Hutchinson
2002

HANDBOOK OF WATER SENSITIVE PLANNING and DESIGN

Edited by
Robert L. France, B.Sc., M.Sc., Ph.D.
Associate Professor of Landscape Ecology
Science Director of the
Center for Technology and Environment (CTE)
Graduate School of Design
Harvard University
Cambridge, Massachusetts

LEWIS PUBLISHERS
A CRC Press Company
Boca Raton London New York Washington, D.C.

chapter II.17

Limnology, plumbing and planning: Evaluation of nutrient-based limits to shoreline development in Precambrian Shield watersheds

Neil J. Hutchinson

Abstract

The concept of using water quality as a planning tool for recreational lakes has been in active practice in Ontario and parts of the United States for approximately 25 years. In practice, assumptions regarding anthropogenic loadings of phosphorus to a watershed (generally septic systems servicing shoreline development) are linked to estimates of natural phosphorus loading. The resultant model estimates total phosphorus concentration and the response of trophic status indicators such as water clarity and dissolved oxygen in specific lakes. Linking the model to a water quality objective allows planners to set capacities for anthropogenic phosphorus loads, and hence shoreline development such as cottages, resorts, or permanent homes. This chapter presents an example of how the concept can be applied in practice, based on the application of the author's experience to a test watershed in south-central Ontario. Practical examples are given to show the development and calibration of accurate trophic status models, the use of monitoring data to set ecologically valid water quality objectives and their translation into shoreline development capacities, and to show the strengths and weaknesses of the approach.

The availability of a scientifically based water quality model has overemphasized water quality as a planning tool and generated unrealistic expectations of a single-capacity determinant among the public. Recent advances in our understanding of the geochemistry of domestic septic systems indicates that less phosphorus may be mobile than was previously assumed. In addition, as alternative septic technologies for phosphorus abatement are developed a refocusing of capacity determinants will be required. A combination of land-use regulations and a scientifically based management program is recommended as an alternative to a single, phosphorus-focused approach. These could address stresses to the ecology of the riparian and littoral zones and acknowledge the importance of social determinants such as noise, crowding, powerboats, and the wilderness aesthetic. This would promote a diversity of planning approaches, shift the existing focus away from plumbing and septic systems, and provide a more holistic management program which protected more components of the lake system.

1-56670-562-2/02/$0.00+$1.50

1. An annual spring overturn measurement of total phosphorus for comparison with water quality predictions made by the model
2. Biweekly measurements of Secchi depth during the summer to track long-term changes in water clarity, the recreational attribute that forms the basis of the water quality program
3. An annual measurement of the dissolved oxygen profiles made at the end of summer, when oxygen stress is most likely, to determine the oxygen status of lakes for model input, to establish the suitability of aquatic habitat, and to track long-term changes

The results of the monitoring program can be used to calibrate the water quality model and to identify those lakes for which the model does not produce accurate estimates of trophic status.

Model calibration

The primary requirement for a water quality model, once accuracy has been demonstrated, is that it be based on a solid mechanistic understanding of watershed and lake dynamics. A purely empirical approach, in which understanding and technical substantiation are ignored and the model "fit" is the only rationale for model acceptance, may not be technically defensible. The coefficients and assumptions that make up the predicted water quality must be clear and documented, as they will form the basis of challenges to the model. Clear technical rationale is also required so that all model users can understand the model and improve it in the future. Wherever possible, the water quality model should be substantiated by reference to the primary scientific literature.

The Ontario Lakeshore Capacity Study calibrated its trophic status model (Dillon et al., 1986) on research lakes that had no shoreline development. This was done in order to quantify basic lake processes in the absence of the additional uncertainty inherent in assumptions of human phosphorus loading from shoreline septic systems. While this is mechanistically sound and represents the ideal approach, it may not be practical for municipalities or other jurisdictions. Water quality programs are focussed on those lakes where shoreline development is present, because they are the lakes that require management activities such as development capacities. Uninhabited lakes are not generally monitored as part of a water quality program, posing difficulties in calibrating basic model elements such as settling velocity, natural watershed loads, or in-lake retention. These factors must be well quantified before considerations of the uncertainties in quantifying human phosphorus loadings.

Where the number of uninhabited lakes in the calibration set is not considered adequate for model development, then the calibration exercise should include lakes in which only limited shoreline development is present. A cutoff where less than 10% of the total potential load is added from shoreline development may suffice in these cases. Measurements of water quality may be available for larger numbers of these "sparsely inhabited" lakes to assist with model calibration.

Calibrating natural phosphorus sources. Consideration of two factors is recommended to improve model fit for natural phosphorus loading.

Incorporation of wetlands to describe natural phosphorus export. Recent research on south-central Ontario watersheds showed that phosphorus export from wetlands (plus atmospheric deposition) determined natural phosphorus loading to a lake. This was stated as the following estimate of phosphorus load (from Dillon and Molot, 1997):

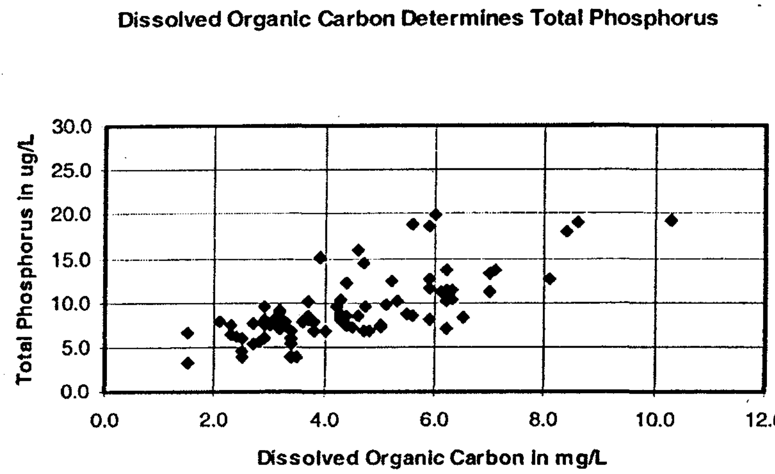
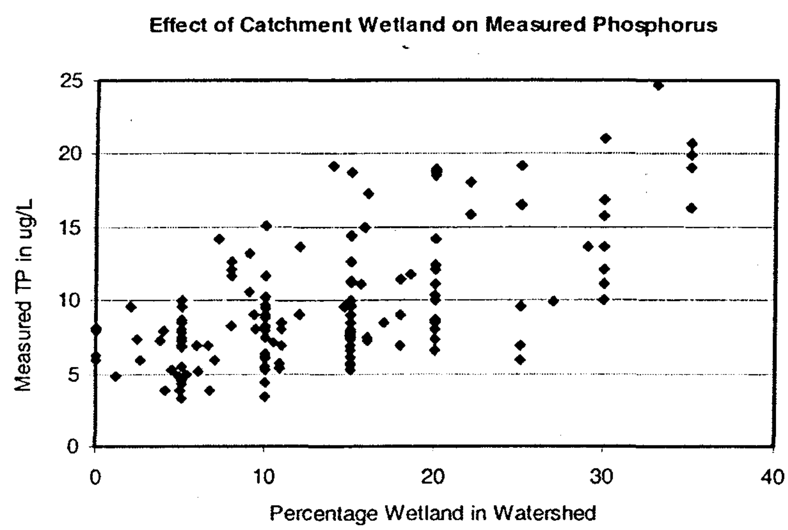


Figure II.17.3 Influence of dissolved organic carbon (DOC) on average long-term total phosphorus concentrations in Precambrian Shield lakes.



The more wetland in basin, the higher P in the lake.

Figure II.17.4 Relationship of average long-term measured phosphorus in Precambrian Shield lakes with wetland area in catchment.

$$\text{kg TP/year} = \text{catchment area (km}^2\text{)} * (3.05 + (0.54 * \%\ \text{wetland}))$$

P export to lake with various proportions of wetland in basin

This relationship is driven by the export of phosphorus with dissolved organic carbon from wetlands in the catchments of the lakes. This is shown for lakes of the Muskoka River watershed in Figure II.17.3. Total phosphorus concentrations were significantly related ($p < 0.000001$, $r^2 = 0.39$) to the amount of wetland in the catchments of lakes in the Muskoka River watershed (Figure II.17.4.). Natural phosphorus loading from all catchments containing wetland can therefore be estimated from wetland area.

Phosphorus retention in shallow lakes. Both the Dillon–Rigler and Lakeshore Capacity Study models were developed and calibrated for use in lakes that are deep enough to