondary treatment discharge, nuisance levels of algal response and macrophyte growth could be expected.

Vers la fin de l'été, le lac Freshwater, situé dans l'Île du Cap Breton, est caractérisé par une eau claire (2-8 Hazen u), une température de l'eau élevée (10-12°C) et de faibles niveaux d'oxygène (0-20% de saturation d'air) dans l'hypolimnion. Le lac reçoit environ 27 mg P/m²/ an des diverses exploitations et de l'embrun marin en plus de la charge naturelle de phosphore édaphique de 106 mg P/m²/an. Ce lac est considéré oligo-mésotrophe basé sur la transparence (profondeur du disque de Secchi 7 m), le phosphore total (7.6 mg/m³), la moyenne annuelle et le maximum de chlorophylle (2.5 et 6.4 mg/m³ respectivement), le faible taux d'oxygène de l'hypolimnion et la croissance relativement dense des macrophytes en eaux peu profondes. Une proposition d'exploitation augmenterait la charge de phosphore de 5 mg P/m² pendant l'été, ce qui aurait pour effet d'augmenter la concentration totale de phosphore de l'épilimnion à 8.6 mg/m³ et le maximum de chlorophylle à 9.8 mg/m³, en supposant une reponse moyenne pour le lac. Ces transformations placeraient le lac dans la catégorie des lacs mésotrophes. Une croissance nuisible d'algues et de macrophytes peut survenir près de la bouche d'écoulement du traitement secondaire des eaux.

Introduction

Freshwater Lake (46° 38' 40"N, 60° 23' 45" W) is the second largest lake in Cape Breton Highlands National Park and the largest boulder-beach (barachois) pond in the National Parks in Canada. Its location near the Park entrance, makes it highly visible and it is used for swimming. This necessitates that the lake and its catchment be managed to ensure its unimpaired recreational and aesthetic values.

Recently a development site on the northwest shore of the lake near the park entrance has been proposed as a preferred location for several reasons. Concerns have been raised about possible detrimental impact of the facility on the lake, which is already showing some signs of man-made eutrophication, unlike the other pristine, oligotrophic lakes nearby.

The freshwaters of Cape Breton Highlands National Park were surveyed during 1976 and 1977 and the information thus obtained was used in combination with some of the findings (Vollenweider & Kerekes 1980) of the Organization for Economic Co-operation and Development (OECD) Cooperative Programme on Monitoring of Inland Waters (Eutrophication Control) to evaluate the possible impact of phosphorus addition on Freshwater Lake which might result from the proposed facility.

Methods

Sampling procedures and methods of measurements are given in detail by Kerekes et al. (1978).

Water temperature, dissolved oxygen, hydrogen ion concentration and specific conductance (low-range probe) were measured in situ using a Hydrolab Surveyor II instrument equipped with a 20 m cable. Chlorophyll-a and phaeophytin were determined by the fluorometric method of Yentch and Menzel (1963) as modified by Holm-Hansen et al. (1965). Total phosphorus was determined on unfiltered duplicate samples, digested with potassium persulfate (Menzel & Corwin, 1965). The phosphate thus produced was then estimated, along with inorganic phosphate originally present in the sample, by the method of Murphy and Riley (1962).

Annual total phosphorus loading and annual mean total phosphorus inflow concentration were estimated from lake concentration using the formula and its derivations developed by Vollenweider (1976).

$$(L(P)/q_s)/(1 + \sqrt{T(w)}) = [\bar{P}]_i/(1 + T(w))$$

$$[\bar{P}]_i = [\bar{P}]_\lambda \cdot (1 + \sqrt{T(w)});$$

$$L(P) = [\bar{P}]_i \cdot q_s$$

where L(P) = specific loading of total phosphorus per unit lake surface area ($mg\ P/m^2/y$)

$[\bar{P}]_i$ = average annual inflow concentration of total phosphorus ($mg\ P/m^3$)

$[\bar{P}]_\lambda$ = average annual concentration of total phosphorus in the lake ($mg\ P/m^3$)

T(w) = water residence time (y)

q_s = hydraulic load (m/y).

The validity of the estimated annual mean inflow concentration of total phosphorus (13.7 $mg\ P/m^3$) was checked by examining the available total phophorus concentration measurements taken once a month between April, 1976 and March, 1977 in one of the major inflow streams. The annual mean total phosphorus concentration of the inflow was found to be 9.5 $mg\ P/m^3$ ((range 4.8 to 15.0 $mg\ P/m^3$) monthly values). Occasional measurements taken in a minor inflow stream gave similar results.

Mean chlorophyll-a and peak chlorophyll-a concentrations were predicted from lake total phosphorus concentrations using the formulae developed by Vollenweider and Kerekes (1981):

$$[\overline{Chl}] = 0.28\,[\bar{P}]_\lambda^{0.96}$$

$$[Chl]^{max} = 0.64\,[\bar{P}]_\lambda^{1.05}$$

where $[\overline{Chl}]$ = average annual concentration of chlorophyll-a in the euphotic zone (mg/m^3)

$[Chl]^{max}$ = annual peak concentration of chlorophyll-a in the euphotic zone.

Description of Freshwater Lake

Freshwater Lake (Fig 1, Table I) is a barachois pond separated from the sea by a pebble barrier which forms Ingonish Beach. A public beach is located at the northeast corner of the lake. The National Park Headquarters and staff residences are on the northwest side. Residential and commercial developments (part of the village of Ingonish Beach) and various roads on the drainage basin, all lie close to the lake. Beyond this area of development around the lake, the drainage basin is covered by white spruce, maple and balsam fir forest, underneath which lies compacted glacial till. Approximately 60% of the lake volume lies below MSL.

There is some evidence from specific conductance measurements that a small influx of saline water occurs during the winter (Fig 2), but in the spring and fall it mixes with the overlying water.

After spring breakup and a brief isothermal period, a layer of cold, dense, oxygen-poor water remained below 15 m depth, while water in the lake above it circulated freely (Fig 3). The epilimnion reached temperatures over 22°C while the hypolimnion was between 10-12°C. The volume of the hypolimnion decreased from 13% of the total lake volume in June (depth >10m) to 5% in September (>13m). During autumn mixing, the water gradually cooled off to around 1°C before freezing and warmed somewhat under ice by late March. Because long, windy, cool springs and autumns lead to long mixing periods, such relatively high hypolimnetic and cold under-ice temperatures are common in lakes in Atlantic Canada.

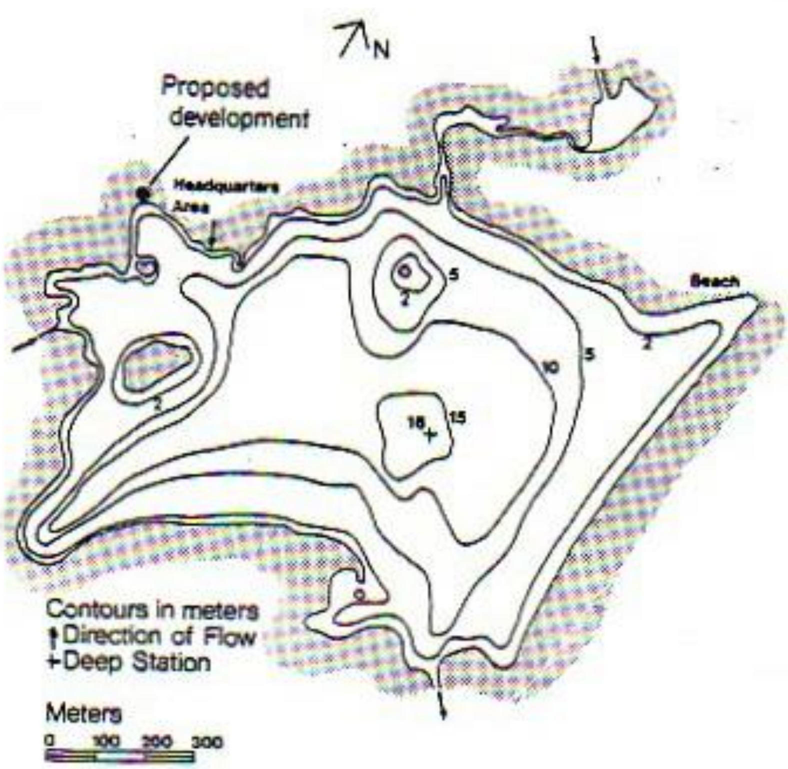

Fig 1. Bathymetric map of Freshwater Lake, Cape Breton Highlands National Park, Nova Scotia.

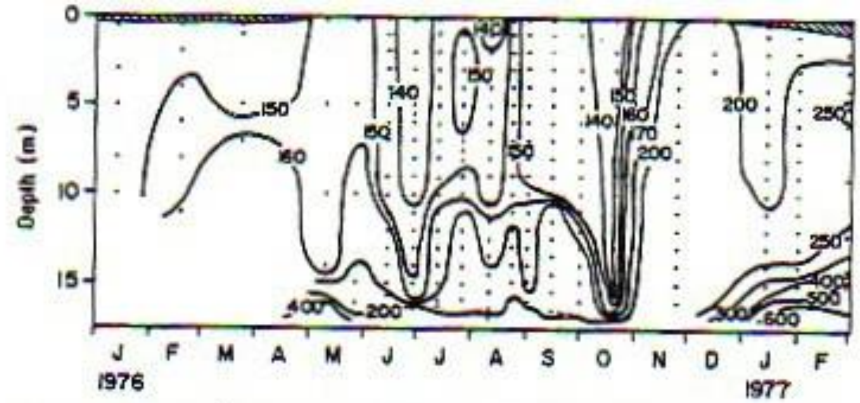

Fig 2. Isopleths of specific conductance µhmos/cm in Freshwater Lake. Dots in panel indicate depths of measurements on which the graph is based. Ice cover shown to scale.

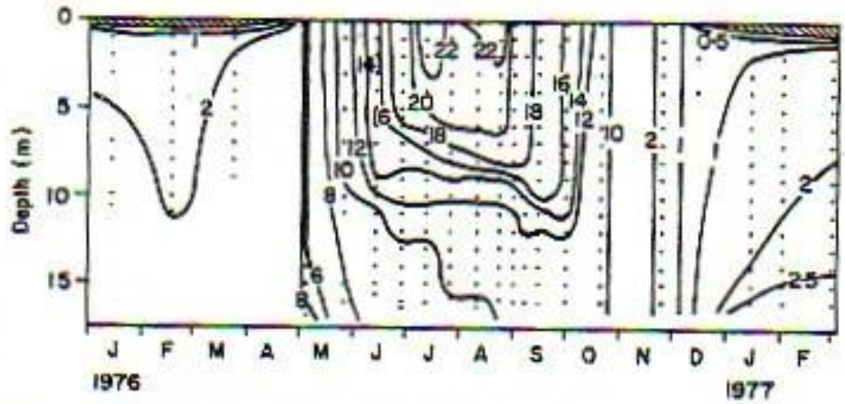

Fig 3. Isotherms °C of Freshwater Lake. See Fig. 2.

Dissolved oxygen concentrations in the euphotic zone were high throughout the study period, often exceeding air saturation (Fig 4). Hypolimnetic oxygen levels declined steadily throughout the summer and almost disappeared by mid-September. They remained above 50% air saturation during winter in all but the bottom meter of water.

The clarity of water in terms of both colour and turbidity, allowed the euphotic zone to extend to a maximum of 12 m depth with an ice-free seasonal mean of slightly over 11 m (Kerekes et al. 1981). Thus the tropholytic zone was restricted to the lower hypolimnion.

Table I. Selected morphometric and chemical features of Freshwater Lake, Cape Breton Highlands National Park, Nova Scotia.

Lake Surface, A_o 0.422 km²; Drainage Area, A_d 3.4 km²

Mean Depth, 6.49m; Max Depth, 16.3m; Cryptodepression Depth, 13.3m

**Water Residence Time, T(w) 0.67y; Water Surplus (runoff), ws 1.2m

Hydraulic load, q_s 9.69 m/y

*pH (range) 7.1 - 7.6; *Colour, 2 - 8 Hazen u

*Specific Conductance, 138 - 200 μmhos/cm, $\bar{x}$ = 164 μmhos/cm

*Secchi depth, 4.6 - 9.3m, $\bar{x}$ = 6.98m

Cations (mg/l)	Anions (mg/l)	(August 10, 1976)
Ca^{++} 11.0	HCO_3^- 15.1	SiO_2 0.2 mg/l
Mg^{++} 1.8	$SO_4^{=}$ 18.1	
Na^+ 19.5	Cl^- 28.0	
K^+ 0.7		

*Surface, ice-free period in 1976.
**T(w) = z/q_s
***q^s = z/T(w) or $1_y/A_o$ where Q_y = A_d · ws

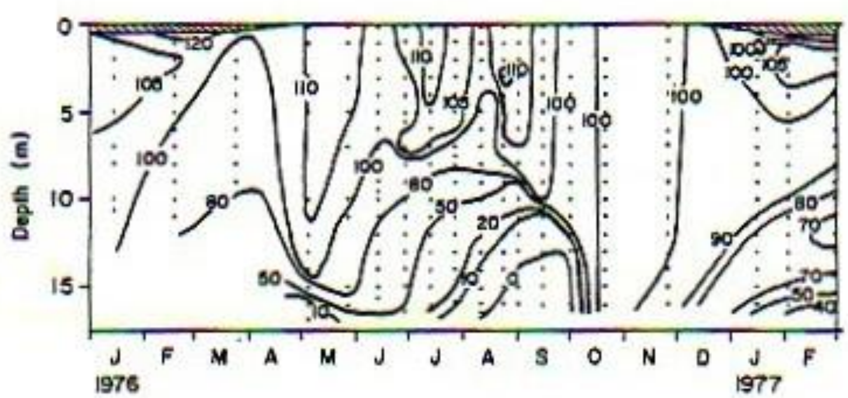

Fig 4. Isopleths of dissolved oxygen as air saturation in Freshwater Lake, January, 1976 - March, 1977. See Fig. 2.

The influx of some sea water either as salt spray or directly through the outlet stream during storms affects the water chemistry of the lake. Na^+ and Cl^- are the dominant ions and the specific conductance (Table I) is much higher than in the other lakes in the Park, with the exception of two ponds also located close to the sea. Winter salting of the highway in the lake's catchment also contributes to the

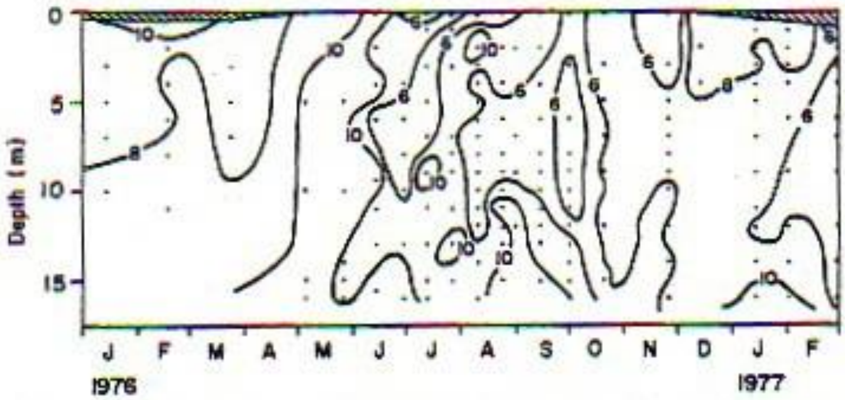

Fig 5. Isopleths of total phosphorus concentration (mg P/m^3) in Freshwater Lake. See Fig. 2.

high conductance. Specific conductance of 470 µmhos/cm was measured in one of the inflows in early March, 1976. Specific conductance through the water column increased considerably during the fall and remained high through the winter of 1976, higher than in the previous year (Fig 2). The winter influx of some sea water into the deepest part of the lake gave a specific conductance near the bottom of 680 µmhos/cm by March, 1976.

Total phosphorus concentrations were the highest after breakup in May (Fig 5). The mean annual total phosphorus concentration in the lake (7.6 mg P/m^3) is higher than in other Park lakes which were deep enough to stratify, including two pristine lakes (6.0 mg P/m^3) located approximately 5 km from Freshwater Lake. The somewhat elevated phosphorus concentration is presumably the result of human activity on the drainage basin and of the seawater influx into the lake. Total phosphorus concentrations remained low, about 10 mg P/m^3, in the deeper part of the lake at the end of the summer and during winter stagnation periods.

Mean total phosphorus concentrations in the mixed layer exhibited seasonal trends strikingly similar to that of chlorophyll-a concentration and turbidity (Fig 6). A spring peak of chlorophyll-a appeared in May, throughout the water column (Fig 7). During periods of thermal stratification the highest chlorophyll-a concentrations were found near 1% surface light intensity, i.e., at depths 10 m or greater, or 4 to 5 m under the ice. This condition has been described by Kerekes (1974, 1976) in Atlantic Canada and by Fee (1976) in northwestern Ontario.

Freshwater Lake exhibits annual mean and peak chlorophyll-a levels in relation to total phosphorus concentration that are higher than the "average" described by Vollenwinder and Kerekes (1980). Kerekes (1980) and Janus and Vollenweider (1981) showed among 18 lakes in Atlantic Canada that Freshwater Lake, along with two other clear-water lakes receiving anthropogenic phosphorus, had higher than average chlorophyll-a response to total phosphorus (above the OECD relationship), while the 15 pristine lakes, free from direct human influence, all show average or below average chlorophyll-a response to total phosphorus (Fig 8).

The number of phytoplankton cells/*l* in an integrated sample from Freshwater Lake (29 June, 1976) was 2.05 x 10^5. The most common species present was the xanthophyte *Chlorochromonas minuta* (9.77 x 10^4 cells/1), a species which con-

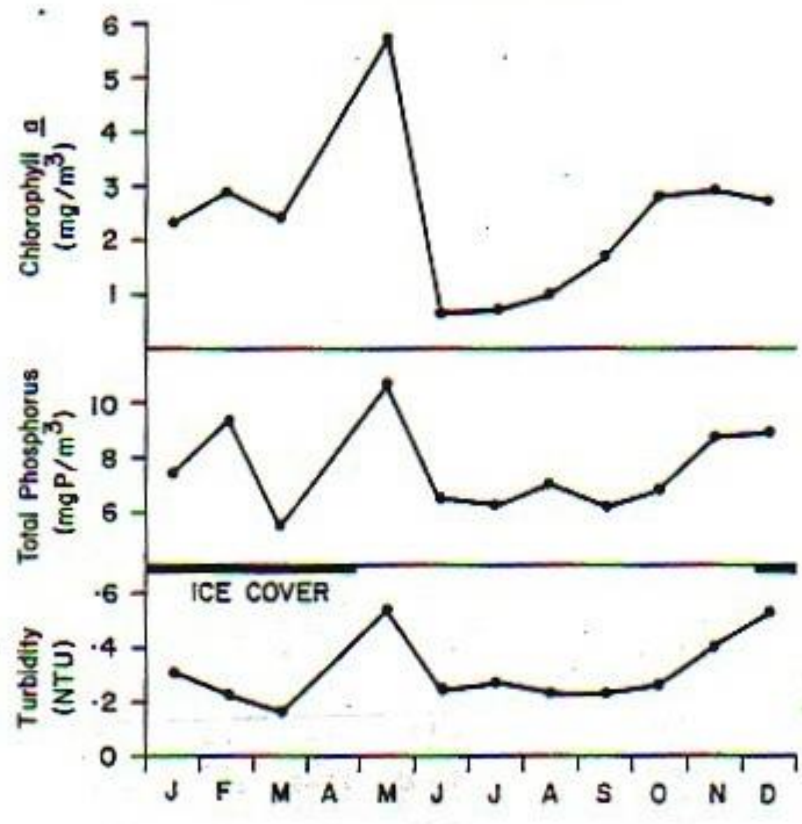

Fig 6. Mean monthly values of turbidity, total phosphorus and chlorophyll-a in Freshwater Lake, in 1976.

tributes to the spring phytoplankton bloom in Lake Mendota (Hutchinson 1967) and may well be responsible for a large part of the high spring chlorophyll-a concentration in Freshwater Lake. Two of the common diatoms, *Cyclotella meneghiniena* (4.31 x 10^4 cells/1) and *Synedra delicatissima* (2.27 x 10^5 cells/1), are also known to contribute to spring phytoplankton blooms.

The lake also supports dense growth of submergent aquatic vegetation at the western end in small sheltered embayments with mud bottoms. Twenty-two aquatic plant species were recorded in Freshwater Lake on August, 1976, including *Chara globularis*, five species of *Potamogeton* and two species of *Myriophyllum* (Davis and Wilson 1979).

The trophic characteristics of Freshwater Lake indicate that the lake is in transition between an oligotrophic and a mesotrophic state. According to the "fixed boundary system" for trophic categories developed in the OECD Eutrophication

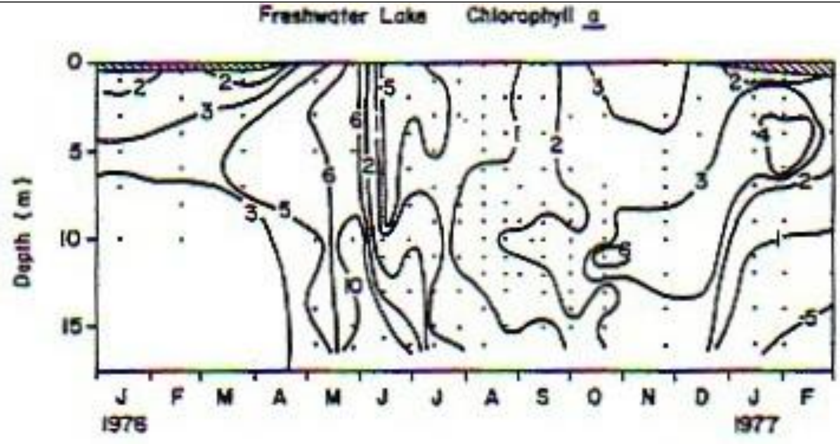

Fig 7. Isopleth of chlorophyll-a concentration (mg Chl/m³) in Freshwater Lake. See Fig. 2.

Table II. Proposed boundary values for trophic categories (fixed boundary system) based on total phosphorus, chlorophyll-a concentrations and Secchi disc transparency. After Vollenweider and Kerekes (1981).

Trophic Category	Variable (mg/m³)			Secchi depth (m)	
	$[\bar{P}]_\lambda$	$[\bar{Chl}]$	$[\overset{max}{Chl}]$	$[\bar{Sec}]_Y$	$[\overset{min}{Sec}]_Y$
ultra-oligotrophic	<4.0	1.0	2.5	>9.0	>6.0
oligotrophic	<10.0	2.5	8.0	>6.0	>3.0
mesotrophic	10—35	2.5—8	8—25	6—3	3—1.5
eutrophic	25—100	8—25	25—75	3—1.5	1.5—0.7
hypertrophic	>100	25	75	<1.5	<0.7

Program (Table II), the lake could be considered as oligotrophic based on annual mean total phosphorus, Secchi depth and peak chlorophyll, and as oligo-mesotrophic based on annual mean chlorophyll. The hypolimnetic oxygen depletion, the relatively high abundance of several species of algae often associated with a higher trophic condition and the relatively dense growth of macrophytes all indicate a higher-than-oligotrophic condition in Freshwater Lake.

The transitional nature of Freshwater Lake between oligotrophy and mesotrophy is also reflected in trophic characteristics expressed in terms of probability, also developed in the OECD Eutrophication Programme. The total phosphorus value of 7.5 mg/m³ has an attached probability of 22% for ultra-oligotrophic, 65% for oligotrophic, 13% for mesotrophic (Fig 9). The annual mean chlorophyll (2.5 mg/m³) implies probability of 6% for ultra-oligotrophic, 50% for oligotrophic, 42% for mesotrophic and 2% for eutrophic; for peak chlorophyll (6.4 mg/m³) 58% for oligotrophic, 36% for mesotrophic, 5% for eutrophic and 1% for hypertrophic conditions.

Overall, I believe that Freshwater Lake is best classified as oligo-mesotrophic with a definite tendency toward mesotrophy. This is in sharp contrast to the clearly

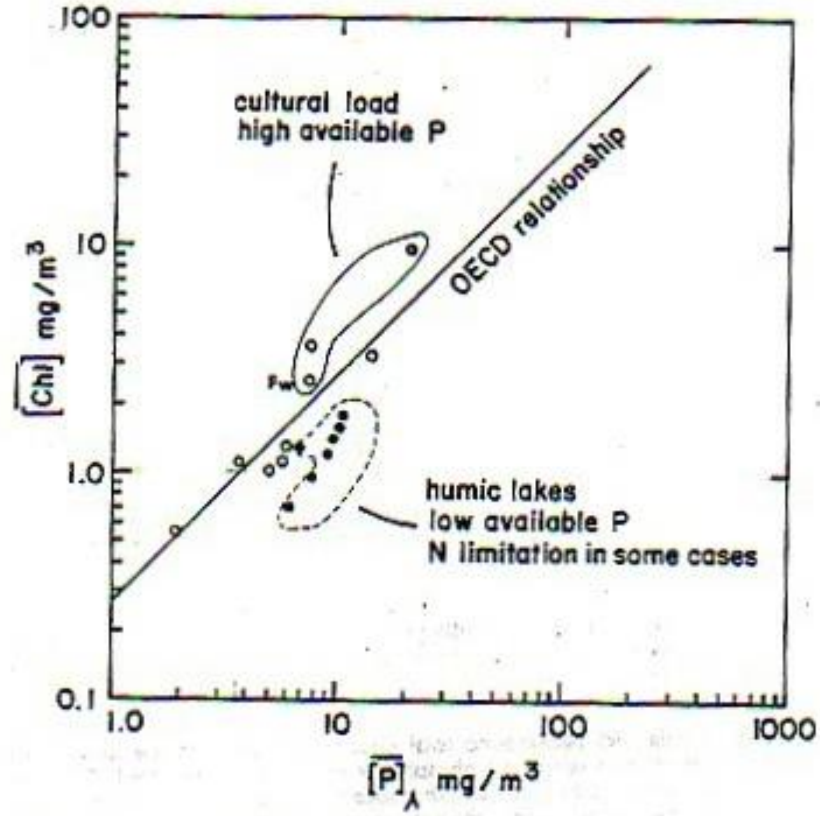

Fig 8. Annual mean chlorophyll-a in relation to annual mean total phosphorus concentration in selected lakes in the Atlantic Region of Canada. Freshwater Lake is indicated by the letters FW (after Kerekes 1980).

oligotrophic conditions found in two pristine, undisturbed lakes nearby (Kerekes et al., 1981). It is not possible (see below) to separate the additional natural phosphorus contribution (sea spray) from the anthropogenic contribution (i.e., lawn fertilizers, septic tank leakage). However, it is safe to conclude that without the anthropogenic phosphorus addition, Freshwater Lake would be closer to the oligotrophy, which is the management objective for this particular lake.

Estimation of Loads of Natural and Existing Anthropogenic Phosphorus

Considering the estimated inflow total phosphorus concentration of 13.7 mg/1, it can be assumed that without the contribution of the existing diffuse anthropogenic load and direct sea spray, the total phosphorus concentration in the lake would be about 6 mg P/m^3, like those of two undisturbed pristine lakes nearby. Using this value and the value for total phosphorus concentration in the lake, the annual

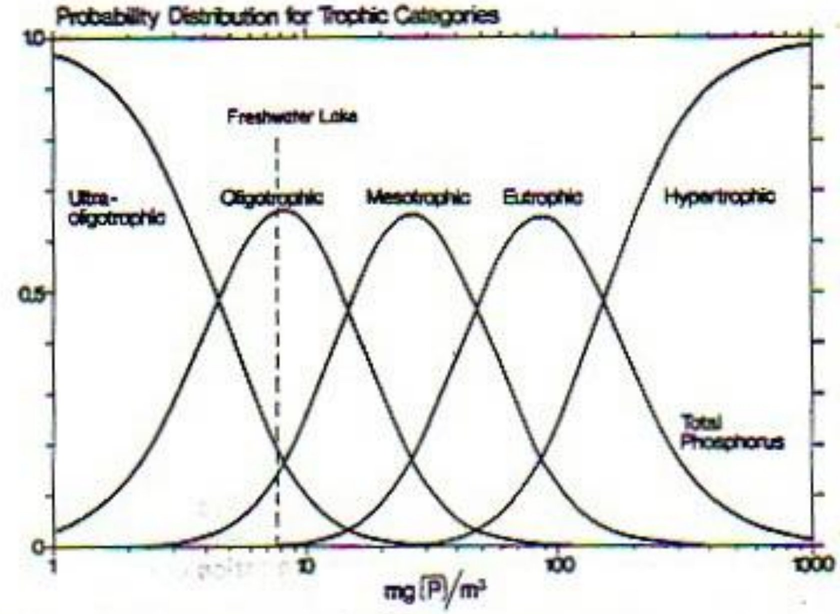

Fig 9. Predicted trophic conditions in terms of probability (5 trophic categories) for annual mean total phosphorus concentrations (after Vollenweider and Kerekes, 1981).

natural (edaphic) background total phosphorus load and the total annual anthropogenic (plus sea spray) phosphorus load can be calculated (Table III). It is reasonable to assume that the anthropogenic phosphorus is proportionately more available biologically than is the natural, phosphorus load. This may explain why the lake has a higher than average chlorophyll-a indicated previously (Fig 8).

The Estimated Impact of Phosphorus from Secondary Sewage Treatment.

The planners estimate that the proposed secondary treatment facility would yield 2.16 kg total phosphorus to Freshwater Lake. The proposed facility would only operate during summer when the lake is thermally stratified and water renewal minimal. It would therefore be misleading to consider the impact of additional total phosphorus load on an average, annual basis. Instead the expected response should be examined as it affects the epilimnion during the summer.

During summer 2.16 kg P added to the mixed layer (2.19×10^7 m^3) would increase the epilimnetic total phosphorus concentration by 1.1 mg P/m^3 (Table III). (On an average annual basis the total phosphorus concentration in the lake would increase only by 0.29 mg P/m^3). This additional phosphorus however is in a form highly available for algal growth. According to the relationship of inorganic phosphorus and total phosphorus relationship given in the OECD Eutrophication study (Vollenweider and Kerekes 1980), the 1.1 mg/m^3 of secondary-treatment phosphorus is approximately equal to 4.0 mg/m^3 of total phosphorus under phosphorus concentration levels applicable to Freshwater Lake. By substituting the

Table III. Selected trophic and hydrological features and phosphorus loading estimates of Freshwater Lake, Nova Scotia. Abbreviations are given in methods.

	Existing Conditions	Natural (edaphic) Conditions	Expected Epilimnetic Concentration After Development
$[\overline{P}]_\lambda$ mg/m³	7.5	6.0	*8.6
$[\overline{P}]_i$ mg/m³	13.7	10.9	—
L(P) mg/m²/y	132.7	105.6	—
Annual total phosphorus load kg/y	56.0	44.6	—
Anthropogenic total phosphorus load kg/y	**11.4	—	(13.56)
T(w) y	.67	.67	—
q_s m/y	9.69	9.69	—
$[\overline{Chl}]$ mg/m³	2.5	1.6	*3.8
$[\overline{Chl}]^{max}$ mg/m³	6.4	4.2	*9.8

*summer epilimnetic value
**includes sea spray

latter value to the phosphorus-chlorophyll-a relationships (Vollenweider and Kerekes 1980), the expected increase in chlorophyll and peak chlorophyll would be 1.3 and 3.5 mg/m³ respectively (Table III).

These estimated chlorophyll values would put the lake into mesotrophic category. This is based on the assumption that the lake would respond "normally" without a shift in algal (chlorophyll) response.

The foregoing discussion would apply for the lake as a whole. Close to the outflow of the secondary treatment discharge in a relatively well sheltered, shallow part of the lake, a more dense, nuisance-type algal response and macrophyte growth could be expected.

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