LAKE STEWARDSHIP AND ENVIRONMENTAL COMMITTEE OF MCKELLAR TOWNSHIP

Agenda
THURSDAY, April 13th, 2023

Zoom Link
Jennifer Ghent-Fuller is inviting you to a scheduled Zoom meeting.

Topic: Lake Stewardship and Environmental Committee of McKellar Township
Time: Apr 13, 2023 07:30 PM Eastern Time (US and Canada)

Join Zoom Meeting
https://us02web.zoom.us/j/87167649544?pwd=THd3Lys0SkpVdlFaTUhjYlowU0ZVQT09

Meeting ID: 871 6764 9544
Passcode: 046909

Dial by your location
+1 647 374 4685 Canada
+1 647 558 0588 Canada

Item	Time	
1.		In the spirit of reconciliation and co-operation, we wish to acknowledge that the land on which we gather is the traditional territory of the Anishinaabe and Mississauga people. Its boundaries fall within the Robinson-Huron Treaty of 1850 and the Williams Treaty of 1923. We are grateful to live here and we thank all the generations of people who have taken care of this land for thousands of years. To honour the suffering of Indigenous people and the love and wisdom they have carried for thousands of years, we pledge to work in community and harmony with each other and the environment we inhabit and work towards Truth and Reconciliation.
2.		**Roll Call:** Tony Best () ; Jennifer Ghent-Fuller ( ) ; Melanie Jeffrey () ; Al Last () ; Axy Leighl () ; Carl Mitchell (on LOA); Suzanne Poff (); Nick Ryeland (); Lynda Taylor (). **We need 5 committee members to have a quorum ()** Declarations of pecuniary and/or personal interest and general nature thereof - none
3.		Motion to accept the minutes of March 9th, 2022. (attached). Moved: Seconded: Approved: () Amendments:
4. Goals		**General Updates on Current Issues.**
4.1	X	**Waterfront/ Shoreline protection –** **April 13, 2023** - Axy & Jennifer have been working on expanding the Tree Canopy Policy to include Shorelands. The first draft of this proposed policy as well as some references are attached. We need to decide how to proceed with the fine tuning and public education/familiarization with this new policy.
4.2	X	**Water Sampling –** Jennifer is making plans with MLCA to continue E. coli sampling and add in regular phosphorus sampling for about six lakes in McKellar Township in May and August (Jennifer will consult with Carl about scheduling).

		April 13 - MLCA has purchased new equipment to facilitate gathering samples from deep water and collecting data in deep water. A lab has been found in Barrie that will give results for phosphorus in mcg/L in order to compare LPP data. Samples will be taken at LPP sites simultaneously with LPP data and results compared as different sampling techniques are used.
4.3	X	**Septic Education –** concern relayed to Watersheds Canada and FOCA re: lakeside residents using too much water on a daily basis possibly causing a rapid exit to the lake with leakage of bacteria before they can be broken down and processed in the septic bed and before phosphorus can be absorbed by shoreline plants. **April 13 –** A proposed flyer on septic use has been distributed and it attached for discussion. **March 9** – the Committee agreed to the proposal that we make education on reduced water usage a priority for 2023. Provincial guidelines on septic use include the need to reduce water usage but no detail is given. **March 9th** – We agreed to print a limited number of copies of the Septic Smart booklet and have them available at the library and the Township office for new residents.
4.4		**Presentations -** YouTube videos from this committee are posted here: https://www.mckellar.ca/en/township-services/resources/Links-to-YouTube-Videos.pdf along with other videos
4.5		**Microplastics/Microfibres/ Washing Machine Filters** – video on our YouTube channel posted
4.6	X	**Earth Day / Clean Up Our Lakes –** schedule for end of April to end of May – suggestion was made to include roads and add it to the slogan – "Clean up our Lakes, Rivers and Roads" for publicity this spring. April 13th – Greg suggested that we present this to the current Council. Jennifer will make a deputation to Council on April 18th. We hope that the bin will be available about April 28th for the 4th annual Clean up our Lakes campaign and we hope to establish this as an annual event. March 9th Greg Gostic has been emailed to ask him to book the container for the transfer station and he is in favour of including roads in our publicity. The committee approved as well.
4.7		**Fishing - Draft Fisheries Management Plan Highlights Proposal Summary - Seeking Indigenous Community Feedback - October 25, 2022** received from Steve Scholten, MNRF – posted on Township web site under Environment and FB as publicity was requested – committee members agreed to review it.
4.8		**Fish Catch reporting signs for Armstrong Lake -** are up at Armstrong Lake beach.
4.9		**Catch and Release Signs** are up at township launch sites**.** Copies of the Catch and Release sign are on the back of the Safe Boating flyer and were printed for distribution by the Township with the tax mailing to all households at the end of February 2023.
4.10		**Benthic Study –** **Dec 2022** The Draft report was received from GBB. We will leave this expenditure in the budget for now and confer whether there is benefit in continuing this annual sampling at a later meeting. We should do some knowledge translation with the actual study, like what we're measuring and what it means, so that we can answer why we are doing this, what is the added value. **March 9 2023** Jennifer distributed an evaluation of the value of the 2022 Benthic report along with a suggestion that LSEC recommend to Council that this research be continued. Proviso: that the data from the Lake Manitouwabing studies be posted on an existing publicly available website at no extra charge to the township or the MLCA. We passed a resolution supporting the continuation of Benthic sampling by the GBB.

4.11		**Pesticides/Fertilizers – (**would be included in any Drinking Water Source Protection) From Oct 13/22 minutes on planning: 4. Pesticides – we will fold a discussion of pesticide use on lawns into the work/education on waterfront vegetation. Melanie and Jennifer.
4.12		**Invasive Species –** Signs are up at boat launch sites; additional signs are available from FOCA Dec 8 - Jennifer picked up 16 newer road signs for boat launches on Invasive Species from FOCA (on behalf of MLCA) – they are designed to educate people who are launching their boats about prevention of transfer of invasive species from one water body to another. We need to contact Greg Gostic again for approval and assistance to replace the existing Invasive species signs with the new ones. Al will assist with getting the new signs up and removing the old stop-sign shaped invasive species signs. **March 9** – **Motion** The LSEC will ensure that older invasive species signs at boat launches be removed and replaced them with the newer signs as well as placing signs at boat launches where there is not yet a sign about invasive species. Moved: Sue Seconded: Al Approved Flyers on Invasive species and Catch and Release and Safe Boating were distributed to all households in the Township with the tax bills at the end of February. A waterless boat cleaning system to prevent the transfer of invasive species was advertised at the FOCA AGM on March 4th. The committee agreed that we need to work with MLCA to find someone to look at the feasibility of having such a system in McKellar Township.

4.13		**Dark Skies –** From Oct 13/ minutes on planning: Sue and Jennifer will continue the work on Dark Skies.
4.14		**Water Levels –** A paper detailing previous work on water levels is posted on our section of the web page.
4.15	X	**Pollinator Patches –** **Apr 13 –** update (Sue) March 9 2023 Council approved the planting of two pollinator gardens, with a third to come after work is done on the Hemlock Church site. We will also upgrade the pollinator patch planted at the Community Centre. We will consult with Greg Gostick. Sue chose 6 pollinator plants that are native to the McKellar area and avoided those that are toxic to animals or susceptible to disease. LSEC passed a budget resolution. Dec 8 – The Township will provide us with a map of Township properties. We will need to get approval from staff on placement of pollinator patches/butterfly gardens. The David Suzuki program is interested in our work as they have no "ranger" in this area. Sue is researching Pollinator Patches and putting together a list of plants that are Suitable for our zone, and that are considered not in invasive or that could be a problem with being toxicity especially to farm animals. From Oct 13/ minutes on planning: 1. Sue, Axy and Al will work on a program of ***pollinator patches*** in the township including applying to the David Suzuki butterfly ranger program. 2. Axy will schedule a meeting of this subcommittee and complete the application to the David Suzuki foundation program. 3. Al suggested that we may be eligible for beautification grants from the Township and also from some companies such as MacDonald's who are looking for non-profit donations to make.

4.16		**ICECAP –** Nick and Tony tracking Nick plans to organize a meeting to iron out some issues about our ICECAP participation. On Feb 7 2023, a deputation from Dr. Rebecca Pollock, Executive Director of the Georgian Bay Biosphere was made to Council on behalf of the Integrated Communities Energy and Climate Action Plans (ICECAP) partnership. This is a Canada wide program for municipalities. **March 9 –** Nick spoke to Benjamin John of GBB on Feb 16 about the steps the Township of McKellar needs to take to move ahead with energy management and they have scheduled a follow up meeting. Nick and Roshan will follow up concerning the amount of money owed by McKellar Township to the GBB in relation to the ICECAP program. Nick will attend the ICECAP Stakeholder meeting on May 30th. There is practical value to the township in saving energy.
4.17		**EV Chargers –** **March 9** A review of the current need for an EV charger by committee members earlier this year (2023) by email resulted in a decision of the majority of the LSEC members not to support a proposal that Council fund the installation of an EV charger in McKellar at this time.
4.18		**Organic Waste Planning** investigate the possibility of a processing facility shared with other townships in the future
4.19		From Oct 13/22 minutes on planning: Jennifer will start to research the background on **Drinking Water Source Protection** with a view to eventually having McKellar Township included in such a program. This will likely be a multi-year project as it involves working with other townships and communities in the local watersheds and finding a Conservation Association willing to manage the program. March – Greg Gostic inquired whether we could test the water at the public tap
5.		Our **postings** (listings and a table of contents) are uploaded on the township web page under “Residents/Environment.” Jennifer has been gradually updating the page with Mary’s help. https://www.mckellar.ca/en/living-in-our-community/environment.aspx

6.		**Budget** – Our suggestions for the 2023 LSEC budget was approved by the committee members at the December LSEC meeting. It will be forwarded to Council. Attached at end.
7.		Next meeting date and time is Thursday March 9th , 7 pm on zoom We need a committee member to attend in the community centre, please. LSEC meetings will continue at 7 pm on the second Thursday of the month in 2023: ~~January 12th~~ July 13th ~~February 9th~~ August 10th ~~March 9th –~~ September 14th April 13th October 12th May11th November 9th June 8th December 14th Dec 8th Motion: To cancel January and February meetings to have a winter break. Moved: Tony, Seconded: Sue. Carried with one abstention. Project work will continue. **Next meeting May 11th.**
8.	X	**Motion to adjourn.** **Moved: Seconded: Approved?** **Time: PM**

Lake Stewardship and Environmental Committee Budget - Final Estimate for 2023

	Budget estimate 2021	Actual Expenditure 2021	Budget estimate 2022	Actual Expenditure 2022	Budget Estimate 2023
E. Coli Sampling	$ 4,248	$4800.24	$5,000.00	$ 3,616.47	$ 4,000.00
Phosphorus and calcium sampling				$ 630.00	$4,000.00
Microcystin (if there is a BGA bloom)	$265	$0	$265	$0	$ 300.00
Standardizing solutions (q2yrs)	$500	$120	$0	$0	$150
Benthic 4 sites	$4420 (MLCA pays ¼)	$3315	$4915	3 – $4915.20 Twp (1 - $2320.00 MLCA)	3 sites $ 5,260
Educational Materials	Bookmarks and flyers - $300	Bookmarks and Flyers $300	Bookmarks and flyers $500	Bookmarks and Flyers $344.65	$ 2,000
Educational Materials	Lake Protection Workbook $3000.00	Lake Protection Workbook $2,224.97		Presentations $947.50	$1,500
Educational Materials			Septic Smart Booklet $5000	Septic Smart Booklet $4418.30 + $207= $4,625.30	$ 500
Educational Materials	Catch and Release Signs and Posts $500	Catch and Release Signs and Posts $1,028.30			
			Other educational materials plus new initiatives $3,900	2 pamphlets – 2000 copies for mailing $2497.30	$2000
			Remedial Plantings $2500	0	$ 2,500.00
Sub Total			$22,080	$17,576.42	$22,210.00
PLUS GBB ICECAP	$ 8500	$8500	$8500	$ 8,000	$8,000
Grand Total			$30,580	$25,576.42	$ 30,210

Comparison of Bylaw 2019-12 (left) and proposed 2023 revision (right)

CORPORATION OF THE TOWNSHIP OF MCKELLAR BY-LAW NO. 2019-12 Being a By-law to Adopt a Tree Canopy and Natural Vegetation Policy WHEREAS Subsection 270(1) of the Municipal Act 2001 S.O. 2001, c.25, as amended, requires municipalities to adopt and maintain a policy with respect to the manner in which the municipality will protect and enhance the tree canopy and natural vegetation in the municipality by March 1, 2019; AND WHEREAS Council has deemed it expedient to formally adopt a Tree Canopy and Natural Vegetation Policy; NOW THEREFORE the Council of the Corporation of the Township of McKellar enacts as follows: 1. THAT the Township of McKellar Tree Canopy and Natural Vegetation Policy is hereby adopted as set out in Schedule “A” attached hereto and forming part of this by-law; 2. THAT this By-law shall come into force and effect on the date of final passing thereof. READ a FIRST and SECOND time this 4th day of February, 2019. Original signed by Peter Hopkins, Reeve Original signed by Tammy Wylie, Clerk _______________________________ _______________________________ Reeve Clerk READ a THIRD time and PASSED in OPEN Council this 4th day of February, 2019. Original signed by Peter Hopkins, Reeve _______________________________ Reeve Original signed by Tammy Wylie, Clerk _______________________________ Clerk	Draft Revision of BY-LAW NO. 2019-12 of the CORPORATION OF THE TOWNSHIP OF MCKELLAR Being a By-law to Adopt a Tree Canopy and Natural Vegetation *Policy with a view to shoreline preservation in order to maintain and improve water quality and wildlife habitat in McKellar Township’s lakes and rivers, and foster an appreciation of naturalized shorelines.* WHEREAS the common loon is an important ecological indicator species for a healthy lake environment and the official bird of the province of Ontario, this by-law may be known as the “Loon By-law.” WHEREAS Subsection 270(1) of the Municipal Act 2001 S.O. 2001, c.25, as amended, requires municipalities to adopt and maintain a policy with respect to the manner in which the municipality will protect and enhance the tree canopy and natural vegetation in the municipality by March 1, 2019; AND WHEREAS Council is encouraged to deem it expedient to continue and improve the Tree Canopy and Natural Vegetation Policy, By-law No. 2019-12; *AND WHEREAS healthy lakes and rivers in McKellar Township are of immeasurable benefit to all residents.* AND WHEREAS Residential development and settlement along lakeshores and nearby properties can cause changes to lake habitat structure and ecosystem function through changes in sediment distribution and stability, nutrient levels, and habitat, which in turn can lead to eutrophication, decreased water quality, and change the number of species and quantity of fish and other organisms in the littoral zone *AND WHEREAS preservation, replacement and maintenance of a naturalized shoreline buffer promotes better water quality, controls erosion and flooding, removes sediment and pollutants and provides insect and animal habitat and a healthy littoral zone, the Council of McKellar Township encourages the residents*

	to aim toward an environmental net gain on their properties to mitigate the effects of human settlement on a healthy aquatic environment NOW THEREFORE the Council of the Corporation of the Township of McKellar enacts as follows: 1. THAT this revision of the Township of McKellar Tree Canopy and Natural Vegetation Policy is hereby adopted as set out in Schedule “A” attached hereto and forming part of this by-law; 2. THAT this By-law shall come into force and effect on the date of final passing thereof. READ a FIRST and SECOND time this _____________. Original signed by Original signed by READ a THIRD time and PASSED in OPEN Council this

TREE CANOPY AND NATURAL VEGETATION POLICY BACKGROUND AND PURPOSE Section 270 (1) (7) of the Municipal Act, 2001, S.O. 2001, c.25 requires a municipality to adopt a plan which describes how to protect and enhance the tree canopy and natural vegetation. The purpose is to offer a summary understanding of local vegetation, conservation considerations and promote best practices for a sustainable tree canopy in the Township’s settlement areas as well as on it shorelines and rural residential properties	TOWNSHIP OF MCKELLAR Revision of the existing TREE CANOPY AND NATURAL VEGETATION POLICY (2019 – 12) 2023 BACKGROUND AND PURPOSE Section 270 (1) (7) of the Municipal Act, 2001, S.O. 2001, c.25 requires a municipality to adopt a plan which describes how to protect and enhance the tree canopy and natural vegetation. The purpose is to offer a summary understanding of local vegetation, conservation considerations and promote best practices for a sustainable tree canopy *and vegetative buffers* in the Township’s settlement areas as well as on its shorelines and rural residential properties.

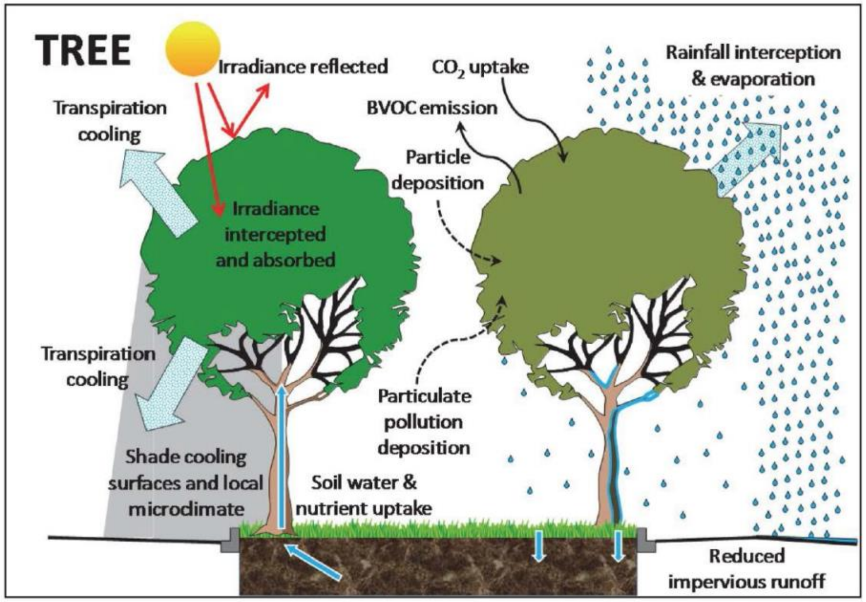
Comparison of Bylaw 2019-12 (left) and proposed 2023 revision (right)

WHO IS IT FOR? This policy applies to all properties and development, on public and private lands, in the Township of McKellar. It is a resource which can be referred to and utilized as guiding principles for residential, commercial and Township purposes	WHO IS IT FOR? This policy applies to all properties and development, on public and private lands, in the Township of McKellar. It is a resource which can be referred to and utilized as providing guiding principles for residential, commercial and Township purposes.
WHAT IS A TREE CANOPY? “Tree canopy” or “tree cover” includes all areas of coverage by plant material exceeding 1.5 metres in height, and the extent of tree canopy in excess of 10 years maturity. The canopy includes the layer of leaves, branches and stems that cover the ground when viewed from above.	WHAT IS A TREE CANOPY? “Tree canopy” or “tree cover” includes all areas of coverage by plant material exceeding 1.5 metres in height, and the extent of tree canopy in excess of 10 years maturity. The canopy includes the layer of leaves, branches and stems that cover the ground when viewed from above.

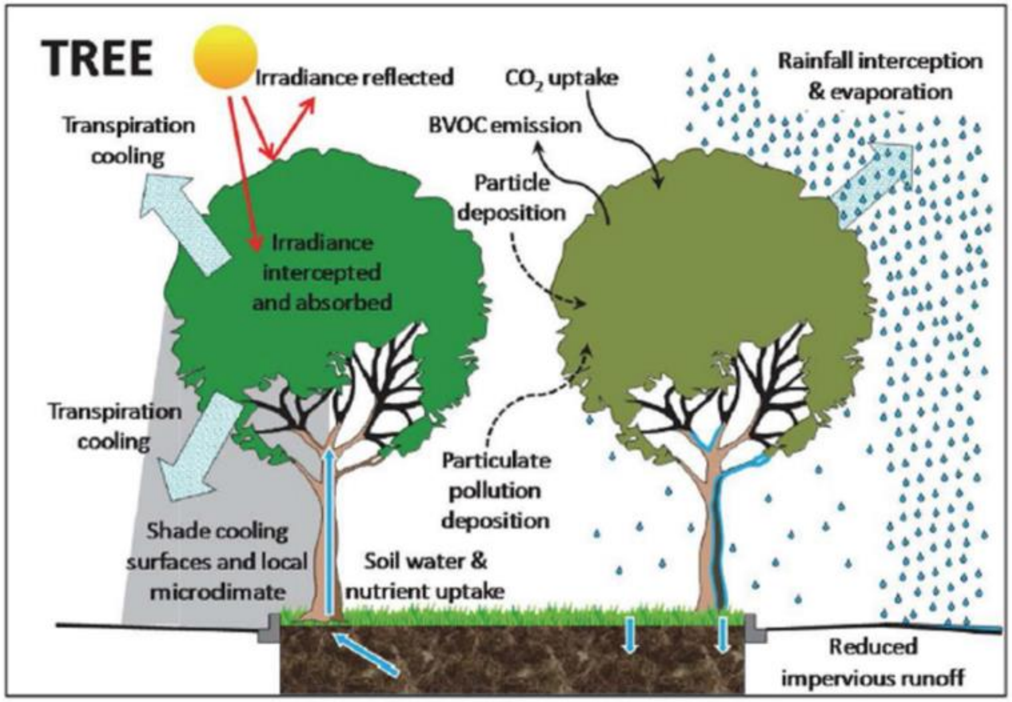
BENFITS There are several benefits to an urban tree canopy, including: • A mature urban tree canopy creates shade, which lowers energy consumption for a community. This is accomplished via the direct link of shading properties and the buildings therein; • Reduces air pollution; • Increases property value; • Provides shelter for wildlife; • Improves the usability of public parks; • Improves the aesthetics of properties; • Assists in stormwater management; and • Prevents erosion, especially along slopes	BENFITS There are several benefits to a healthy tree canopy, including: • The cooling effect of its shade, decreasing energy used for cooling and decreasing the temperature of surface water • the sequestration of carbon, thereby decreasing air pollution ; • the provision of shelter for birds and animals; • the improvement and maintenance of the aesthetics and value of properties; • the assistance in stormwater management, and retention of moisture in the soil • the prevention soil erosion, especially along slopes

Comparison of Bylaw 2019-12 (left) and proposed 2023 revision (right)

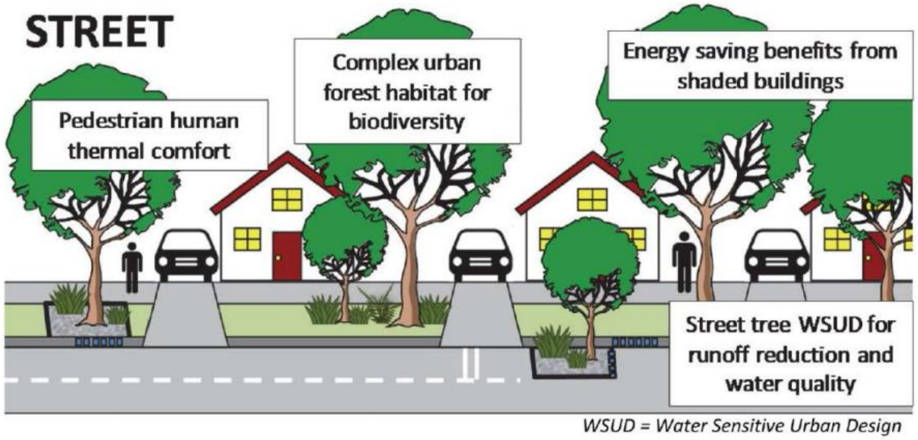
<table>
<tr>
<td>
The following from Water the Journal of Environmental Quality illustrates the above



BVOC = Biological volatile organic compounds
</td>
<td>
The following from Water the Journal of Environmental Quality illustrates the above:



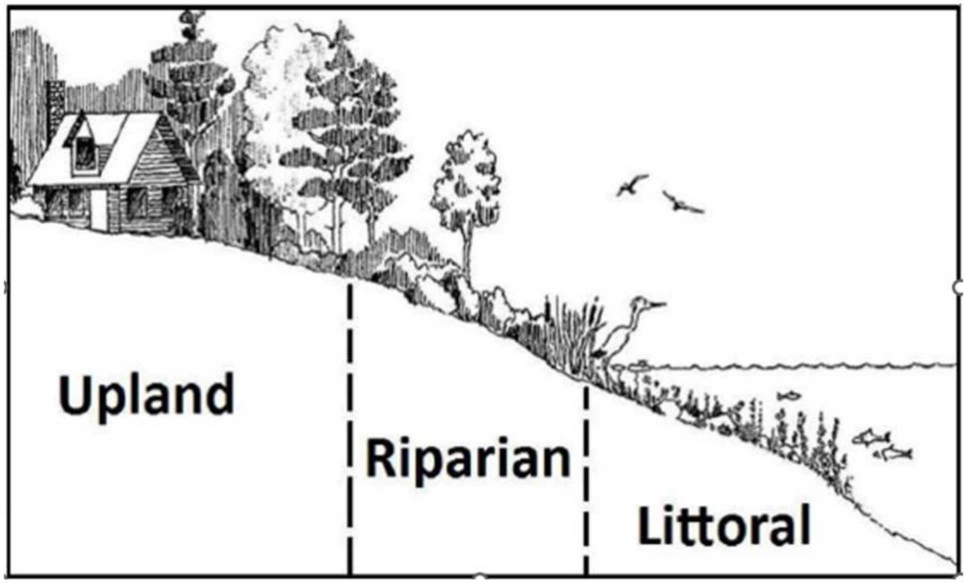
BVOC = Biological volatile organic compounds
</td>
</tr>
</table>

	
NATIVE PLANTINGS When planting any vegetation, local species/native vegetation should be utilized. Some examples of local species/native vegetation are included in Schedule "A".	*WHAT IS A VEGETATIVE BUFFER?* • Buffers may be a combination of trees, shrubs, and herbaceous or grassy vegetation • In general, maintenance and restoration of native plants in the shoreline buffer is preferred to use of non-native species, since native species are adapted to local conditions, support local biodiversity, and do not require the use of fertilizers, herbicides, and pesticides, which can degrade water quality (Muskoka Watershed Council 2013). WHY IS VEGETATION ESPECIALLY IMPORTANT NEAR SETTLED WATERWAYS? • The Lakeshore Capacity Study was coordinated by the Ministry of Municipal Affairs and Housing and published in 1986. MOE's Lakeshore Capacity Model is based on the total phosphorus concentration or trophic status of a lake. It provides an accurate and quantitative linkage between the level of shoreline development and the level of phosphorus in a lake. This output can subsequently be used to predict the impacts of development on water clarity and deepwater oxygen content. • The main human sources of phosphorus to many of Ontario's recreational inland lakes are sewage systems from houses and cottages. Clearing the shoreline of native vegetation, use of fertilizers, stormwater

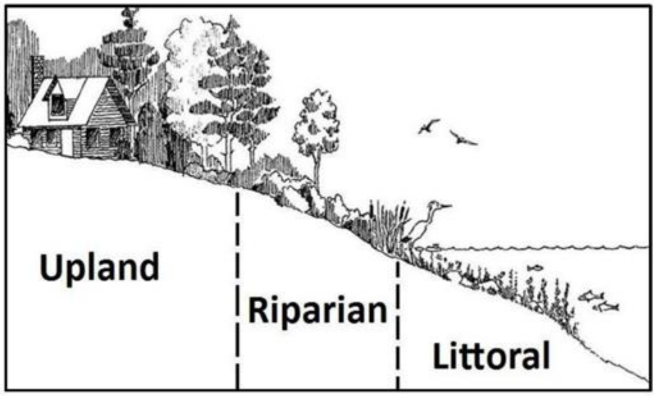
	runoff and increased soil erosion also can contribute significant amounts of phosphorus to a lake. *LCAH 26* • The building of roads and dwellings with septic systems threaten the ecological balance of the environment. Replacing vegetation that has been lost due to settlement produces environmental net gain. A buffer of vegetation is especially important to maintain between a dwelling, road or business and a lake or river. Maintenance of a naturalized shoreline will prevent excess nutrients from entering the waterways and therefore prevent the growth of toxin-producing blue-green algae to excess which results in contamination of the water supply, requiring extensive treatment before ingestion by people and animals. (Lake Capacity Assessment Handbook (LCAH) p 44) • Best management practices (BMPs) are planning, design and operational procedures that reduce the migration of phosphorus to water bodies, thereby reducing the effects of development on water quality. These BMPs apply to all lots, vacant or developed. A vegetated buffer is still considered to be a Best Management Practice (LCAH, p 18) • “Natural vegetation is better able to trap pollutants and stabilize shorelines than manicured lawn due to deeper roots. Furthermore, native vegetation does not require the use of fertilizers, herbicides and pesticides, provides improved habitat for terrestrial and aquatic species, and does not tend to attract nuisance species such as Canada Geese. Maintaining natural shorelines also provides privacy, increases property value, and contributes to the aesthetic quality of the lake environment.” (**Hutchinson** Environmental Sciences Ltd. (2021) Natural Shorelines and their Role in the Protection of Water Quality and Aquatic Habitat State of the Science Report, p. 5) • A setback is a minimum distance from the waterway, to minimize the negative effects of human settlement and enterprise on the surface waters. A buffer can be maintained and/or replaced within that setback distance to maintain the viability and health of the aquatic ecosystem.

	• Lakeshore capacity assessment is based on controlling the amount of one key pollutant — phosphorus — entering a lake by controlling shoreline development. Phosphorus is a nutrient that affects the growth of algae and aquatic plants. Excessive phosphorus can lead to excessive algal and plant growth, which in turn leads to unsightly algal blooms, the depletion of dissolved oxygen and the loss of habitat for cold-water fish such as lake trout — a process known as eutrophication. The maintenance of shoreline vegetation, installing vegetative buffers and minimizing the amount of exposed soil helps to reduce phosphorus loading (LCAH p21) • A buffer of less than 5-10 m between the shoreline and a dwelling with a septic sewage system is insufficient for protecting the natural physical, chemical, and biological characteristics of adjacent aquatic features. A minimum 15-30 m buffer [is] recommended, with the lower end of the range identified as the minimum size necessary to maintain physical and chemical functions, and the upper end of the range identified as the minimum necessary to maintain biological functions (Hutchinson p15) • Avoid tidying the shore (e.g., removing of woody debris, terrestrial or aquatic vegetation). Plants, woody debris such as fallen trees and branches, and overhanging vegetation should be maintained along the shoreline in the littoral zone to provide habitat and to prevent a rise in the water temperature.

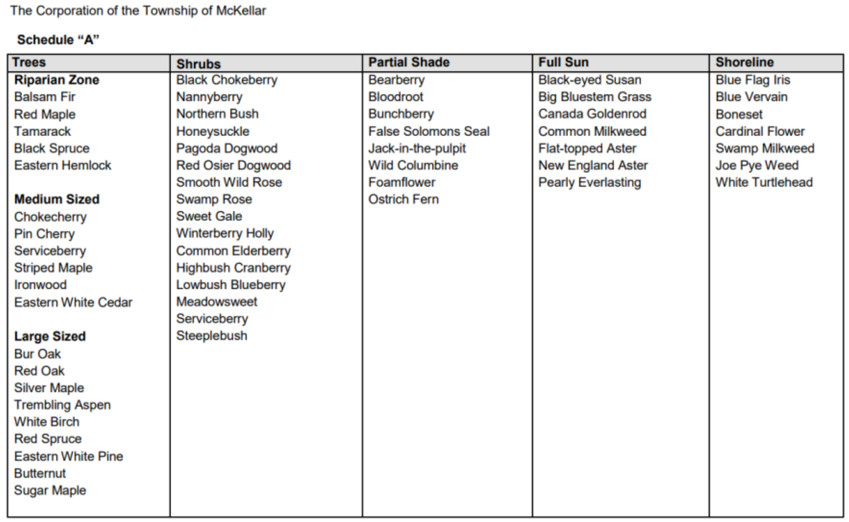
Comparison of Bylaw 2019-12 (left) and proposed 2023 revision (right)

	The types of vegetation by zone are illustrated below:  Courtesy of the Muskoka Watershed Council 2013 A healthy Riparian zone significantly mitigates the impact of human activity in the Upland zone, bolstering the health of the Littoral zone, which is vital to the overall health of the lakes and rivers of McKellar Township.
WHERE TO PLANT Consideration should be given to where trees and vegetation are planted. Prior to planting a tree, property lines, utilities (power lines, buried water/sewer laterals or other 'hard' infrastructure) should be considered. The location of a tree should take into context its future size as it relates to a building's foundation and roof.	A healthy Riparian zone significantly mitigates the impact of human activity in the Upland zone, bolstering the health of the Littoral zone, which is vital to the overall health of the lakes and rivers of McKellar Township. • NATIVE PLANTINGS When planting any vegetation, local species/native vegetation should be utilized. Some examples of local species/native vegetation are included in Schedule "A". • 75% of the shoreline, and 75% of the area of the property (including buildings) should be maintained in a naturalized state • Pathways should be curved, and made of pervious material such as gravel, in order to impede the flow of rain water run off into the lake (water movement below the surface tends to be slower than surface flow, creating more time for plants to take up the nutrient. (Hutchinson, p 17)

	• Setback for septic system beds should be _____________, and for the health of the septic system, only grass and other short-rooted vegetation such as clover should be planted on top. • For new builds, The dwelling should be between the septic system and the waterway. • Regular inspection and maintenance of the septic tank and drainage bed should be carried out by all property owners. Water use should be reduced in comparison to the use of a municipal sewage system and water use should be spaced throughout the day and the week. • Avoid shoreline hardening.
SHORELINE VEGETATION Vegetated areas adjacent to watercourses, lakes, rivers and wetlands are known as shoreline buffers. Shoreline buffers protect water from pollutants by filtering contaminants, providing habitat for native species and preventing shoreline erosion. Shoreline buffers should be: • At least 20 metres upland from the shore or greater as recommended by the Ministry of Natural Resources and Forestry. • Be composed of natural vegetation with a broad corridor of undisturbed vegetation. • Not be grassed. • Avoid shoreline hardening.	In regard to insects: • Avoid the use of pesticides. Land-based insects are a major source of food for fish in the waterways. • Leave leaf litter on the ground in the fall and clean up in the spring after the temperature has stayed above 5 ° C for three or four days to support the survival of insects through the winter • Plant native species that are a source of food for pollinating insects • Keep leaf litter and bushes clear of pathways to decrease the opportunity for deer ticks to “quest” from nearby bushes.

The types of vegetation by zone are illustrated below.  Courtesy of the Muskoka Watershed Council 2013	
MAINTENANCE AND PRESERVATION Trees and vegetation require special care and treatment. If it appears the vegetation is struggling, it is recommended you speak to a professional. COMMERCIAL / INDUSTRIAL USES In addition to this policy applying to single detached homes and smaller residential uses, it can also provide guidance to commercial/multiple residential developments. In addition to the benefits listed previously, increased vegetative buffers help beautify commercial properties and match the natural beauty of the Township of McKellar. Other benefits that can be considered: • Green parking lots to reduce stormwater flows and the costs of stormwater maintenance. • Vegetated aisles and parking islands to increase shaded areas and reduce micro climates. • Green roofs to reduce total stormwater runoff and enhance the urban canopy. DISCLAIMER This policy does not take priority over any By-laws, Resolutions or Agreements of the Township of McKellar Council.	

Comparison of Bylaw 2019-12 (left) and proposed 2023 revision (right)



The Corporation of the Township of McKellar

Schedule "A"

Trees	Shrubs	Partial Shade	Full Sun	Shoreline
Riparian Zone Balsam Fir Red Maple Tamarack Black Spruce Eastern Hemlock **Medium Sized** Chokecherry Pin Cherry Serviceberry Striped Maple Ironwood Eastern White Cedar **Large Sized** Bur Oak Red Oak Silver Maple Trembling Aspen White Birch Red Spruce Eastern White Pine Butternut Sugar Maple	Black Chokeberry Nannyberry Northern Bush Honeysuckle Pagoda Dogwood Red Osier Dogwood Smooth Wild Rose Swamp Rose Sweet Gale Winterberry Holly Common Elderberry Highbush Cranberry Lowbush Blueberry Meadowsweet Serviceberry Steeplebush	Bearberry Bloodroot Bunchberry False Solomons Seal Jack-in-the-pulpit Wild Columbine Foamflower Ostrich Fern	Black-eyed Susan Big Bluestem Grass Canada Goldenrod Common Milkweed Flat-topped Aster New England Aster Pearly Everlasting	Blue Flag Iris Blue Vervain Boneset Cardinal Flower Swamp Milkweed Joe Pye Weed White Turtlehead

Schedule "A" 2023

Trees	Shrubs	Partial Shade	Full Sun	Shoreline
Riparian Zone Balsam Fir Red Maple Tamarack / Larch Black Spruce Eastern Hemlock **Medium Sized** Chokecherry Pin Cherry Service Berry Striped Maple Ironwood Eastern White Cedar **Large Sized** Bur Oak Red Oak Silver Maple Trembling Aspen White Birch Red Spruce Eastern White Pine Butternut Sugar Maple	Black Chokecherry Nannyberry Northern Bush Honeysuckle Pagoda Dogwood Red Osier Dogwood Smooth Wild Rose Swamp Rose Sweet Gale Winterberry Holly Common Elderberry Lowbush Blueberry Meadowsweet Serviceberry Steeplebush	Bearberry Bloodroot Bunchberry False Solomon's Seal Jack in the Pulpit Wild Columbine Foamflower Ostrich Fern	Black-eyed Susan Big Bluestem Grass Canada Goldenrod Butterfly weed Flat-topped Aster New England Aster Pearly Everlasting	Blue Flag Iris Blue Vervain Boneset Cardinal Flower Swamp Milkweed Joe Pye Weed White Turtlehead

Notwithstanding the information provided above, residents whose properties are adjacent to forested areas are encouraged to consult the information at Firesmart Canada for guidelines on mitigating the possibility of their dwelling being involved in an adjacent forest fire by carefully choosing the plants that are immediately adjacent to the house. Notably plants in these areas should be those that show more fire resistance, such as: deciduous trees and shrubs, plants that retain water well, have low fuel volume, are low growing and non-resinous ground cover of succulents. Pathways and driveways should be composed of permeable gravel, rather than bark or wood chips in these areas.

Hutchinson

Environmental Sciences Ltd.

Natural Shorelines and their Role in the Protection of Water Quality and Aquatic Habitat

State of the Science Report

Prepared for: County of Haliburton
Job #: J210039

August 18, 2021

1-5 Chancery Lane, Bracebridge ON P1L 2E3 | 705-645-0021
202-501 Krug Street, Kitchener ON N2B 1L3 | 519-576-1711

Hutchinson
Environmental Sciences Ltd.

1-5 Chancery Lane, Bracebridge, ON P1L 2E3 | 705-645-0021
202-501 Krug Street, Kitchener, ON N2B 1L3 | 519-576-1711

www.environmentalsciences.ca

August 18, 2021 HESL Job #: J210039

Mike Rutter
Chief Administrative Officer
County of Haliburton
Box 399 Minden, Ontario
K0M 2K0

Dear Mr. Rutter:

Re: Natural Shorelines and their Role in the Protection of Water Quality and Aquatic Habitat – State of the Science Report

We are pleased to submit the *State of the Science Report* for the *Natural Shorelines and their Role in the Protection of Water Quality and Aquatic Habitat* project. The State of the Science Report addresses the first component of our Shoreline Preservation Review and Consultation. This report summarizes a literature review of current science and Best Management Practices related to shoreline protection. The information contained herein will be used in combination with the jurisdictional review and stakeholder consultation to develop a Shoreline Preservation By-law that balances environmental stewardship and public best interests.

Sincerely,
Per. Hutchinson Environmental Sciences Ltd.

Andrea Smith

Andrea Smith, Ph.D.
Senior Scientist

Signatures

Report Prepared by:

Brent Parsons, M.Sc.
Senior Aquatic Scientist

Andrea Smith, Ph.D.
Senior Scientist

Neil J Hutchinson

Neil Hutchinson, Ph.D.
Founder and Senior Scientist

Executive Summary

The County of Haliburton has identified shoreline protection as a key policy area and aims to develop a county-wide Shoreline Preservation By-law. The County hired Hutchinson Environmental Sciences Ltd. (HESL) and J. L. Richards & Associates Ltd. (JLR) to guide the development of the Shoreline Preservation By-law. The State of the Science Report addresses the first component of our Shoreline Preservation Review and Consultation. The information contained herein will be used in combination with the jurisdictional review and stakeholder consultation to develop a Shoreline Preservation By-law that balances environmental stewardship and public best interests.

Shorelines link terrestrial and aquatic ecosystems, acting as a transition zone between land and water. They are biological hotspots and highly productive habitats that provide a myriad of ecological services, including maintenance of water quality, flood protection, and wildlife habitat Shorelines are also attractive locations for human settlement, offering access to lakes and rivers for recreation, nature appreciation, sustenance, cultural traditions, and spirituality. Residential development is often concentrated around shorelines, and most development-related impacts to freshwater habitats occur at the shoreline interface. Natural shoreline vegetation is commonly cleared during development and replaced partially or completely by manicured lawn. Shorelines may also be altered by the addition of docks, boathouses, paths, and seawalls. Shoreline development is increasing in many jurisdictions and has been identified as the main threat to lake health in the United States. If not properly managed, waterfront development can degrade sensitive shoreline habitats, and alter the ecological integrity of adjacent lakes and rivers.

Shoreline buffers can play an important role in protecting lake health. The physical separation they provide between upland human activity and the aquatic environment can aid in mitigating the effects of development and site alteration on water quality, erosion and flood control, and wildlife habitat. However, no single type or size of buffer will perform optimally in all conditions, and determination of buffer characteristics should consider a variety of factors, including the desired function of the buffer, the sensitivity of the adjacent aquatic environment, the intensity of the land use, and site-specific physical features, such as slope, hydrology, and soil type. Characterizing these factors and developing static buffer requirements informed by scientific research over a large landscape, however, is extremely challenging.

The scientific literature on shoreline buffers over the past 30 years has largely focused on watercourses and wetlands, and the impacts of agriculture and forestry. Relatively little research has examined buffer performance in protecting lakes from shoreline development. While this gap in knowledge should be addressed, the existing literature on buffers can still provide useful information that can be applied to the lake context.

Shorelines provide numerous benefits and in general, larger buffers are better at consistently providing a range of protective functions. A 15 m buffer has been found to be the minimum size necessary to maintain physical and chemical functions while 30 m is the minimum necessary to maintain biological functions. Efficient removal of some pollutants (notably sediment) can occur in buffers of 10-20 m width, but other pollutants (such as nutrients) may require buffer widths of 30 m or more for effective attenuation. Water quality improvements generally increase with buffer size (e.g., 10 m removes 65% of sediment from overland runoff while 30 m removes 85% of sediment from overland runoff). Larger buffers are also better at protecting the diversity of aquatic and terrestrial species that rely on shorelines. Semi-aquatic species, such as amphibians and reptiles, can use terrestrial habitat up to 300 m inland from the water’s edge. Some turtle species nest up to 80 m inland. Waterbirds may react to human activity close to their nests, and loons may require several hundred metres between their nests and development.

Site-specific factors and the characteristics of the buffers are important. Low to moderate slopes (<10%) appear to positively influence sediment removal, while steeper slopes have a negative effective on performance. It is challenging determining how site-specific factors should influence buffer size over a large geographic range, but lake classification and lake specific management plans are two potential tools that could be utilized to generalize characteristics of the shoreline and sensitivities of the adjacent waterbody.

Natural vegetation is better able to trap pollutants and stabilize shorelines than manicured lawn due to deeper roots. Furthermore, native vegetation does not require the use of fertilizers, herbicides and pesticides, provides improved habitat for terrestrial and aquatic species, and does not tend to attract nuisance species such as Canada Geese. Maintaining natural shorelines also provides privacy, increases property value, and contributes to the aesthetic quality of the lake environment.

The scientific literature demonstrates that a 30 m buffer generally provides a range of ecological services, and this buffer size is commonly recommended in the peer-reviewed literature focused on shoreline development, aligning with Provincial guidance. While smaller buffers provide some benefits for water quality and aquatic habitat protection, larger buffers provide more ecological services, more completely. Buffers will likely become more important in protecting lake health as climate change effects on freshwater systems continue to intensify. Buffer recommendations are often included in municipal and provincial policies but are seldom enforced, so the theoretical debate of buffer size is outweighed by the reality on the land. To be truly effective, buffer recommendations based on the best available science, and informed by the jurisdictional review and public consultation, will need to be implemented and enforced consistently across the County.

Table of Contents

List of Tables

List of Figures

Appendices

1. Introduction

Shorelines link terrestrial and aquatic ecosystems, acting as a transition zone between land and water. They are biological hotspots and highly productive habitats that provide a myriad of ecological services, including maintenance of water quality, flood protection, and wildlife habitat (Strayer and Findlay 2010; Kardynal et al. 2011). Shorelines are also attractive locations for human settlement, offering access to lakes and rivers for recreation, nature appreciation, sustenance, cultural traditions, and spirituality. Residential development is often concentrated around shorelines, and most development-related impacts to freshwater habitats (such as alteration of sediment and nutrient inputs, light pollution, and disturbance from boat wakes) occur at the shoreline interface (Hampton et al. 2011). A common development practice in the shoreline environment is the establishment and maintenance of manicured lawn. Manicured, carpet-like green grass lawns are a relatively recent phenomenon that became established during suburbanization after World War II (Steinberg 2007). Shorelines may also be altered by the addition of various structures, such as docks, boathouses, and seawalls, as well as pathways (Taillon and Fox 2004). Shoreline development is increasing in many jurisdictions and has been identified as the main threat to lake health in the United States (Amato et al. 2016). If not properly managed, waterfront development can degrade sensitive shoreline habitats, and alter the ecological integrity of adjacent lakes and rivers (Francis and Schindler 2009; Cole et al. 2018).

Shoreline management should be informed by the best available science to ensure this important habitat is protected. Policies grounded in sound science will ultimately be more defensible, and better able to address environmental challenges effectively and realistically. Scientific knowledge of environmental issues is constantly evolving, and policies should reflect the most up-to-date scientific information and best management practices (BMPs) for successful environmental management.

The County of Haliburton has identified shoreline protection as a key policy area and aims to develop a county-wide Shoreline Preservation By-law. The County hired Hutchinson Environmental Sciences Ltd. (HESL) and J. L. Richards & Associates Ltd. (JLR) to guide the development of the Shoreline Preservation By-law. As part of this process, HESL and JLR are

- conducting an independent State of the Science Report of current science and BMPs related to shoreline protection,
- conducting a jurisdictional review of the approach of other Ontario municipalities to shoreline protection, and
- consulting with stakeholders in the County to gauge public opinion on how shorelines should be protected.

The following State of the Science Report addresses the first component of our Shoreline Preservation Review and Consultation. The literature review summarizes current science on the relationship between shoreline preservation and the protection of water quality, erosion and flood control, and wildlife habitat, and identifies and evaluates BMPs to promote shoreline protection. The focus of the Report is on lake shorelines and the effects of residential development, although some of the science reviewed addresses river, stream and wetland shorelines, and other human land uses, such as agriculture and forestry, where the principles and methods can be applied to the lake environment.

The information contained in the State of the Science Report will be used in combination with the jurisdictional review and stakeholder consultation to develop a Shoreline Preservation By-law that balances environmental stewardship and public best interests. It is anticipated that the By-law will include a variety of recommendations regarding shoreline use, such as buffer sizes, shoreline setbacks, and maximum access path widths. It should be noted that, while the scientific peer-reviewed literature provides the scientific rationale for approaches to shoreline protection, it cannot explicitly address all By-law components because a) the research may either be limited in certain areas or b) the research is not designed to address specific questions related to shoreline management empirically (e.g., how wide of a path can someone have to the shoreline?). Furthermore, while the science can evaluate the role of natural shorelines in protecting water quality and aquatic habitat, it cannot determine what level of protection people desire, or how best to implement and enforce resulting policy. Information gleaned from the jurisdictional review and stakeholder consultation will be used to help inform the development of specific recommendations that cannot be directly addressed by the State of the Science Report.

2. Information Sources

Resource materials and information for the literature review were compiled from a variety of sources. We began our search for relevant scientific information by consulting with experts on shoreline protection. We focussed on experts who were experienced lake managers that a) had a wide exposure to shoreline management from working as consultants for a large range of clients (vs. only government expertise that may be more limited) and which b) had no vested or otherwise interest in Ontario and who could therefore provide truly independent expertise. Six individuals were identified from the North American Lake Management Society[1]'s (NALMS) subject matter expert database:

- Amy Gianotti, Certified Lake Manager and founder of AquaSTEM Consulting,
- Sandy Kubillus, Certified Lake Manager and geologist at Integrated Lakes Management
- Moriya Rufer, Scientist and watershed planner at Houston Engineering Inc.,
- Dr. Ann St. Amand, President and aquatic scientist at Phycotech Inc.,
- Levi Sparks, Certified Lake Manager, aquatic ecologist and water quality scientist at Bandera County River Authority and Groundwater District, and
- Eli Kersh, Certified Lake Manager and aquatic resource consultant at elimnology.

We supplemented resources recommended by these experts with information collected through a desktop search of the peer-reviewed scientific literature. Two online research search engines, Google Scholar and Web of Science™, were used to identify and assemble an initial list of current scientific literature related to shorelines. Search terms included 'shoreline management', 'shoreline naturalization', 'shoreline preservation', 'shoreline protection', 'nearshore', 'riparian', 'aquatic health', 'lake ecology', 'lake health', 'lake management', 'water quality', 'buffer', 'erosion', 'flooding', 'wildlife habitat', and 'best management practices'. The literature review focused on studies published in the last 10 years but did not exclude older studies (1994-2010) generated in our search, since these might still contain relevant information.

---

[1] https://www.nalms.org/subject-matter-experts/ NALMS is an international society that brings diverse stakeholders together in the interest of lake management: *"Our mission is a simple, but powerful one: to forge partnerships among citizens, scientists and professionals to foster the management and protection of lakes and reservoirs…for today and tomorrow".*

A total of 60 papers were identified through our expert consultation and online search. These publications were then screened by scanning abstracts and narrowed down to studies focused on freshwater temperate systems (46 papers). All relevant literature was then read in full and key information was documented in a spreadsheet (Appendix A). The following sections of the report provide a synthesis and our interpretation of this literature review.

3. Ecological Functions of Shorelines

Shorelines are where land and water meet. The shoreline area can be divided into three distinct zones, which overlap to some degree:

- Upland Zone: the land farthest away from the lake or river, located on higher and drier ground, typically comprised of trees and shrubby vegetation, and often where human dwellings are located;
- Riparian Zone: the land closest to the water, representing a transition from terrestrial to aquatic habitat, which may contain trees, shrubs, grasses, or a mix of vegetation types; and
- Littoral Zone: the aquatic portion, extending from the water's edge to the maximum depth at which sunlight penetrates to the bottom of the water. Vegetation in the littoral zone can include submerged and emergent plants.

Although the upland zone does not directly interact with the lake, its characteristics and activities carried out there influence the waterbody as the gradient of drainage moves downhill, transporting water and any associated pollutants or sediments into the lake. Naturally vegetated shorelines play an important role in protecting water quality, preventing soil erosion, reducing flooding, and providing wildlife habitat for aquatic and terrestrial organisms (Strayer and Findlay 2010, Wehrly et al. 2012). Vegetation in the shore zone traps and filters sediment, nutrients, and other pollutants from surface and subsurface flow, preventing these contaminants from entering waterways where they can cause algal blooms, reduce water clarity and hypolimnetic oxygen, lead to the loss of aquatic habitat, and promote the establishment of invasive species, among other problems (Strayer and Findlay 2010). Plant roots hold soil in place, keeping topsoil from being washed away by rain, currents, and waves. Vegetation litter also shields the ground from the direct impact of rainfall, reducing erosion (France et al. 1998). Vegetation in the littoral zone provides structure, dissipating wave energy which might damage natural shorelines (Borre et al. 2016). Vegetation acts as a barrier to flooding, slowing the movement of water downstream, spreading it over the floodplain, and reducing the magnitude and force of floodwaters (Castelle et al. 1994). Intact upland and riparian vegetation shade the shoreline, reducing overall heating of the lake and providing thermal refuge for aquatic life (Steedman et al. 2001).

Natural shorelines are often referred to as the "Ribbon of Life" because of their disproportionate contribution to supporting biodiversity (OMNR 2000). The exchange of nutrients and organic materials between land and water provides abundant resources for a wide variety of species. For example, inputs of coarse woody debris (including logs, large branches, snags, bark and coarse roots) from riparian trees increases the complexity of littoral zones, providing food and shelter in the nearshore (Czarnecka 2016). Fine particulate organic matter is generated as coarse woody debris breaks down and is a major food source for many aquatic organisms, such as invertebrates, which provide food for fish and birds (Beacon 2012). Vegetation also provides shading to shallow water, moderating water temperatures and making the littoral zone suitable wildlife habitat (Sweeney and Newbold 2014). Aquatic plants (macrophytes) in the littoral zone stabilize sediments, and provide habitat and nutrients for fish, zooplankton, and macroinvertebrates (Hicks and Frost 2011). Ninety percent of all life in lakes, including many fish species, depends on shorelines for breeding, shelter, and foraging (OMNR 2000). Shorelines also provide key habitat for wildlife that rely on both aquatic and terrestrial environments for parts of their life cycle, such as dragonflies, salamanders, frogs, turtles, snakes, mammals, and birds (Semlitsch 1998, Whitaker and Montevecchi 1999, Roth 2005). In addition, shorelines serve as dispersal corridors for many plants and animals, protecting biodiversity by connecting suitable habitat that might otherwise be isolated due to human activity and development (Strayer and Findlay 2010).

4. Threats to Shorelines

Human activity in or near shoreline zones can cause many changes to the ecological structure and function of these areas. Strayer and Finlay (2010) identify the following human impacts to the shoreline:

- Compression and stabilization of soils (e.g., through dredging, filling, and repeated activities),
- Changes to the hydrological regime (e.g., through vegetation removal and hardening of surfaces or drainage management),
- Shortening and simplification (e.g., by straightening natural drainage channels or culverting drainage),
- Hardening the shoreline to protect against erosion (e.g., via seawalls, wooden bulkheads, armouring with riprap),
- Tidying the shore (e.g., removal of woody debris, terrestrial or aquatic vegetation),
- Nearshore dredging, which removes shallow water sediments and vegetation that dissipate wave energy,
- Pollution (e.g., from runoff of sediment, nutrients, and chemical contaminants),
- Disturbance (e.g., trampling of vegetation, boat wakes, artificial lighting),
- Resource extraction (e.g., sand, gravel, plants, fish, and waterfowl),
- Introduction of non-native plant and animal species,
- Increased impervious surfaces (e.g., paved roads, driveways, paths, and buildings).

Climate change is amplifying many of these impacts on shorelines, especially where natural systems have been altered and hardened (Borre et al. 2016). Climate change is expected to have profound effects on freshwater systems, through increased water temperature, and the effects of increased frequency and intensity of both floods and droughts (Abrahams 2008).

Residential or cottage development can result in significant alteration to shorelines through construction (of dwellings, boathouses, docks, boat lifts, and seawalls), installation of septic systems, and landscaping. A study on 12 Kawartha lakes found that cottage development was strongly related to the composition of aquatic plants in the littoral zone (Hicks and Frost 2011). Macrophyte biomass declined with increasing cottage density, and more developed lakes had less diverse aquatic plant assemblages, with a switch from floating leaf and emergent plants on undeveloped lakes to submerged plants on developed lakes (Hicks and Frost 2011). In contrast, a study on the effects of shoreline development to fish in the littoral zone in Pigeon Lake (also in the Kawarthas) found that development had no effect on fish species richness, and that all life stages were most abundant at moderately developed sites (compared with undeveloped and highly developed sites; Taillon and Fox 2004). The authors suggested that the absence of development effects may have been partly related to the abundance of aquatic plant cover at all sites, providing enriched habitat for littoral fish. Furthermore, they suggested that the long history of development on Pigeon Lake, and previous modifications to the shoreline during the Trent-Severn Waterway construction (i.e., flooding, raising of shoreline) may have already eliminated more sensitive fish species (Taillon and Fox 2004).

While poorly managed shoreline development may produce localized impacts, the effects can also be manifested on a larger lake-wide scale, given the strong link between shoreline dynamics and overall lake productivity (Hampton et al. 2011). The cumulative effects of shoreline development, however, have not been well studied (Wehrly et al. 2012). Residential development along lakeshores can cause changes to lake habitat structure and ecosystem function through changes in sediment distribution and stability, nutrient levels, and habitat, which in turn can lead to eutrophication, decreased water quality, and impacts on fish and other organisms (Goforth and Carman 2005, Francis and Schindler 2009).

Shoreline development has been linked to the potential for elevated nutrient inputs (Dillon et al. 1994; Paterson et al. 2006) which, in turn, can cause a host of problems including reduced water clarity, reduced hypolimnetic oxygen and the proliferation of algal blooms. Algal blooms are a common concern because of aesthetic and health concerns associated with algae, namely blue-green algae (or cyanobacteria). The public reporting of algal blooms in Ontario increased significantly from 1994 to 2009 (Winter et al. 2011) which is consistent with worldwide trends. Climate change is a potent catalyst for further expansion of algal blooms (Paerl and Huisman 2008) and therefore the importance of shoreline management and the establishment of best management practices to limit nutrient loading to lakes is more important than ever before.

Goforth and Carman (2005) studied the impact of shoreline development and substrate stability on nearshore ecology in Lake Erie and Lake Michigan. They found that developed sites (modified by erosion control structures and human land use, and mainly comprised of unstable substrate) had lower densities of zooplankton and small shallow water prey fish (based on catch per unit effort – CPUE) compared with natural sites (comprised entirely of highly stable substrate). Densities of benthic macroinvertebrates did not differ by shoreline type but were lower at sites with less substrate stability (i.e., development was not a factor unless it resulted in reduced substate stability). The CPUE of larger nearshore fish, however, showed no difference between shoreline types and substrate stability regimes. The results suggest that physical habitat changes in the littoral zone due to shoreline hardening directly influence invertebrate and prey fish communities. Larger fish species may not have been affected because they are more mobile than their prey. Nonetheless, the long-term cumulative effect of reduced prey availability due to shoreline hardening could be a problem for overall fish productivity in the Great Lakes (Goforth and Carman 2005).

Shoreline hardening was found to affect both macrophyte and fish communities along shorelines in Wisconsin lakes. Shorelines reinforced with riprap had coarser substrates, lower organic content, and cooler water temperatures than natural shorelines. Natural sites had more floating-leaved plants, and larger and more abundant fish populations than the armoured shorelines (Gabriel and Bodensteiner 2011).

The loss or reduction in riparian forest due to shoreline development has been linked to marked declines in habitat and food subsidies (such as coarse woody debris and terrestrial insect prey) to littoral zones, which can have varied effects on lake ecology (Frances and Schindler 2006, 2009, Helmus and Sass 2008). In an experiment on an undeveloped and unfished lake in Wisconsin, Helmus and Sass (2008) removed

70% of coarse woody debris from the littoral zone in one basin physically separated from another reference basin which was left undisturbed. Yellow Perch (*Perca flavescens*), which was the most abundant fish in both basins before the experiment, showed drastic declines in the manipulated basin, compared to no change in the reference basin. In contrast, the macroinvertebrate community had similar composition, diversity and density levels between the two basins. Helmus and Sass (2008) concluded that Yellow Perch likely lost both spawning habitat (leading to reduced reproductive success) and refuge habitat (leading to increased predation by Largemouth Bass, *Micropterus salmoides*) when the coarse woody debris was removed.

Francis and Schindler (2009) examined fish diets along a gradient of shoreline development in north temperate lakes. The contribution of terrestrial insects to diet was negatively correlated with development, comprising up to 100% of fish diet mass in undeveloped lakes compared to an average of 2% in developed. Trout (*Oncorhynchus* spp.) also had an average 50% greater daily energy intake (of which up to 50% was comprised of terrestrial prey) in undeveloped lakes. Terrestrial food sources from intact shorelines thus can play an important role in enriching fish productivity in lakes.

The effects of shoreline development on aquatic habitat were compared in Vermont and Maine, two states with different approaches to regulating lakeshore activity (Merrell et al. 2013). Vermont had no lakeshore zoning, focusing instead on encouraging individual stewardship. Maine had a Mandatory Shoreland Zoning Act, which placed land use restrictions on all land within 76 m of waterbodies. The study examined 234 reference lakeshore sites and 151 unbuffered developed lakeshore sites on 40 lakes in Vermont, and 13 reference lakeshore sites and 36 developed sites on five lakes in Maine, from 2005 to 2008. Development on many of the Vermont lakes included conversion of treed shorelines to lawn, lot leveling, addition of impervious surfaces such as roofs, driveways, patios, and decks close to shore, and seawalls along shorelines. Maine's regulations, meanwhile, required setbacks of at least 30 m from the lakeshore, as well as minimum levels of tree and shrub retention and canopy coverage within the setback.

In Vermont, all littoral habitat components studied differed significantly between developed and reference lakeshore sites, with developed sites having

- less shading, and lower amounts of coarse woody debris, fine and medium woody structure, deciduous leaf litter, periphyton, and dragonfly larval exoskeletons (used as an indicator of suitable habitat for dragonfly emergence), and
- more sand and embedded sediments (smothering habitat for fish and macroinvertebrates).

In contrast, only one parameter (dragonfly larval exoskeletons) showed significant differences between developed and reference sites in Maine (Merrell et al. 2013).

Shoreline development may also threaten the aesthetic value of lakes which attracts people to settle there in the first place. A survey of lakeshore residents on 10 Michigan lakes found that common landscaping practices (such as replacing natural shorelines with lawns, seawalls, beaches, docks and accessory buildings) conflicted with the top reasons residents chose to live or vacation on the lakes, namely the view, interaction with nature, and open spaces (Lemberg and Fraser 2005). Fewer than 5% of residents surveyed considered their properties as being in a natural state, with more than 80% classifying them as having manicured lawn with some shade trees or ornamental shrubs (Lemberg and Fraser 2005).

A 12-year study of Lake Ontario coastal wetlands found a strong relationship between water quality and natural land cover at the watershed scale, indicating that shoreline protection is only one component contributing to overall lake health (Croft-White et al. 2017). Water quality declined in watersheds with more than 6-7% urban coverage but increased in watersheds with more than 10% wetlands and forest cover respectively. .

5. Shoreline Buffers

Shoreline buffers are commonly used to protect lakes and rivers from adjacent human activity. A buffer is a vegetated portion of land that serves as a physical separation between natural features and functions, and development (such as residential development, forestry, agriculture) which may disturb or degrade these features and functions (OMNR 2000, Sweeney and Newbold 2014). A buffer differs from a Critical Function Zone (or Core Habitat), which is the part of a species' habitat critical for its survival, because the buffer is the protection zone which should be applied around this critical habitat (Beacon 2012). In other words, the buffer should not be considered an extension of the natural feature it is meant to protect (OMNR 2000). Similarly, a buffer differs from a setback, which is the minimum distance required between a structure or infrastructure and a natural feature, although a buffer may be included within a setback.

In the shoreline context, buffers are naturally unmowed vegetated land extending along the waterfront, typically in the riparian zone. Buffers may be a combination of trees, shrubs, and herbaceous or grassy vegetation In general, maintenance and restoration of native plants in the shoreline buffer is preferred to use of non-native species, since native species are adapted to local conditions, support local biodiversity, and do not require the use of fertilizers, herbicides, and pesticides, which can degrade water quality (Muskoka Watershed Council 2013). In addition, native vegetation appears better able to trap pollutants in runoff from entering adjacent waterbodies (Zhang et al. 2010) and to stabilize shorelines with its deeper network of roots, compared to lawn. Preservation of natural shorelines also costs less than a manicured lawn and gardens to maintain, provides more privacy along the lakefront, and promotes the aesthetics that attract people to lakeshores (Lemberg and Fraser 2005).

Natural shorelines are also generally avoided by nuisance species like Canada Geese (*Branta canadensis*), which are attracted to open lawns along shorelines, where they can more easily access riparian lands. It is challenging to quantify the impact of waterfowl such as Canada Geese on nutrient loading, because approximately 87% of the phosphorus from goose feces is derived from the lake itself, as food passes quickly through a goose and the process is part of the nutrient cycle, as opposed to a nutrient source (Fleming and Fraser 2001). The impact is magnified beyond the remaining ~13% phosphorus load, however, as phosphorus from feces is more bioavailable for uptake by aquatic plants and algae.

The design of buffer type and width should be determined based on the buffer's desired function, and consideration of site-specific conditions, such as slope, hydrology, soil type, and adjacent land uses (Castelle et al. 1994, McDonnell 2012).

Shoreline buffers can provide numerous benefits including

- Sediment removal and erosion control,

- Removal of excess nutrients (mainly phosphorus and nitrogen) and other pollutants (including pathogens, pesticides, and heavy metals),
- Moderation of stormwater runoff,
- Moderation of water temperature,
- Maintenance of habitat diversity and protection of core habitat (e.g., as a source of habitat and food subsidies to the littoral zone),
- Reduction of human impact (by acting as a screen or barrier between human activity and wildlife; Beacon 2012; McDonnell 2012).

Numerous studies have been conducted over the last 30 years on buffer effectiveness. Most of the research has focused on riparian buffers along watercourses or wetlands, and their role in buffering agricultural and forestry impacts. In comparison, relatively few studies have examined the application of buffers to lake ecosystems and lakeshore development (Owens et al. 2021). Research has also been uneven in its focus on different buffer functions. For example, Beacon (2012) identified gaps in research on the role of buffers in mitigating storm flows and intercepting toxins and pathogens. More recently, Stutter et al. (2019) highlighted the lack of research on the capture and retention of soluble phosphorus and nitrogen in subsurface flows through buffers, and on the role of buffer design and management on protecting terrestrial and aquatic wildlife habitat. In addition, research has demonstrated wide variability in buffer effectiveness, partly because of variation in conditions among sites, but also because standardized approaches to measuring buffer performance are lacking (Beacon 2012).

Although much of the research on shoreline buffers has not directly focused on lakeshore environments and waterfront residential development, the findings from other studies are still broadly applicable to lake systems. Different types of land uses (e.g., agriculture, forestry, urban development) may produce similar disturbance patterns along the shoreline through widespread clearing of vegetation. Buffers are expected to function in similar ways across different aquatic systems, although the scale of their influence may vary (Beacon 2012). For example, the equivalent sized buffer along a small stream compared with a large lake may differ in its effectiveness. Nonetheless, while gaps remain in our knowledge of buffer performance in the lakeshore context, the following review provides a general overview of their potential in such systems.

5.1 Case Studies

Castelle et al. (1994) conducted a review of the literature on buffer effectiveness around streams and wetlands. Smaller buffers were generally adequate when they were in good condition (i.e., comprised of dense native vegetation and undisturbed soils), surrounded by low intensity land uses (such as park land or low density development), and when the stream or wetland had low functional value (e.g., the feature was highly disturbed or dominated by non-native vegetation). The size of the buffer needed to be increased, however, if buffer condition was poor, if adjacent land uses intensified, and if the feature to be protected was of higher ecological value (Castelle et al. 1994). Buffers less than 5-10 m were typically found to be insufficient for protecting the natural physical, chemical, and biological characteristics of adjacent aquatic features. A minimum 15-30 m buffer was recommended, with the lower end of the range identified as the minimum size necessary to maintain physical and chemical functions, and the upper end of the range identified as the minimum necessary to maintain biological functions (Figure 1).

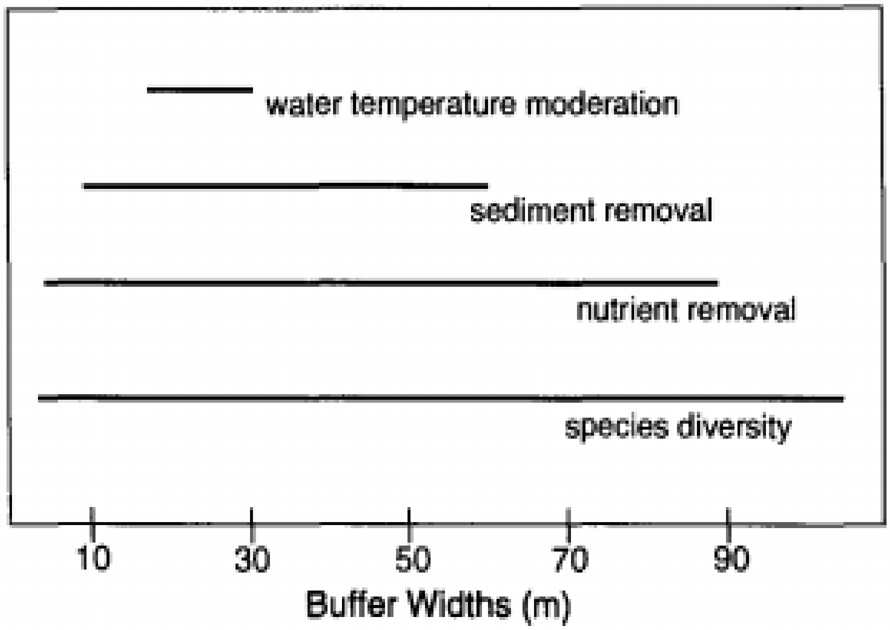


Figure 1. Range of buffer widths necessary to protect specific ecological functions in streams and wetlands (from Castelle et al. 1994).

5.1.1 Removal of sediment and pollutants

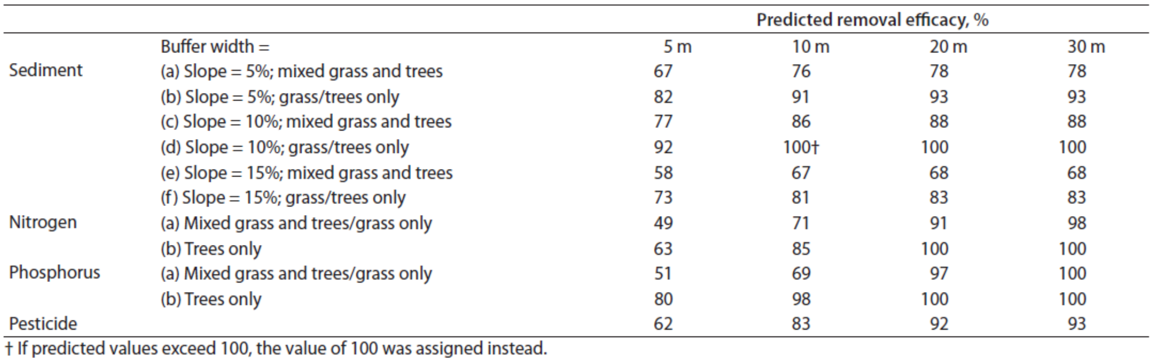
Buffers reduced phosphorus and total suspended solids (TSS) in stormwater runoff from residential development in Maine (Woodard and Rock 1995). Buffer effectiveness was evaluated for different slopes (2.3-12%) and ground cover (sparse to moderate cover, seeded or not seeded lawn) and compared to a control site which had a moderate slope (5.7%) and was forested and undeveloped. Ground cover had a greater influence on buffer function than slope. At all sites, a 15 m buffer reduced phosphorus concentrations to within the control range. TSS was also reduced but to a lesser degree. Buffers in which the ground was stabilized with underbrush and a layer of decomposing forest litter were most effective at removing pollutants, while buffers containing exposed soil contributed TSS to overland flow. Woodard and Rock (1995) concluded that a 15 m buffer should be sufficient for trapping phosphorus and TSS at sites with low to moderate slopes (<12%), sufficient ground cover, a stable soil matrix, and minimal channelization.

Phosphorus is generally considered the limiting nutrient for the growth of aquatic plants and algae in freshwater environments because reducing nitrogen inputs favors nitrogen-fixing cyanobacteria and nitrogen fixation is generally sufficient to allow for increased plant and algae biomass in proportion to phosphorus (Schindler et al. 2008). However, other scientists argue that nitrogen-deficient growth occurs at specific total nitrogen : total phosphorus ratios (e.g., <20; Guildford and Hecy, 2000) so nitrogen was considered during the literature review. A 2005 review of riparian buffers by the U.S. Environmental Protection Agency found that their effectiveness at nitrogen removal was highly variable (Mayer et al. 2005). Narrow buffers (1-15 m) sometimes removed up to 96% of nitrogen loads, but in other cases, they contributed nitrogen. Wider buffers (>50 m) were more consistent in removing nitrogen, ranging from 58 to 100% effective. Nitrogen removal from surface flows was generally inefficient (average 33% effective), compared to subsurface removal, which was typically high (average 90% effective) and appeared unrelated to buffer width. Nitrogen is an essential nutrient for plant growth and reproduction, and plants absorb it from the soil through their roots, explaining why subsurface removal is superior. Furthermore, water movement below the surface tends to be slower than surface flow, creating more time for plants to take up the nutrient. A variety of vegetation types (grass, grass/forest, forest, forest/wetland, wetland) had similar removal abilities for subsurface flow. Mayer et al. (2005) generated a linear regression model to estimate buffer thresholds for nitrogen removal. They found that overall, a 3 m buffer was predicted to have a 50% removal effectiveness, vs. 75% for a 28 m buffer, and 90% for a 112 m buffer. Mayer et al. (2005) concluded that soil type, watershed hydrology, and subsurface biogeochemistry may be more important than vegetation type or buffer width in determining nitrogen removal capabilities in riparian buffers, because these factors influence microbial denitrification and plant uptake of the nutrient.

Zhang et al. (2010) conducted a review of the effects of buffer width, slope, soil type, and vegetation type on the capacity of buffers to reduce non-point source pollution. Of the pollutants examined, buffer width influenced the removal of pesticides the most (explaining 60% of the total variance in removal efficiency), followed by nitrogen (44%), sediment (37%) and phosphorus (35%). Buffer capacity to remove sediment showed a greater influence of width at smaller buffer sizes than larger ones. For example, increasing buffer width from 5 to 10 m would improve function by 8-9%, while increasing buffer width beyond 20 m would accrue no additional gain for sediment removal. Buffer slope had a positive relationship with sediment removal efficiency for slopes less than 10%, but a negative effect on steeper slopes. Soil drainage type (i.e., well, moderately or poorly drained) had no influence on buffer function.

Zhang et al. (2010) found that vegetation type affected the removal efficacy of all pollutant types except pesticides. Grass buffers and treed buffers removed more sediment than buffers with a mix of grass and trees. Treed buffers performed better at removing phosphorus and nitrogen than those with either a mix or just grass. The type of grass buffer (e.g., native grasses vs. cultivated lawn) was not specified in the literature review. However, Zhang et al. (2010) reported on a study by Abu-Zreig et al. (2004) which found that riparian buffers comprised of native grasses were more effective at phosphorus removal than ones made up of perennial ryegrass and red fescue adjacent to cropland in southern Ontario. As with sediment, greater gains in removal efficiency were seen with buffer width increases in smaller (5 to 10 m) than larger (20 to 30 m) buffers, with no change for treed buffers in their ability to remove nutrients (100%) beyond 20 m. Zhang et al. (2010) concluded that a 30 m buffer with low to moderate slopes would remove at least 85% of the pollutants tracked in the study.

Table 1. Predicted pollutant removal efficiency of buffers (from Zhang et al. 2010).



		Predicted removal efficacy, %			
	Buffer width =	5 m	10 m	20 m	30 m
Sediment	(a) Slope = 5%; mixed grass and trees	67	76	78	78
	(b) Slope = 5%; grass/trees only	82	91	93	93
	(c) Slope = 10%; mixed grass and trees	77	86	88	88
	(d) Slope = 10%; grass/trees only	92	100†	100	100
	(e) Slope = 15%; mixed grass and trees	58	67	68	68
	(f) Slope = 15%; grass/trees only	73	81	83	83
Nitrogen	(a) Mixed grass and trees/grass only	49	71	91	98
	(b) Trees only	63	85	100	100
Phosphorus	(a) Mixed grass and trees/grass only	51	69	97	100
	(b) Trees only	80	98	100	100
Pesticide		62	83	92	93

† If predicted values exceed 100, the value of 100 was assigned instead.

Beacon (2012) conducted a critical synthesis of the scientific and technical literature on buffers, scanning more than 3000 studies, and reviewing 250 in detail. Average buffer sizes of 10 to 40 m for watercourses and 15 to 80 m for wetlands were widely documented to attenuate sediments and other pollutants. Sediment and phosphorus were typically well attenuated by narrower buffers than was nitrogen. Buffers 2-9 m captured some sediment and phosphorus, but larger buffers (9-30 m) were generally more consistent in their performance and were able to achieve full attenuation. In comparison, studies on nitrogen removal recommended widths of 15 to more than 40 m. Grass (or herbaceous) buffers were better able to capture phosphorus and nitrogen in surface runoff than forested buffers, but forested buffers trapped more subsurface nitrogen than grassed buffers, likely because they had high levels of organic matter and deep-rooted vegetation, promoting denitrification and plant uptake. Types of grass buffers reviewed included ones comprised of Reed Canary Grass (*Phalaris arundinacea*) an invasive species, and Switchgrass (*Panicum virgatum)*, a native plant. Overall, a 30 m buffer was recommended to achieve multiple water quality benefits (Beacon 2012).

The ability of riparian buffers to intercept subsurface nitrogen is strongly influenced by subsurface water flux (or the amount of water flowing through the buffer below the surface). A review of 30 studies of buffer function along watercourses found that the median removal efficiency of 89% for subsurface nitrate was not related to buffer width or vegetation type (grass vs. trees) but was inversely related to subsurface water flux (Sweeney and Newbold 2014). Under equivalent rates of water flux (>50 l/m/day) buffers less than 40 m wide had a median removal efficiency of 55%, compared to 89% for buffers greater than 40 m (Sweeney and Newbold 2014). Under average water flux conditions, 30 m and 100 m buffers were predicted to remove 48% and 90% of subsurface nitrogen respectively. Given the variation in efficiency across sites, Sweeney and Newbold (2014) recommended at least 30 m wide buffers for effective nitrogen removal at the watershed scale, and indicated that removal efficiency was likely to continue to increase above 30 m.

Sweeney and Newbold (2014) also reviewed sediment removal by watercourse buffers. Up to 65% of sediment from overland flows could be captured in 10 m buffers, increasing to 85% in 30 m buffers. Larger particle sizes of sediments (such as sand) typically settle out of flow within a few metres, but wider buffers are needed to effectively trap finer silts and clays that can impair water quality.

The capacity of riparian buffers to remove sediment was further assessed in a meta-analysis of more than 90 studies (Ramesh et al. 2021), which examined the role of a suite of factors including buffer width, length, and area, as well as vegetation type, area ratio (upland contributing area to buffer area), sediment loads, and flow rates. Overall, buffers had an average removal efficiency of 75%. Buffers comprised of grass only or a mix of grass and woody vegetation (trees and/or shrubs) were better than woody vegetation buffers at sediment removal (Figure 2; although data were limited for some of these types). The literature review did not provide details on the type of grass buffers (e.g., native grasses vs. cultivated lawn), other than indicating that they could include grasses, stiff grass hedges, and herbaceous crops. Buffer widths in the 10 to 20 m range were most effective at trapping sediment (Figure 3).

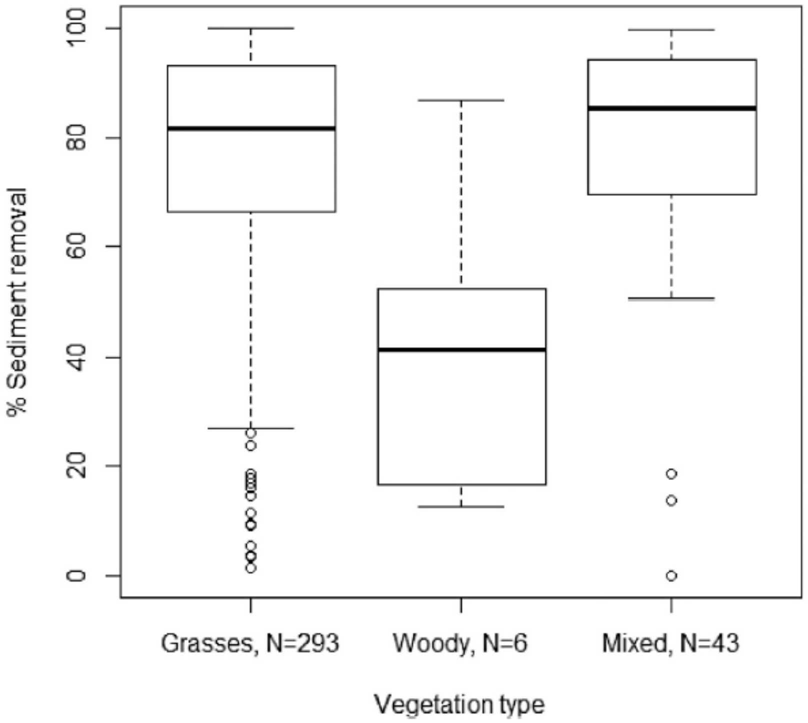


Figure 2. Boxplot of sediment removal in different types of buffers (from Ramesh et al. 2021). The lower and upper boundaries indicate the 25th and 75th percentiles, respectively. The bold line within the box indicates the median. The bars above and below the box represent the 90th and 10th percentile of sediment reduction, respectively.

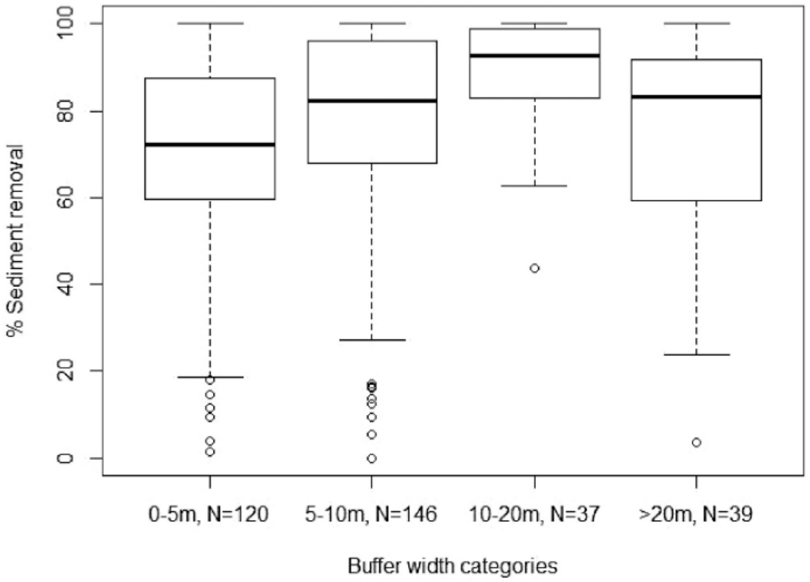


Figure 3. Boxplot of sediment removal for different buffer widths (from Ramesh et al. 2021).

In contrast, riparian forest buffers did not appear to improve benthic community structure in a study of lakes in New York state (Owens et al. 2021). The benthic macroinvertebrate community composition of buffered and unbuffered lakes with a mix of land uses (including agriculture, forestry, and residential development) were compared as an indicator of water quality. No difference was found in the biotic index of water quality among lakes, suggesting that a forested buffer would not trap pollutants from entering the lake through inlet streams or stormwater runoff drains (Owens et al. 2021) or that effects in water quality were too small to influence benthic community structure. In addition, lakes in the study area likely were experiencing the legacy effects of historical agricultural activity in their watersheds, through internal loading of nutrients, which could interfere with any changes resulting from treed buffers. Furthermore, invasive alien species (including Zebra Mussels, *Dreissena polymorpha*) were present in all study lakes, which may have confounded results by homogenizing macroinvertebrate communities (Owens et al. 2021). The findings of this study emphasize that buffers, on their own, cannot address all factors contributing to lake health, and that broader landscape level effects, as well as historical influences, should be considered.

5.1.2 Maintenance of habitat diversity and protection of core habitat

Characteristics of buffers designed to protect wildlife habitat will vary depending on the species of interest. Semi-aquatic organisms, like frogs, salamanders, snakes, and turtles may need significant areas of terrestrial habitat adjacent to their aquatic habitat for feeding, shelter, nesting and overwintering. For example, a literature review of the habitat requirements of six salamander species in the northeastern United States found that adults used upland habitat on average 125 m from the edge of wetlands, while juveniles were up to 70 m from shorelines (Semlitsch 1998). A review of the habitat requirements of 65 amphibian and turtle species (which included species found in Ontario) documented core terrestrial habitat ranging from 159 to 290 m from the aquatic edge for amphibians and 127 to 289 m for reptiles (Semlitsch and Bodie 2003). To adequately protect both the aquatic and terrestrial core habitat of these species from human disturbance, Semlitsch and Bodie (2003) recommended at least a 30 to 60 m aquatic buffer (which would be encompassed by protection of core terrestrial habitat) and a 50 m buffer terrestrial buffer beyond the core terrestrial portion (Figure 4). In Ontario, the mean distance to water of freshwater turtle nests ranges from 33.5 m and 35.7 m (for Spotted Turtle, *Clemmys guttata* and Northern Map Turtle, *Graptemys geographica* respectively), 51.8 m (for Snapping Turtle, *Chelydra serpentina*), and 71.2 m and 77.8 m (for Blanding’s Turtle, *Emydoidea blandingii* and Painted Turtle, *Chrysemys picta* respectively; Steen et al. 2012).

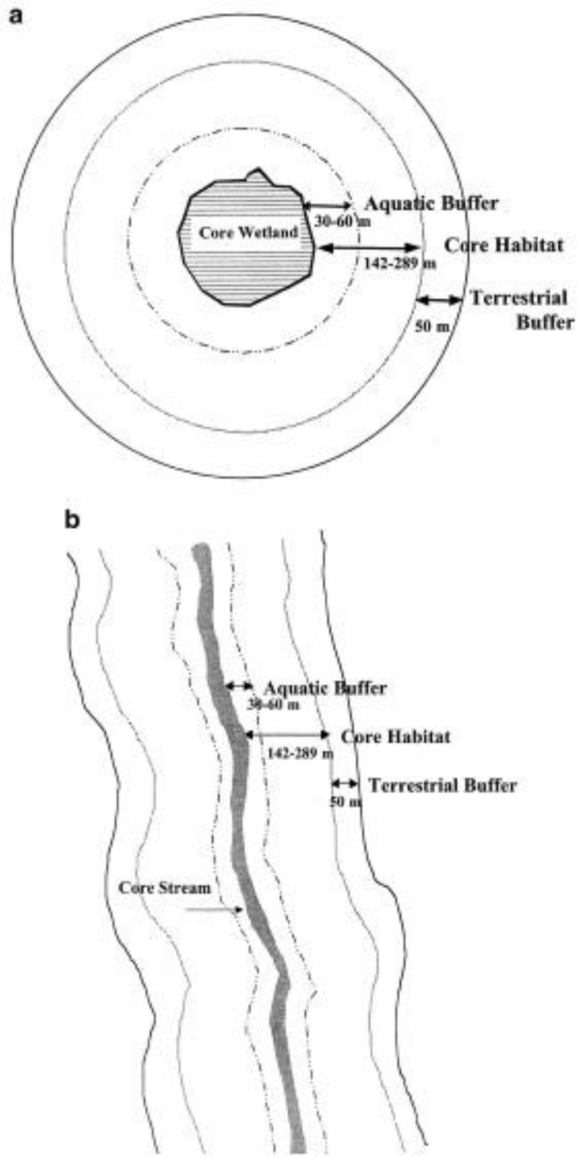


Figure 4. Proposed zones of protection for amphibians and reptiles using (a) wetlands and (b) streams (from Semlitsch and Bodie 2003).

Numerous wildlife studies have examined the minimum distance at which species are disturbed by human activity. While this research is not directly focused on buffer effectiveness, it can be useful for identifying minimum buffer size to protect wildlife habitat from human disturbance (Beacon 2012). Sensitivities vary widely among species and depending on the type and intensity of disturbance. Beacon (2012) reported a study by Rodgers and Smith (1997) which found that waterbirds were flushed from their nests by noise within 14-24 m and were more sensitive to pedestrians (requiring up to 34 m distance) than cars (up to 24 m distance). In general, minimum buffers of 15-100 m were recommended for waterbird species (Beacon 2012).

A study on the effects of lakeshore development on the Common Loon (*Gavia immer*) in New York State found that breeding success was affected by proximity to development (Spilman et al. 2014). Successful nests were on average 442 m away (range 41-1500 m) from human settlement, while unsuccessful nests were closer, on average 342 m away (range 2-1223 m).

Buffer vegetation type can influence the composition of adjacent aquatic invertebrate communities. Forested buffers were associated with greater stream shading, increased gravel content, and faster flow velocities, as well as more larvae in the sensitive insect orders Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies), compared with unbuffered reaches dominated by grass and herbaceous vegetation (Sargac et al. 2021).

5.2 Summary of Buffer Recommendations

Buffers are often intended to achieve multiple benefits, including water quality protection, provision of wildlife habitat, and aesthetics. Their design will thus involve balancing a variety of factors to optimize their performance and determining what level of performance is desired. For example, if 95% removal of a pollutant is the goal, the buffer width required will likely be larger than if 50% removal is the goal (Beacon 2012). In addition, consideration of site-specific features affecting buffer effectiveness is necessary, as well as the type, intensity, and configuration of adjacent land uses (Beacon 2012).

The following table summarizes characteristics of effective shoreline buffers documented in the scientific literature.

Table 2. Summary of characteristics of effective shoreline buffers.

Function	Recommended Buffer Width	Type of Aquatic Feature	Comments	Source
Water quantity, water quality, water temperature, core habitat protection, barrier to human disturbance	15-30 m	Watercourse and wetlands	• Lower end of range minimum sufficient for protection of chemical and physical components of aquatic systems • Upper end of range minimum sufficient for protection of biological components of aquatic systems	Castelle et al. 1994
Water quality	15 m	Lake	• Reduced phosphorus and TSS at sites with <12% slopes, sufficient ground cover, stable soil matrix, and minimal channelization	Woodard and Rock 1995
Core habitat protection	192-339 m	Watercourse and wetlands	• Calculated as 50 m terrestrial buffer beyond terrestrial core habitat for amphibians and turtles	Semlitsch and Bodie 2003
Water quality	>50 m • 3 m: 50% effective	Watercourse and wetlands	• 58-100% effective at nitrogen removal • Surface removal 33% average removal efficiency	Mayer et al. 2005

	• 28 m: 75% effective • 112 m: 90% effective		• Subsurface removal 90% average removal efficiency	
Water quality	20-30 m	Watercourse	• Up to 85% of pollutants (sediments, nutrients, pesticides) removed at 30 m • Buffer slope positively associated with sediment removal for <10% slopes • Grass buffer and treed buffer removed more sediment than grass/tree mix • Treed buffer removed more phosphorus and nitrogen than grass/tree mix or just grass buffer	Zhang et al. 2010
Water quantity (e.g., attenuation of storm flows)	20-150 m	Watercourse	• Empirical data lacking, based mainly on anecdotal evidence • Influenced by factors such as local hydrologic regime, catchment area, topography, soil type, impervious cover, and land use in the watershed	Beacon et al. 2012
Water quality	1-122 m		• Sediment and phosphorus can generally be well	

	• Average range between 10-40 m • Average single recommendation of ~30 m		attenuated in narrower buffers than nitrogen • Combination of herbaceous and woody vegetation most effective for overall nutrient attenuation • Most attenuation is documented within the first 30-40 m	
Barrier to human disturbance or changes in land use	15-100 m		• Empirical data lacking • Range based on flight initiation distance research on waterbirds, distance depends on species and type of human impact	
Core habitat protection	10-75 m • Average single recommendation 50 m		• For large woody debris, 40-60% of input occurs within 10 m of shore; 30 m tends to capture 100% of contribution • For particulate organic matter, 60-85% of input occurs within 15 m of shore; 40 m needed for 100% of contribution	
Water quality	15-80 m	Wetlands	• Sediment and phosphorus can generally be well	

	• 30 m recommended for multiple water quality benefits		attenuated in narrower buffers than nitrogen • Combination of herbaceous and woody vegetation most effective for overall nutrient attenuation	Beacon et al. 2012
Hazard mitigation zone (e.g., stabilize steep slopes)	10-50 m		• Empirical data lacking • Influenced by slope, condition, and height of trees (if present), composition of vegetation	
Core habitat protection	15-300+ m • Average range 45-110 m		• Depends on focal species and land use context • Buffers often conflated with critical function zones (or core habitat)	
Water quality	10-30 m	Watercourse	• 10 m removes 65% of sediment from overland flow • 30 m removes 85% of sediment from overland flow	Sweeney and Newbold 2014
Temperature regulation	20-30 m		• Buffer ≥ 20 m maintains water temperature within 2ºC of that within fully forested watershed • Buffer ≥ 30 m maintains water temperature the	

			same as within fully forested watershed	
Core habitat protection	30+ m		• Coarse woody debris input equivalent to natural levels if buffer width equal to height of mature streamside trees (~30 m) • Diversity and abundance of macroinvertebrate and fish communities, and the condition of instream habitat remain similar to within fully forested watershed with ≥ 30 m	
Water quality	10-20 m	Not specified	• 75% sediment removal efficiency • Grass or grass/woody mix remove more sediment than woody vegetation only	Ramesh et al. 2021

5.3 Provincial Guidance

Preservation of a naturally vegetated shoreline buffer has long been recognized as a best management practice to minimize the impacts of development on adjacent waterbodies and watercourses. The Provincial Policy Statement (PPS; 2020), under the Planning Act, identifies significant natural heritage features that must be protected from development and site alteration. While the PPS does not set out specific requirements to establish buffers around significant natural heritage features, buffers are often used by planning authorities as a protective measure and a means to allow development while still protecting the feature of interest. The Natural Heritage Reference Manual, which provides guidance on natural heritage policies under the PPS, recommends minimum distances of naturally vegetated buffers adjacent to fish habitat to protect it from development and site alteration (OMNR 2010; Table 3). These buffer recommendations are based primarily on research by Castelle et al. (1994) and Environment Canada (2004). The Manual indicates that planning authorities may apply larger buffers if additional sensitivities are identified, such as a highly stressed aquatic feature, the presence of aquatic species at risk, or the need to enhance ecological function (e.g., bank stabilization, pollutant removal, wildlife habitat; OMNR 2010). The Manual acknowledges that buffer recommendations may evolve as more research is generated on the impacts of development on natural heritage features and functions (OMNR 2010).

Table 3. Minimum recommended buffer sizes to protect fish habitat (from OMNR 2010).

Type of Fish Habitat	Minimum Recommended Buffer
Warmwater streams	30 m or 15 m if it can be demonstrated that there will be no negative impact on the natural feature and its ecological functions
Coolwater streams	30 m or 20 m if no negative impact on the natural feature and its ecological functions
Coldwater streams and inland waterbodies on the Precambrian Shield[2]	30 m

The Province's Lake Capacity Assessment Handbook provides guidance on controlling phosphorus entering lakes through management of shoreline development (Government of Ontario 2010). The Handbook encourages the maintenance and restoration of natural shoreline vegetation as one way to reduce phosphorus loading to lakes (in addition to minimizing amount of exposed soil, reducing fertilizer use, and maintaining properly functioning septic systems). No overall buffer size is recommended in the Handbook, but for lakes on the Precambrian Shield, where soils are typically thin, and fractured bedrock common, a minimum 30 m setback or no development zone from waterbodies is recommended. In general, as large a setback as possible is recommended (Government of Ontario 2010). A 30 m buffer is also recommended for stream environments by Environment Canada in "How Much Habitat is Enough?" (2013).

---

[2] *The Precambrian Shield (also known as the Canadian Shield)* is a geologic region extending across central and northern Ontario (including Haliburton County) which is characterized by thin soil and exposed bedrock.

Buffers are referred to as vegetation protection zones in provincial land use plans (the Greenbelt Plan, the Lake Simcoe Protection Plan, the Niagara Escarpment Plan, and the Oak Ridges Moraine Conservation Plan). These zones, comprised of naturally self-sustaining vegetation, are to be established and maintained around key natural heritage features and key hydrologic features outside of settlement or urban areas. Development and site alteration are generally prohibited within vegetation protection zones, with some exceptions (e.g., for conservation and flood or erosion control, and low intensity recreational use). Vegetation protection zones must be of sufficient width to protect key natural heritage features and key hydrologic features and their ecological functions. Buffer width is to be determined on a site-specific basis in the Niagara Escarpment Plan (Government of Ontario 2017a). In the Greenbelt Plan and the Oak Ridges Moraine Plan, buffers of at least 30 m are required adjacent to wetlands, fish habitat, kettle lakes, and the meander belt of permanent and intermittent streams (Government of Ontario 2017b,c). The Lake Simcoe Protection Plan designates minimum vegetation protection zones of 30 m from the Lake Simcoe shoreline in shoreline built-up areas (or wider if deemed appropriate through a natural heritage evaluation) and 100 m for the remaining Lake Simcoe shoreline outside existing settlement areas (Government of Ontario 2009). Structures are only permitted within these shoreline vegetation protection zones if (i) no other alternative location exists and the area affected within the vegetation protection zone is minimized, (ii) the ecological functions of the zone are maintained, and (iii) pervious materials and designs are used as much as possible (Government of Ontario 2009).

The Province of Ontario has produced fact sheets for the public on best management practices to preserve and restore natural shorelines. These resources encourage various approaches to protecting natural shorelines, through maintenance of natural vegetation, minimizing human activity, allowing degraded sites to re-naturalize, planting native species and removing non-native vegetation (Government of Ontario 2000, Government of Ontario and DFO 2000).

6. Other Considerations

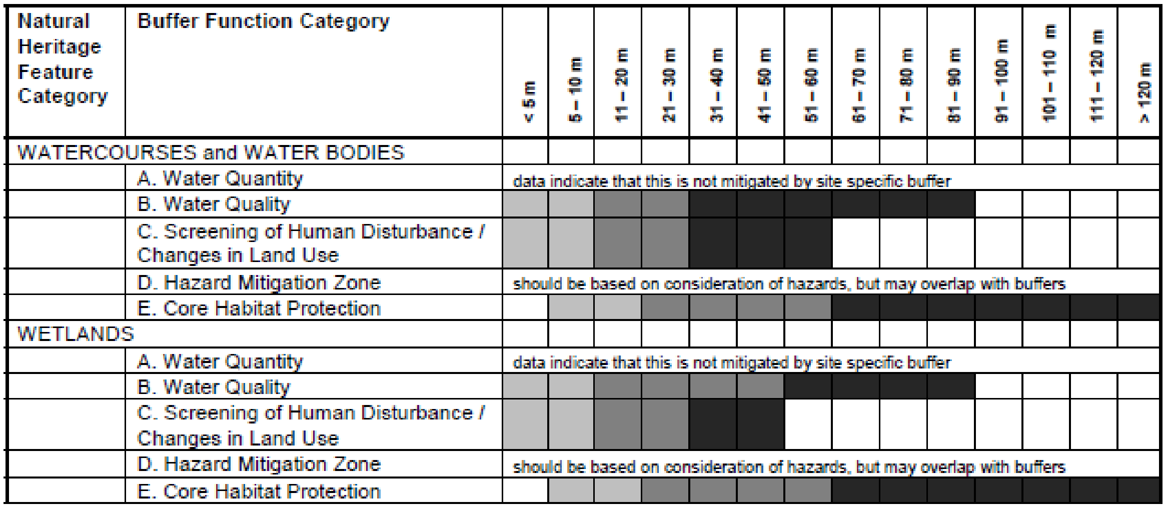
6.1 Variable Width Approach

The scientific literature indicates that buffer effectiveness depends on a combination of buffer characteristics, site-specific conditions, surrounding land uses, and the desired function(s) of the buffer. Applying a single buffer width across a variety of situations, therefore, may not adequately account for this variation (Castelle et al. 1994). Furthermore, using a fixed-width approach may lead to the minimum recommended buffer width becoming the standard width adopted in all situations, regardless of situations where a larger buffer might be more appropriate (Beacon 2012), or conversely, where a smaller buffer may achieve the desired protection.

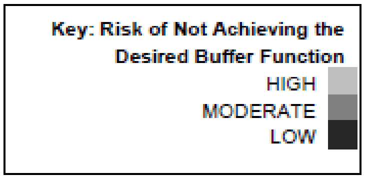
Numerous researchers thus advocate a more flexible approach in delineating buffer size, that is informed not only by the general science on buffer function, but also on local and landscape contexts (Castelle et al. 1994, Beacon 2012, Stutter et al. 2021). Yet, the fixed-width approach to buffers is typically used by planning authorities because it requires less technical knowledge of existing conditions and the underlying science on buffers, is more easily enforced, provides more regulatory certainty, and is less expensive and time-consuming than the alternative variable-width approach (Castelle et al. 1994, Beacon 2012).

Beacon (2012) describes a detailed buffer determination process that combines general scientific knowledge on buffer effectiveness with consideration of site-specific factors. The process begins with the identification of a 'Base Buffer Width', which is the lowest range of buffer widths identified in the literature as providing a specific buffer function (in other words, the range of buffer widths with the greatest risk of not achieving the desired function; Table 4). The next step is to increase the buffer width, as necessary, based on site-specific biophysical and land use considerations (such as hydrologic dynamics, slopes, buffer vegetation composition, and soils) and sensitivity of the natural heritage feature to be protected, to generate a 'Preliminary Buffer Width'. This 'Preliminary Buffer Width' may then be further adjusted depending on site-specific constraints or opportunities (Beacon 2012).

Table 4. Risk-based guidelines for buffer width determination (from Beacon 2012).



Natural Heritage Feature Category	**Buffer Function Category**	< 5 m	5 – 10 m	11 – 20 m	21 – 30 m	31 – 40 m	41 – 50 m	51 – 60 m	61 – 70 m	71 – 80 m	81 – 90 m	91 – 100 m	101 – 110 m	111 – 120 m	> 120 m
WATERCOURSES and WATER BODIES															
	A. Water Quantity	data indicate that this is not mitigated by site specific buffer													
	B. Water Quality	░	░	▒	▒	█	█	█	█	█	█				
	C. Screening of Human Disturbance / Changes in Land Use	░	░	▒	▒	█	█	█							
	D. Hazard Mitigation Zone	should be based on consideration of hazards, but may overlap with buffers													
	E. Core Habitat Protection		░	░	▒	▒	▒	▒	█	█	█	█	█	█	█
WETLANDS															
	A. Water Quantity	data indicate that this is not mitigated by site specific buffer													
	B. Water Quality	░	░	▒	▒	▒	▒	█	█	█	█				
	C. Screening of Human Disturbance / Changes in Land Use	░	░	▒	▒	█	█								
	D. Hazard Mitigation Zone	should be based on consideration of hazards, but may overlap with buffers													
	E. Core Habitat Protection		░	░	▒	▒	▒	▒	█	█	█	█	█	█	█



Key: Risk of Not Achieving the Desired Buffer Function

HIGH	░
MODERATE	▒
LOW	█

HESL (2014) assessed existing site evaluation guidelines for waterfront development used by conservation authorities in eastern Ontario, which included consideration of buffer determination. The review examined the site evaluation guidelines recommended in the "Rideau Lakes Basin Carrying Capacities and Proposed Shoreland Development Policies" (the 'Rideau Lakes Study", Michalski and Usher, 1992). Biophysical site characteristics were examined by Michalski and Usher (1992) to determine shoreline setbacks via a scoring system. The authors acknowledged that the approach "*has not been developed on the basis of reams of data collected in a rigorous and scientific fashion; rather, it represents the results of our experience in applying and implementing development setbacks in a wide range of biophysical landscapes across Ontario for a variety of environmental protection and resource management purposes*." Several references were cited by Michalski and Usher (1992) to support the attributes of individual site characteristics and the subsequent development scores identified. HESL (2014) determined that the Rideau Lakes study was thorough and provided an abundance of information at both the regional and site-specific scales allowing for development of effective policy aimed at reducing the impacts of shoreline development on water quality. Review of site evaluation guidelines included an update to the site-specific biophysical criteria , which are presented in **Error! Reference source not found.** and **Error! Reference source not found.**.

Table 5. Updated biophysical criteria for shoreline setbacks.

Site Characteristic	**Criteria**			**Score**
Soil Depth	**Depth (cm)**			
	>150			0
	100-150			2
	75-100			4
	50-75			6
	25-50			8
	<25			10
Soil Texture	**Type**	**Percolation Rate**	**Phosphorus Retention Capability**	
	Coarse sand and gravel	Excessively rapid	Low	10
	Silty clay and clay	Low to impermeable	High	7
	Well-graded sands	Permeable to moderate	Low to medium	5
	Silty sand, clayey sand, silt and fine sand	Moderate to low	Medium to high	3
	Sandy loam	Moderate to low	Medium to high	3
	Loam	Permeable to moderate	Medium to high	0
Soil Analysis	If native soil between tile field and lake is > 1m deep, <1% $CaCO_3$ and >1% Iron/Aluminum			-10
Slope	**Slope Class**			
	0%-13%			0
	13%-20%			8
	20%-25%			10
	>25%			12
Vegetation	**Vegetation Cover Type**			
	Undisturbed woodlands, old fields, and meadows			0
	Disturbed woodlands, old fields, and meadows			3
	Close-seeded legumes (clover, alfalfa) and rotation meadows			5
	Row crops			7
	Fallow fields and base bedrock outcrops			10

Once criteria have been evaluated and scored based on biophysical characteristics (Table 5), the results are used to determine the shoreline buffer width as presented as “horizontal setback distance” by Michalski and Usher in the Rideau Lakes Study.

Table 6. Biophysical site scores and recommended shoreline buffer.

Total Score	Recommended Depth of Shoreline Buffer (m)
36-40	90
31-35	80
26-30	70
21-25	60
16-20	50
11-15	40
≤10	30

Consideration of site-specific information and determination of individual shoreline buffer sizes is challenging to complete on a large scale. It is also challenging to characterize general conditions that influence buffer effectiveness at a large watershed or County scale because of the variability in site conditions and characteristics of adjacent waterbodies. Nonetheless, the variable width approaches described highlight the importance of considering site-specific factors in determining suitable buffer widths.

6.2 Lake Classification

The primary purpose of lake classification is to group lakes with similar characteristics or management needs so that appropriate management tools (e.g., buffer sizes) can be applied to protect desired attributes from the impacts of shoreline development. The complexity of the classification approaches and information requirements can vary considerably from the use of complex models to more simple qualitative approaches.

Lake classification is an effective management tool because it is not a “one size fits all approach” and individual characteristics of the lake, watershed, existing development, and social factors can be accounted for across a large area. Classification allows for planning decisions or the scaling of BMPs to be determined objectively even if the initial selection of classification criteria is subjective. Importantly, classification schemes can be tailored depending on information and resource availability, which is especially important when attempting to classify a large number of lakes over large spatial scales, with variable data availability and often limited resources, as is the case in Ontario.

A challenge in completing the classification scheme is determining appropriate classification criteria. Criteria could include physical and biological lake characteristics (e.g., depth, flushing rate, shoreline irregularity, fishery, natural heritage features, past occurrences of algal blooms, invasive species, trends in concentrations of nutrients or other pollutants), “responsiveness” to phosphorus calculated using the Lakeshore Capacity Model, social factors (e.g., existing development and development pressure, distance to urban centres), and watershed characteristics (e.g., existing land use, soil conditions). The selection of classification criteria is dependent on several factors, including the information and resources that are available, the scale at which the classification is applied, and the intent of the classification (i.e., which attributes are being managed) and the available accepted management tools (e.g., minimum development standards, limits to amount and type of development, BMPs, etc.).

6.3 Lake Specific Management

Individual lake plans that address shoreline development can also be completed. The primary advantage of lake-specific approaches to managing shoreline development is that local concerns and/or lake-specific issues can be addressed, which may not be possible with a provincial or local government approach designed to accommodate more general jurisdiction-wide issues. Disadvantages of this approach can include difficulty in reaching consensus on issues, and resource requirements (technical and financial support). Resource requirements can be substantial to conduct required studies, develop development standards to address concerns and implement the recommendations into planning.

7. Summary/Conclusion

Shoreline buffers can play an important role in protecting lake health. The physical separation they provide between upland human activity and the aquatic environment can aid in mitigating the effects of development and site alteration on water quality, erosion and flood control, and wildlife habitat. However, no single type or size of buffer will perform optimally in all conditions, and determination of buffer characteristics should consider a variety of factors, including the desired function of the buffer, the sensitivity of the adjacent aquatic environment, the intensity of the land use, and site-specific physical features, such as slope, hydrology, and soil type. Characterizing these factors and developing static buffer requirements informed by scientific research over a large landscape is, however, extremely challenging.

The scientific literature on shoreline buffers over the past 30 years has largely focused on watercourses and wetlands, and the impacts of agriculture and forestry. Relatively little research has examined buffer performance in protecting lakes from shoreline development. While this gap in knowledge should be addressed, the existing literature on buffers can still provide useful information that can be applied to the lake context.

Shorelines provide numerous benefits and in general, larger buffers are better at consistently providing a range of protective functions. Castelle et al. (1994) noted that a 15 m buffer is the minimum size necessary to maintain physical and chemical functions while 30 m is the minimum necessary to maintain biological functions. Efficient removal of pollutants (notably sediment) can occur in buffers of 10-20 m width, but other pollutants (such as nutrients) may require buffer widths of 30 m or more for effective attenuation. Water quality improvements generally increase with buffer size (e.g., 10 m removes 65% of sediment from overland runoff while 30 m removes 85% of sediment from overland runoff; Sweeney and Newbold 2014). Larger buffers are also better at protecting the diversity of aquatic and terrestrial species that rely on shorelines. Semi-aquatic species, such as amphibians and reptiles, can use terrestrial habitat up to 300 m inland from the water’s edge. Some turtle species nest up to 80 m inland. Waterbirds may react to human activity close to their nests, and loons may require several hundred metres between their nests and development.

Site specific factors and the characteristics of the buffers are important. Low to moderate slopes (<10%) appear to positively influence sediment removal, while steeper slopes have a negative effective on performance. It is challenging determining how site-specific factors should influence buffer size over a large geographic range, but lake classification and lake specific management plans are two potential tools that could be utilized to generalize characteristics of the shoreline and sensitivities of the adjacent waterbody.

Natural vegetation is better able to trap pollutants and stabilize shorelines than manicured lawn due to deeper roots. Furthermore, native vegetation does not require the use of fertilizers, herbicides and pesticides, provides improved habitat for terrestrial and aquatic species, and does not attract nuisance species such as Canada Geese, which can add to the nutrient loading to a lake. Maintaining natural shorelines also provides privacy, increases property value, and contributes to the aesthetic quality of the

The scientific literature demonstrates that a 30 m buffer generally provides a range of ecological services, and this buffer size is commonly recommended in the peer-reviewed literature focused on shoreline development, aligning with Provincial guidance. While smaller buffers provide some benefits for water quality and aquatic habitat protection, larger buffers provide more ecological services, more completely. Buffers will likely become more important in protecting lake health as climate change effects on freshwater systems continue to intensify. Buffer recommendations are often included in municipal and provincial policies but are seldom enforced, so the theoretical debate of buffer size is outweighed by the reality on the land. To be truly effective, buffer recommendations based on the best available science, and informed by the jurisdictional review and public consultation, will need to be implemented and enforced consistently across the County.

8. Literature Cited

Abrahams, C. 2008. Climate change and lakeshore conservation: a model and review of management techniques. Hydrobiologia 613: 33-43.

Amato, M. S., B. R. Shaw, E. Olson, N. Turyk, K. Genskow, and C. F. Moore. 2016. The challenge of motivated cognition in promoting lake health among shoreline property owners: biased estimation of personal environmental impact. Lake and Reservoir Management 32(4): 386-391.

Beacon Environmental Ltd. (Beacon) 2012. Ecological Buffer Guideline Review. Prepared for Credit Valley Conservation. 139 pp.

Borre, L., R. L. Smyth, and E. A. Howe. 2016. At the forefront of shoreline management. Lakeline Summer 2016: 8-13.

Castelle, A. J., A. W. Johnson, and C. Conolly. 1994. Wetland and stream buffer size requirements – a review. Journal of Environmental Quality 23(5): 878-882.

Cole, F. R., A. Junker, C. R. Bevier, M. Shannon, S. Sarkar, and P. J. Nyhus. 2018. Assessing LakeSmart, a community-based lake protection program. Journal of Environmental Studies and Sciences 8: 264-280.

Croft-White, M. V., M. Cvetkovic, D. Rokitnicki-Wojcik, J. D. Midwood, and G. P. Grabas. 2017. A shoreline divided: Twelve-year water quality and land cover trends in Lake Ontario coastal wetlands. Journal of Great Lakes Research 43: 1005-1015.

Czarnecka, M. 2016. Coarse woody debris in temperate littoral zones: implications for biodiversity, food webs and lake management. Hydrobiologia 767: 13-25.

Dillon, P.J., W.A. Scheider, R.A. Reid and D.S. Jeffries. 1994. Lakeshore Capacity Study : Part 1 – Test of effects of shoreline development on the trophic status of lakes. Lake and Reservoir. Management 8 : 121 – 129.

Environment Canada. 2013. How much habitat is enough? Third edition.130 pp.

Fleming, R., and H. Fraser. 2001. The Impact of Waterfowl on Water Quality – Literature Review. University of Guelph.

France, R. F., R. Peters, L. McCabe. 1998. Spatial relationships among boreal riparian trees, litterfall and soil erosion potential with reference to buffer strip management and coldwater fisheries. Annales Botanici Fennici 35: 1-9.

Francis, T. B. and D. E. Schindler. 2006. Degradation of littoral habitats by residential development: woody debris in lakes of the Pacific Northwest and Midwest, United States. Ambio 35(6): 274-280.

Francis, T. B. and D. E. Schnidler. 2009. Shoreline urbanization reduces terrestrial insect subsidies to fishes in North American lakes. Oikos 118(12): 1872-1882.

Gabriel, A. O. and L. R. Bodensteiner. 2011. Impacts of riprap on wetland shorelines, Upper Winnebago Pool Lakes, Wisconsin. Wetlands 32: 105-117.

Goforth, R. R. and S. M. Carman. 2005. Nearshore community characteristics related to shoreline properties in the Great Lakes. Journal of Great Lakes Research 31 (Supp1): 113-128.

Government of Ontario. 2000. Extension Notes – Preserving and Restoring Natural Shorelines.

Government of Ontario and Department of Fisheries and Oceans (DFO). 2000. Extension Notes – Buffers Protect the Environment.

Government of Ontario. 2009. Lake Simcoe Protection Plan.

Government of Ontario. 2010. Lakeshore Capacity Assessment Handbook : Protecting Water Quality in Inland Lakes.

Government of Ontario. 2017a. Niagara Escarpment Plan (2017). 161 pp.

Government of Ontario. 2017b. Greenbelt Plan (2017). 98 pp.

Government of Ontario. 2017c. Oak Ridges Moraine Conservation Plan (2017). 88 pp.

Guildford, S., and R. E. Hecky. 2000. Total nitrogen, total phosphorus, and nutrient limitation in lakes and oceans: Is there a common relationship? Limnology and Oceanography. 45(6): 1213-1223.

Hampton, S. E., S. C. Fradkin, P. R. Leavitt, E. E. Rosenberger. 2011. Disproportionate importance of nearshore habitat for the food web of a deep oligotrophic lake. Marine and Freshwater Research 62: 350-358.

Helmus, M. R. and G. G. Sass. 2008. The rapid effects of a whole-lake reduction of coarse woody debris on fish and benthic macroinvertebrates. Freshwater Biology 53: 1423-1433.

Hicks, A. L. and P. C. Frost. 2011. Shifts in aquatic macrophyte abundance and community composition in cottage developed lakes of the Canadian Shield. Aquatic Botany 94: 9-16.

Hutchinson Environmental Sciences Ltd. (HESL). 2014. Assessment of Municipal Site Evaluation Guidelines for Waterfront Development in Eastern Ontario's Lake Country. Prepared for Mississippi Valley Conservation Authority, Rideau Valley Conservation Authority and Cataraqui Region Conservation Authority.

Kardynal, K. J., J. L. Morissette, S. L, Van Wilgenburg, E. M. Bayne, K. A. Hobson. 2011. Avian responses to experimental harvest in southern boreal mixedwood shoreline forests: implications for riparian buffer management. Canadian Journal of Forestry Research 41: 2375-2388.

Lemberg, D. S. and R. Fraser. 2005. The residential lakeshore access allocation problem: minimizing barrier effects on shoreline habitat buffers. Environmental Modeling and Assessment 10: 265-276.

Mayer, P. M., S. K. Reynolds, Jr., T. J. Canfield, M. D. McCuthchen. 2005. Riparian Buffer Width, Vegetative Cover, and Nitrogen Removal Effectiveness: A Review of Current Science and Regulations. U.S. Environmental Protection Agency. 40 pp.

McDonnell, J. 2012. Naturally Vegetated Shoreline Buffers - An overview of the benefits and the science. Ministry of Natural Resources. 10 pp.

Merrell, K., J. Deeds, M. Mitchell, and R. Bouchard. 2013. Determining if Maine's Mandatory Shoreland Zoning Act Standards are Effective at Protecting Aquatic Habitat. Vermont Department of Environmental Conservation and Maine Department of Environmental Protection. 14 March 2013. 26 pp.

Muskoka Watershed Council. 2013. Shoreline Vegetative Buffers. 14 pp.

Ontario Ministry of Natural Resources (OMNR). 2000. Extension Notes- Preserving and Restoring Natural Shorelines.

OMNR and Department of Fisheries and Oceans (DFO). 2000. Extension Notes – Buffers Protect the Environment.

OMNR. 2010. Natural Heritage Reference Manual for Natural Heritage Policies of the Provincial Policy Statement, 2005, Second Edition. Toronto: Queen’s Printer for Ontario. 248 pp.

Owens, M. C., C. J. Williams, and J. M. Haynes. 2021. Effects of forested buffers on benthic macroinvertebrate indicators of water quality in the Western Finger Lakes, New York. Inland Waters 11(1): 78-88.

Paterson, A.M., P.J. Dillon, N.J. Hutchinson, M.N. Futter, B.J. Clark, R.B. Mills, R.A. Reid and W.A. Scheider. 2006. A review of the components, coefficients and technical assumptions of Ontario’s Lakeshore Capacity Model. Lake and Reservoir Management 22(1): 7 – 18.

Paerl, H. W. and J. Huisman, 2008: Blooms like it hot. Science 320:57-58.

Ramesh, R., L. Kalin, M. Hantush, and A. Chaudhary. 2021. A secondary assessment of sediment trapping effectiveness by vegetated buffers. Ecological Engineering 159: 106094.

Roth, E. D. 2005. Buffer zone applications in snake ecology: a case study using Cottonmouths (*Agkistrodon piscivorus*). Copeia 2005(2): 399-402.

Sargac, J., R. K. Johnson, F. J. Burdon, A. Truchy, G. Rîşnoveanu, P. Goethals, and B. G. McKie. 2021. Forested riparian buffers change the taxonomic and functional composition of stream invertebrate communities in agricultural catchments. Water 13: 1028.

Schindler, D.W., R. E. Hecky, D. L. Findlay, M. P. Stainton, B. R. Parker, M. J. Paterson, K. G. Beaty, M. Lyng, and S. E. M. Kasian. 2008. Eutrophication of lakes cannot be controlled by reducing nitrogen input: Results of a 37-year whole-ecosystem experiment. Proceedings of the National Academy of Sciences of the United States of America (PNAS) 105(32): 11254-11258.

Semlitsch, R. D. 1998. Biological delineation of terrestrial buffer zones for pond-breeding salamanders. Conservation Biology 12(5): 1113-1119.

Semlitsch, R. D. and J. R. Bodie. 2003. Biological criteria for buffer zones around wetlands and riparian habitats for amphibians and reptiles. Conservation Biology 17(5): 1219-1228.

Spilman, C. A., N. Schoch, W. F. Porter, and M. J. Glennon. 2014. The effects of lakeshore development on Common Loon (Gavia immer) productivity in the Adirondack Park, New York, USA. Waterbirds 37(sp1): 94-101.

Steedman, R. J., R. S. Kusherneriuk, R. L. France. 2001. Littoral water temperature response to experimental shoreline logging around small boreal forest lakes. Canadian Journal of Fisheries and Aquatic Sciences 58: 1638-1647.

Steen, D. A., J. P. Gibbs, K. A. Buhlmann, J. L. Carr, B. W. Compton, J. D. Congdon, J. S. Doody, J. C. Godwin, K. L. Holcomb, D. R. Jackson, F. J. Janzen, G. Johnson, M. T. Jones, J. T. Lamer, T. A. Langen, M. V. Plummer, J. W. Rowe, R. A. Saumure, J. K. Tucker, and D. S. Wilson. 2012. Terrestrial habitat requirements of nesting freshwater turtles. Biological Conservation 150: 121-128.

Steinberg, T. 2007. American Green: The Obsessive Quest for the Perfect Lawn.

Strayer, D. L. and S. E. G. Findlay. 2010. Ecology of freshwater shore zones. Aquatic Sciences 72: 127-163.

Stutter, M., B. Kronvang, D. Ó hUallacháin, and J. Rozemeijerc. 2019. Current insights into the effectiveness of riparian management, attainment of multiple benefits, and potential technical enhancements. Journal of Environmental Quality 48: 236-247.

Sweeney, B. W. and J. D. Newbold. 2014. Streamside forest buffer width needed to protect stream water quality, habitat, and organisms: a literature review. Journal of the American Water Resources Association 50(3): 560-584.

Taillon, D. and M. G. Fox. 2004. The influence of residential and cottage development on littoral zone fish communities in a mesotrophic north temperate lake. Environmental Biology of Fishes 71: 275-285.

Wehrly, K. E., J. E. Breck, L. Wang, and L. Szabo-Kraft. 2012. Assessing local and landscape patterns of residential shoreline development in Michigan lakes. Lake and Reservoir Management 28: 158-169.

Whitaker, D. M. and W. A. Montevecchi. 1999. Breeding bird assemblages inhabiting riparian buffer strips in Newfoundland, Canada. Journal of Wildlife Management 63(1): 167-179.

Winter, J.G., A.M. DeSellas, R. Fletcher, L. Heinsch, A. Morley, L. Nakamoto and K. Utsumi. 2011. Algal blooms in Ontario, Canada: Increases in reports since 1994. Lake and Reservoir Management 27(2): 107-114.

Woodard, W. E. and C. A. Rock. 1994. Control of residential stormwater by natural buffer strips. Lake and Reservoir Management 11(1): 37-45.

Zhang, X., Z. Liu, M. Zhang, R. A. Dahlgren, and M. Eitzel . 2010. A review of vegetated buffers and a meta-analysis of their mitigation efficacy in reducing nonpoint source pollution. Journal of Environmental Quality 39: 76-84.

Appendix A. Literature Review Summary

Appendix A.   Literature Review Summary

Title	Authors	Year	Source	Focus	Findings
Wetland and stream buffer size requirements - a review	A. J. Castelle, A. W. Johnson, C. Conolly	1994	Journal of Environmental Quality 23: 878-882	buffers: water quality	•3-200 m found effective depending on site, 15 m met most conditions (chemical and physical), but larger needed to cover biological functions (30 m+) •smaller buffer size adequate when in good condition (dense native vegetation, undisturbed soils), low functional value of wetland or stream (highly disutrbed, dominated by non-native plants), and low-impact adjacent land uses (e.g., parkland, low density residences) •larger buffer size needed when buffers in poor condition, with intense land uses adjacent, and higher value water feature
Control of residential stormwater by natural buffer strips	S. E. Woodard, C. A. Rock	1995	Lake and Reservoir Management 11(1): 37-45	buffers: water quality	•evaluated buffer ability to remove phosphorus and suspended solids from residential stormwater under different slopes (1-5% slope vs 10-15%) •inputs from either subdivision or condominium complex •found that residential runoff relatively high in P and suspended solids, especially during the construction phase •buffer effectiveness highly variable, but generally 15 m natural buffer effective in reducing P concentrations to background values observed at control site •ground cover had greater impact on removal ability than slope
Spatial relationships among boreal riparian trees, litterfall and soil erosion potential with reference to buffer strip management and coldwater fisheries	R. F. France, R. Peters, L. McCabe	1998	Annales Botanici Fennici 35: 1-9	buffers:erosion control	•litter cover protects ground from raindrop impact, thereby reducing soil erosion •found litter production in boreal riparian buffer strips (0-20 m from shorelines) lower than in adjacent upland forest (20 to 50 m upslope), due to presence of smaller trees, dominance of coniferous species, and bare exposed bedrock in foreshore •suggests riparian zones in these northwestern ON lakes have less potential to buffer receiving waters from watershed clearcutting then previously thought
Biological delineation of terrestrial buffer zones for pond-breeding salamanders	R. D. Semlitsch	1998	Conservation Biology 12(5): 1113-1119	buffers: wildlife habitat	•lack of clear understanding on extent of terrestrial habitat needed by wetland species, especially semi-aquatic organisms like salamanders •salamanders found average 125 m (adults) and 70 m (juveniles) from edge of aquatic habitats •assuming buffer zone encompasses 95% of population, would need to extend 164 m from wetland's edge into terrestrial habitat for salamander species studied
Breeding bird assemblages inhabiting riparian buffer strips in Newfoundland, Canada	D. M. Whitaker, W. A. Montevecchi	1999	Journal of Wildlife Management 63(1): 167-179	buffers: wildlife habitat	•compared breeding bird assemblages in undisturbed shoreline habitats vs. those in 20-50 m wide riparian buffer strips in boreal forests subject to timber harvesing in Newfoundland •total abundance higher in buffer strips due to presence of species associated with clearcut edge habitats and greater abundance of ubiquitous species •riparian buffer strips supported diverse avian assemblage including many riparian and woodland species •interior forest species were rare even in widest buffers (40-50 m)
Elevated numbers of flying insects and insectivorous birds in riparian buffer strips	D. M. Whitaker, A. L. Carrol, W. A. Montevecchi	2000	Canadian Journal of Zoology 78(5): 740-747	buffers: wildlife habitat	•compared abundance of flying insects along undisturbed lakeshores and riparian buffer strips in clearcuts in boreal Newfoundland forest •significantly more insects captured in buffers likely because they act as windbreaks, collecting airborne insects blown in from adjacent clearcuts and lakes •found concurrent increased abundance of insectivorous birds in buffers vs. undisturbed shorelines, possibly due to increased prey availability

Littoral water temperature response to experimental shoreline logging around small boreal forest lakes	R. J. Steedman, R. S. Kusherneriuk, R. L. France	2001	Canadian Journal of Fisheries and Aquatic Sciences 58: 1638-1647	littoral water temperature	•shoreline logging did not significantly increase average littoral water temperatures in two small boreal forest lakes in northwester Ontario •however, clearcut shorelines had maximum littoral water temperatures 1-2 C greater and increases of 0.3-0.6 C in average diurnal temperature range during early summer compared with undisturbed shorelines or shorelines with 30 m buffer •increased temperatures due to daytime heating
Biological criteria for buffer zones around wetlands and riparian habitats for amphibians and reptiles	R. D. Semlitsch, J. R. Bodie	2003	Conservation Biology 17(5): 1219-1228	buffers: wildlife habitat	•reviewed terrestrial habitat requirements of 19 frog, 13 salamander, 5 snake and 28 turtle species •core terrestrial habitat for amphibians ranged from 159-290 m •core terrestrial habitat for reptiles ranged from 127-289 m
Urban lakes and waterbirds: effects of development on avian behavior	A. H. Traut, M. E. Hostetler	2003	Waterbirds 26(3): 290-302	wildlife habitat	•studied waterbirds along developed and undeveloped shorelines on 4 partially developed urban lakes in Florida •found that many species appeared to favour developed shorelines for a variety of behaviours (e.g., foraging, resting, tending young) •alert/fleeing behaviour observed less frequently along developed shoreline suggesting habituation to localized human disturbance •suggest that undeveloped shoreline may serve as important refuge for birds more sensitive to human disturbance or developed habitat •dense stands of tall emergent vegetation along undeveloped shoreline may limit waterbird behaviour
Quantitative review of riparian buffer width guidelines from Canada and the United States	P. Lee, C. Smyth, S. Boutin	2004	Journal of Environmental Management 70: 165-180	buffers	•reviewed guidelines for retention of treed riparian buffers after timber harvest •mean buffer widths ranged from 15-29 m •Boreal region had widest buffers, southeastern region had narrowest •common modifiers of guidelines were waterbody type and size, shoreline slope, and presence of fish •jurisdictions without modifiers for slope or fish applied wider baseline buffers vs. jursidications with these modifiers •buffer widths were generally protective for aquatic biota and habitats but generally less than recommended size for terrestrial biota
The influence of residential and cottage development on littoral zone fish communities in a mesotrophic north temperate lake	D. Taillon, M. G. Fox	2004	Environmental Biology of Fishes 71: 275-285	wildlife habitat	•examined sites along development gradient (undeveloped, moderately developed and high development) and habitat types •all fish life stages most abundant in moderately development sites •habitat had greater effect than development on fish abundance •absence of effects may be due to shallow sites, extensive macrophyte coverage throughout, and ongoing and previous disturbance due to Trent-Severn waterway (flooding, raised shorelines) •artificial structures may offset natural habitat that is lost •shoreline modification that does not reduce abundance of nearshore macrophytes or complexity of habitat does not appear to adversely affect fish diversity

Nearshore community characteristics related to shoreline properties in the Great Lakes	R. R. Goforth, S. M. Carman	2005	Journal of Great Lakes Research 31 (Supp1): 113-128	wildlife habitat	•benthic macroinvertebrate densities did not differ between shoreline types, but generally lower at nearshore sites with less stable substrates •shallow water prey fish CPUE and zooplankton densities generally lower for nearshore areas adjacent to developed mid-bluff shorelines and sites with less stable substrates •larger fish CPUE seemed unaffected by local shoreline and substrate properties in nearshore
The residential lakeshore access allocation problem: minimizing barrier effects on shoreline habitat buffers	D. S. Lemberg, R. Fraser	2005	Environmental Modeling and Assessment 10: 265-276	buffers	•lower impact landscaping with native species, retaining natural cover except for access paths, becoming more popular along lakeshore developments •provides lower costs to developers, more privacy to homeowner, and preservation of lakeshore aesthetics drawing people to the lakes in the first place •developed mathematical model to select shared access to lakeshore environment from lakeshore homes while protecting shoreline habitat
Riparian Buffer Width, Vegetative Cover, and Nitrogen Removal Effectiveness: A Review of Current Science and Regulations	P. M. Mayer, S. K. Reynolds, Jr., T. J. Canfield, M. D. McCuthchen	2005	U.S. Environmental Protection Agency	buffers: water quality	•found nitrogen removal effectiveness varied widely among riparian zones studied, but overall average 74% effectiveness •subsurface removal of N often high (90% average effectiveness), but did not appear related to buffer width •surface removal of N partly related to buffer width and was generally inefficient (33% average effectiveness) •some narrow buffers (1-15 m) removed significant proportions of N (up to 96% effectiveness), but narrow buffers sometimes contributed to N loads in riparian zones also •wider buffers (>50 m) more consistently removed significant portions of N (e.g., 58-100% effectiveness) •various vegetation types(grass, grass/forest, forest, forest/wetland, wetland) were equally effective at removing N in subsurface but not in surface flow •calculated that 3 m buffer predicted to have 50% removal effectiveness vs. 28 m (75%) vs. 112 m (90%) •findings suggest that soil type, watershed hydrology and subsurface biogeochemistry may be more important factors affecting N removal than vegetation type or buffer width
Buffer zone applications in snake ecology: a case study using Cottonmouths (*Agkistrodon piscivorus*)	E. D. Roth	2005	Copeia 2005(2): 399-402	buffers: wildlife habitat	•radio-telemetry study of riparian snakes •found 83% observation within 10 m of stream, but gravid females found up to 94 m from shoreline •highlight importance of terrestrial areas adjacent to wetlands and riparian habitat as critical to persistence of riparian taxa
Degradation of littoral habitats by residential development: woody debris in lakes of the Pacific Northwest and Midwest, United States	T. B. Francis, D. E. Schindler	2006	Ambio 35(6): 274-280	coarse woody debris	•residential development had a strong negative effect on CWD and riparian forest characteristics •strong positive correlation between riparian forest density and littoral CWD abundance
Stopover habitat along the shoreline of northern Lake Huron, Michigan: emergent aquatic insects as a food resource for spring migrating landbirds	R. J. Smith, F. R. Moore, C. A. May	2007	Auk 124(1): 107-121	wildlife habitat	•found higher arthropod biomass estimates at shoreline vs. inland habitats in spring •suggests more arthropod prey (insects and spiders) available for warblers at shoreline habitats (<0.4 km of shoreline) than inland (>0.4 km) • during spring migration

Climate change and lakeshore conservation: a model and review of management techniques	C. Abrahams	2008	Hydrobiology 613: 33-43	climate change	•climate change has broad effects on freshwater systems including -increased water temperatures -increased sedimentation and pollution, including greater nutrient levels, entering systems -changes to hydrology (especially through more winter runoff and less snowmelt in spring) •increased seasonal variability in precipitation, river flows, evapotransporation due to more intense and frequent flooding and droughts
The significance of littoral and shoreline habitat integrity to the conservation of lacustrine damselflies (Odonata)	R. G. Butler, P. G. deMaynadier	2008	Journal of Insect Conservation 12: 23-36	wildlife habitat	•diversity and composition of damselfly assemblages related to abundance and richness of littoral zone macrophytes, extent of riparian disturbance, benthic substrate granularity, and lake productivity •protection of littoral and shoreline habitat integrity (espcially emergent and floating macrophytes) critical to conservation of lacustrine biodiversity
The rapid effects of a whole-lake reduction of coarse woody debris on fish and benthic macroinvertebrates	Helmus, M. R. and G. G. Sass	2008	Freshwater Biology 53: 1423-1433	coarse woody debris	•whole-lake experiment removed ~70% littoral CWD in one basin and retained 100% CWD in other basin •Yellow perch most abundant fish prior to experiment, declined to very low densities in treatment basin after manipulation •no evidence of effects on macroinvertebrates
Shoreline urbanization reduces terrestrial insect subsidies to fishes in North American lakes	Francis, T. B. and D. E. Schnidler	2009	Oikos 118(12): 1872-1882	terrestrial insect subsidies	•quantified effects of lakeshore urbanization on terrestrial insect subsidies to fish •found negative correlation between subsidies and shoreline development •terrestrial inscets made up 100% of fish diet mass in undeveloped lakes vs 2% in developed lakes •trout in undeveloped lakes had average 50% greater daily energy intake (up to 50% comprised of terrestrial prey)
Multiscale relationships between Great lakes nearshore fish communities and anthropogenic shoreline factors	R. R. Goforth, S. M. Carman	2009	Journal of Great Lakes Research 35: 215-223	wildlife habitat	•relationship between nearshore ecology and shoreline processes poorly understood •compared fish community between intact vs. modified shorelines •found some shallow water and nearshore fish community measures influenced by adjacent shoreline features, and several measures related to urban-residential land uses and shore structure of updrift shoreline areas, suggesting cumulative human influence operating over larger spatial scales •conclude that multi-scale management strategies needed for shorelines that address both local and cumulative, larger-scale environmental impacts to local nearshore biota
Ecology of freshwater shore zones	D. L. Strayer, S. E. G. Findlay	2010	Aquatic Sciences 72: 127-163	shore zone ecology	•shore zones among most productive and most threatened habitats in the world •shore zones are complexes of habitats with high biodiversity •shore zones dissipate large amounts of physical energy, can receive and process high volumes of autochtonous and allochthonous organic matter, and undergo intensive nutrient cycling •the ecological character of shore zones influenced by physical energy, geologic or anthropogenic structure, hydrologic regime, nutrient inputs, biota, and climate

A review of vegetated buffers and a meta-analysis of their mitigation efficacy in reducing nonpoint source pollution	X. Zhang, Z. Liu, M. Zhang, R. A. Dahlgren, M. Eitzel	2010	Journal of Environmental Quality 39: 76-84	buffers: water quality	•quantified role of buffer width, slope, soil type and vegetation type on pollutant removal efficacy •buffer width alone explains 37% (sediment), 60% (pesticides), 44% (nitrogen), and 35% (phosphorus) of total variance in removal efficacy •buffer slope was positively associated with sediment removal efficacy when slope ≤ 10% and negatively when slope ≥ 10% •buffers made of trees had higher N and P removal efficacy vs. those made of grasses or grasses and trees •soil drainage type did not have significant effect on efficacy •conclude that 30 m buffer under favourable slope conditions removes >85% of all the studied pollutants
Impacts of riprap on wetland shorelines, Upper Winnebago Pool Lakes, Wisconsin	A. O. Gabriel, L. R. Bodensteiner	2011	Wetlands 32: 105-117	shoreline hardening	•compared riprapped to natural sites •armoured shorelines had coarser, more compacted substrates with lower organic content; cooler temperatures with higher dissolved oxygen; and greater water clarity •natural sites had more abundant floating-leaved plants, more abundant and larger fish
Disproportionate importance of nearshore habitat for the food web of a deep oligotrophic lake	S. E. Hampton, S. C. Fradkin, P. R. Leavitt, E. E. Rosenberger	2011	Marine and Freshwater Research 62: 350-358	wildlife habitat	•shallow nearshore disproportionately important as feeding and breeding habitat for fish in large deep oligotrophic lakes •found salmonid predators derived >50% carbon from nearshore waters, even though this zone only made up 2.5% total lake volume in Washington State lake
Shifts in aquatic macrophyte abundance and community composition in cottage developed lakes of the Canadian Shield	A. L. Hicks, P. C. Frost	2011	Aquatic Botany 94: 9-16	macrophyte community	•examined 12 lakes across cottage development gradient vs. macrophyte communities at 0.5 and 1.5 m depths •macrophyte biomass declined with increasing cottage density and more developed lakes had less diversity and species richness at shallower (0.5 m) depth •cottage development strongly correlated with community species composition
Avian responses to experimental harvest in southern boreal mixedwood shoreline forests: implications for riparian buffer management	K.J. Kardynal, J. L. Morissette, S. L, Van Wilgenburg, E. M. Bayne, K. A. Hobson	2011	Canadian Journal of Forestry Research 41: 2375-2388	wildlife habitat	•compared responses of riparian and upland-nesting birds to 3 levels of forest harvesting near shorelines of boreal wetlands (0-50%, 50-75%, 75-100% clearing within 100 m of water) •upland-nesting species showed greatest declines in abundance of interior forest nesting species with the highest harvest levels •shrub-nesting and generalist species increased in abundance •riparian birds showed little response to harvest •suggests retention of small buffers may not be an effective management strategy for conservation of birds occupying shoreline forests
Ecological Buffer Guideline Review	Beacon Environmental Ltd.	2012		buffers	•buffers protect water quantity, water quality, core habitat, screen human disturbance/changes to land use, serve as hazard mitigation zone •recommended buffer width depends on function, site-specific factors and wider landscape context •research mainly in agricultural context and on watercourses •generally 10-100 m range recommended
Naturally Vegetated Shoreline Buffers - An overview of the benefits and the science	J. McDonnell, MNR	2012		buffers	•30 m common width in Ontario but no science supporting one-size-fits-all approach

Assessing local and landscape patterns of residential shoreline development in Michigan lakes	K. E. Wehrly, J. E. Breck, L. Wang, L. Szabo-Kraft	2012	Lake and Reservoir Management 28: 158-169	coarse woody debris	•evaluated relationships between residential development intensity and littoral zone habitat and disturbance characteristics in 332 Michigan lakes ≥ 4 ha •residential development had strong negative effects on woody debris •lakes with greater cumulative residential development had greater littoral zone impacts at local scales •larger lakes had greater impacts in littoral zone
Terrestrial habitat requirements of nesting freshwater turtles	D. A. Steen, J. P. Gibbs, K. A. Buhlmann, J. L. Carr, B. W. Compton, J. D. Congdon, J. S. Doody, J. C. Godwin, K. L. Holcomb, D. R. Jackson, F. J. Janzen, G. Johnson, M. T. Jones, J. T. Lamer, T. A. Langen, M. V. Plummer, J. W. Rowe, R. A. Saumure, J. K. Tucker, D. S. Wilson	2012	Biological Conservation 150: 121-128	wildlife habitat	•reviewed records of >8000 nests and gravid female records for 31 species in Canada and the US •distancing encompassing 95% of nests varied among species •in Ontario mean distances from water for nests were 33.5 m (Spotted Turtle), 35.7 m (Northern Map Turtle), 51.8 (Snapping Turtle), 71.2 m (Blanding's Turtle), and 77.8 m (Painted Turtle)
Determining if Maine's Mandatory Shoreland Zoning Act Standards are Effective at Protecting Aquatic Habitat	K. Merrell, J. Deeds, M. Mitchell, R. Bouchard	2013	Vermont Department of Environmental Conservation and Maine Department of Environmental Protection	buffers	•compared lakeshore development in Vermont and Maine to compare different approaches to lakeshore development standards in 2 states •Maine's Mandatory Shoreland Zoning Act requires land use controls for all land within 76 m of ponds; Vermont has no standards and relies on individual stewardship of lakeshores •studied 234 reference lakeshore sites and 151 unbuffered developed lakeshore sites on 40 lakes in Vermont vs. 13 reference lakeshore sites and 36 developed sites on 5 lakes in Maine •found MSZA effective tool for mitigating effects of shoreland development: only 1 parameter (# odonata exuviae), had statistical differences between developed and undeveloped reference sites in Maine vs. all parameters for Vermont developed and undeveloped reference sites
Assessment of Municipal Site Evaluation Guidelines for Waterfront Development in Eastern Ontario's Lake Country	HESL	2014		buffers	•shoreline development linked to potential for elevated nutrient inputs, which can lead to host of problems including reduced water clarity, reduced hypolimnetic oxygen, proliferation of algal blooms •slope and soil characteristics influence potential for phosphorus from shoreline development migrating to lake •shoreline buffers are BMP for mitigating P enrichment •slopes >25% too steep to act as shoreline buffers •slopes up to 13% can effectively attenuate sediments and P if vegetation well established and forest litter present, but steeper slopes require wider buffer widths •vegetation plantings in buffer should focus on native, tolerant species with deep-rooting potential

The effects of lakeshore development on Common Loon (*Gavia immer*) productivity in the Adirondack Park, New York, USA	C. A. Spilman, N. Schoch, W. F. Porter, M. J. Glennon	2014	Waterbirds 37(sp1): 94-101	wildlife habitat	•mean distance from nest site to nearest point of development was greater for successful vs. failed nests •presence of nesting pairs significantly related to increased shoreline length and decreased level of development •Loon chick hatching success significantly related to development density on small but not large lakes •amount of development not as important to nesting Loons as placement: clustering of development allows buffer for nesting areas
Streamside forest buffer width needed to protect stream water quality, habitat, and organisms: a literature review	B. W. Sweeney, J. D. Newbold	2014	Journal of the American Water Resources Association 50(3): 560-584	buffers: water quality/wildlife habitat	•wider buffers with more vegetation have greater capacity to intercept, sequester, degrade and process pollutants •grass buffer can adequately trap sediment and other contaminants, but more effective performance across greater number of functions achieved with forest buffer •focus on nitrogen and sediment removal •subsurface nitrate removal varied inversely with subsurface water flux, with wider buffers removing greater nitrogen under same water flux levels (89% for buffers >40 m vs. 55% median removal efficiency for buffers <40 m) •effective N removal at watershed scale likely requires buffers at least 30 m wide, with performance increasing above 30 m •10 m buffers trapped 65% sediment vs ~85% in 30 m buffers (mostly fine silts and clays make up difference) •protection for macroinvertebrates increases with presence of trees in buffer
The challenge of motivated cognition in promoting lake health among shoreline property owners: biased estimation of personal environmental impact	M.S. Amato, B. R. Shaw, E. Olson, N. Turyk, K. Genskow, C. F. Moore	2016	Lake and Reservoir Management 32(4): 386-391	perception of shoreline development	•property owners viewed own shoreline development as less harmful than it was judged by others •findings highlight barrier to outreach efforts to enlist property owner cooperation in mitigating habitat degradation from shoreline development
At the forefront of shoreline management	L. Borre, R. L. Smyth, E. A. Howe	2016	Lakeline Summer 2016: 8-13	effects of climate change on shorelines and lakes	•changing hydrology and water levels impact shorelines and lakes through erosion and sediment loading (flooding), and loss of wetland connectivity,exposure of aquatic vegetation in littoral zone (drought)
Coarse woody debris in temperate littoral zones: implications for biodiversity, food webs and lake management	M. Czarnecka	2016	Hydrobiologia 767: 13-25	coarse woody debris	•coarse woody debris provides stable habitat for many species in littoral zone of lakes with forested shorelines •creates spatial complexity in nearshore that promotes abundance, diversity and productivity of littoral biota •shoreline development reduces and modifies CWD entering lakes, resulting in (i) loss of fish spawning and refuge habitat, (ii) loss of food and habitat for benthic detritivores
A shoreline divided: Twelve-year water quality and land cover trends in Lake Ontario coastal wetlands	M. V. Croft-White, M. Cvetkovic, D. Rokitnicki-Wojcik, J. D. Midwood, G. P. Grabas	2017	Journal of Great Lakes Research 43: 1005-1015	water quality	•significant relationships between land cover and water quality index score at all scales (500, 1000, 2000 m wetland buffers, a quaternary watershed) but strongest at watershed scale

Inadequacy of best management practices for restoring eutrophic lakes in the United States: guidance for policy and practice	R. A. Osgood	2017	Inland Waters DOI 10.1080/20442041.2017.1368881	eutrophication	•examined effectiveness of watershed BMPs to restore eutrophic lakes •BMPs for P removal fall short of % required to restore lakes (generally require >80% external P reduction) but most BMPs provide 50% reduction (under ideal conditions) and <25% (in practice) •literature review found buffers remove 30-45% of upstream total P, but this results in no significant difference between P inputs and outputs •BMPs may be sufficient in small watersheds (<10x lake surface area), where external and internal P loading rates modest, or where incremental water quality improvement the goal, rather than restoration •in most cases effective P inactivation methods needed to mitigate internal P loading and intercept dissolved P in inflowing waters
A method for assessing shoreline stability of Alpine Lake, West Virginia	C. Rando, L. Hopkinson, M. O'Neal, J. Fillhart	2017	Journal of Contemporary Water Research & Eduction 160: 85-99	shoreline stability	•developed rapid stability assessment tool for lake shoreline based on measures of bank height, bank angle, erosion, armouring, wind and wave action, unconsolidated materials, protection measures, vegetation, and accretion •compared assessment results to observed erosion rates
Assessing LakeSmart, a community-based lake protection program	F. R. Cole, A. Junker, C. R. Bevier, M. Shannon, S. Sarkar, P. J. Nyhus	2018	Journal of Environmental Studies and Sciences 8: 264-280	water quality, BMPs	•participants in LakeSmart program more likely to recognize threat of declining water quality, adopt or enhance existing lake-friendly landscaping bmps, and help foster strong sense of community than non-participants
Current insights into the effectiveness of riparian management, attainment of multiple benefits, and potential technical enhancements	M. Stutter, B. Kronvang, D. Ó hUallacháin, J. Rozemeijer	2019	Journal of Environmental Quality 48: 236-247	buffers: water quality, wildlife habitat	•gaps in knowledge on capture and retention of soluble P and N in subsurface flows through buffers, impact of buffer design and management on terrestrial and aquatic habitats and species; effect of saturated buffers on greenhouse gas emissions •agricultural context
Effects of forested buffers on benthic macroinvertebrate indicators of water quality in the Western Finger Lakes, New York	M. C. Owens, C. J. Williams, J. M. Haynes	2021	Inland Waters 11(1): 78-88	buffers: macroinvertebrate indicators of water quality	•few studies examine effectiveness of buffers in reducing pollutant runoff to lakes (most focus on rivers and streams) •compared macroinvertebrate community composition between oligo-mesotrophic lakes with reforested watersheds (including shoreline buffer strips) and unprotected meso-eutrophic lakes with mix of land uses (mixed, forested, agricultural, developed) •found no difference in biotic index of water quality between lakes •subwatershed land use generally did not correlate with biotic indices of water quality within lakes •suggests nearshore forest buffers do not have significant impacts on benthic macroinvertebrate communities and their biotic indicators of water quality, instead these communities are likely infleunced by within-lake habitat conditions and legacy effects of agricultural land

A secondary assessment of sediment trapping effectiveness by vegetated buffers	R. Ramesh, L. Kalin, M. Hantush, A. Chaudhary	2021	Ecological Engineering 159: 106094	buffers: water quality	•meta-analysis to explore sediment removal capacity of riparian buffers (>90 studies) •assessed role of buffer width, length, area; vegetation characteristics; residence time and roughness (above-ground obstacles to runoff and sediment flow); area ratio (upland contributing area: buffer area); sediment loads; inflow and outflow volumes, flow rates •overall mean sediment removal efficiency 75% and median removal 82% •grass and mixed grass-woody vegetation buffers had higher efficiency than woody vegetation only buffers (but data limited on mixed and woody-only buffers) •buffer width influences efficiency, with 10-20 m buffer better able to trap sediment than smaller or larger width categories •could not identify any critical slope influencing effectiveness of sediment reduction by buffer •developed model describing relationship between buffer sediment removal efficiency, water inflow/outflow volume, and roughness, explaining 50% of variation •findings emphasize importance of considering flow parameters in buffer design
Forested riparian buffers change the taxonomic and functional composition of stream invertebrate communities in agricultural catchments	J. Sargac, R. K. Johnson, F. J. Burdon, A. Truchy, G. Rîşnoveanu, P. Goethals, B. G. McKie	2021	Water 13: 1028	buffers: wildlife habitat	•assessed how different riparian vegetation types influence stream invertebrate communities in agricultural landscapes •forested riparian buffers had greater shading, increased gravel content in stream substrates, and faster flow velocities •detected changes in invertebrate taxonomic composition in response to buffer presence: increase in sensitive Ephemeroptera, Plecoptera, Trichoptera taxa, increase in species with preference for gravel substrates and aerial active dispersal as adults

A Regulatory Guide to Achieving Environmental Net Gain at the Waterfront

PLANNING FOR OUR SHORELANDS

Watersheds CANADA

Citation:
Coyle, Darlene. (2022). A Regulatory Guide to Achieving Environmental Net Gain at the Waterfront. (Watersheds Canada). Retrieved from: https://watersheds.ca/planning-for-our-shorelands

This document was produced and reviewed by the Planning For Our Shorelands program steering committee:

- Cataraqui Conservation Authority
- Federation of Ontario Cottagers' Associations
- Friends of the Tay Watershed Association
- Janet Taylor
- The Land Between
- Mark Snider
- Mary Rae
- Watersheds Canada

The Planning For Our Shorelands program presents webinars and best practices resources to address common and very complex problems facing waterfront communities today by promoting an ecosystem-based approach in land use decision-making. By restoring shoreland vegetation, creating opportunities for environmental net gains, and promoting sustainable development practices, Planning for our Shorelands highlights natural climate solutions as holistic and resilient solutions to these common waterfront challenges. This program is led by Watersheds Canada, a national charitable organization (863555223RR0001): https://watersheds.ca/

Definition: Environmental Net Gain is an approach to ensure that (re)development leaves the natural environment in a measurably improved state compared to prior conditions.

Currently, very few municipalities mention Environmental Net Gain in their existing policies around waterfront development proposals. A more common requirement is to demonstrate that “no adverse effects” or “no negative impacts” will result from the proposed development, often demonstrated through an Environmental Impact Study. However, analyzing the net loss resulting from a single development proposal is difficult to determine because it does not consider the cumulative effects of development surrounding a waterbody and therefore is not a reliable gauge for sustainable development.

Instead, Environmental Net Gain emphasizes actions that can be made on any property to improve the natural environment (namely the shoreline and lake) as a result of the development plan. This includes properties where the existing development no longer meets the legal standards of the municipality (e.g., legally non-complying buildings and structures).

Environmental Net Gain Policies

Environmental Net Gain should be consistently highlighted throughout all policy documents, including the Official Plan, Zoning By-law, Site Alteration By-law, and Site Plan Control By-law, to address situations where development cannot avoid occurring within the regulated setback and to protect the ecological function of the land and adjacent water.

Examples of Environmental Net Gain Provisions

Innisfil Community Planning Permit By-law: "If a proposal does not achieve the requirements of Section 5.5.2(a), an overall net gain of shoreline vegetation shall be required." (s 5. 5. 2. 2.)

Lake of Bays Development Permit By-law: "If a proposal does not achieve the requirements of Sections 4.73 to 4.75, a Category 2 Council Variation Development Permit is required, and an overall net gain of shoreline vegetation shall be required." (s 4.77)

Rideau Lakes Site Plan Control Enforcement and Vegetated Shoreline Buffer Policy: "Natural shoreline buffers are often required as a result of a development application. When development occurs in and around sensitive natural areas a negative impact on the lake or river is anticipated. One of the easiest ways to offset this impact is to establish a natural shoreline buffer along your waterfront. This environmental 'net gain' allows landowners to complete their development project while ensuring environmental integrity is maintained." (pg. 5)

Muskoka Lakes Official Plan: "The role of natural vegetated shorelines in buffering waterbodies from erosion, siltation and nutrient migration adjacent to the sensitive littoral zone is critical to the protection of water quality. Preservation and restoration, where appropriate, of shoreline buffers is therefore required. The frontage of a lot will be maintained in a natural state to a target depth of 15 metres (50 feet) from the shoreline where new lots are being created and where vacant lots are being developed. Where lots are already developed and further development or redevelopment is proposed, these targets should be achieved to the extent feasible. Where these targets cannot be met, a net improvement over the existing situation is required." (s 6.5)

Using Environmental Net Gain

Implementing Environmental Net Gain

1. Ensure that Environmental Net Gain is clearly outlined in the Official Plan (OP), Zoning By-law (ZBL), and other relevant policies (see examples on previous page).
2. Upon receiving a development proposal, ensure the OP & ZBL standards can be met.
3. If standards cannot be met due to existing constraints, require an environmental net gain on the property as a condition for development to occur.
4. Follow up with the property to ensure environmental net gains are implemented and maintained.

If a site assessment determines that a development proposal cannot meet the Official Plan and Zoning standards due to site constraints, Environmental Net Gain may be a condition to allow development to proceed. Some examples of how to achieve this could include:

- ☐ Restoring and maintaining 75% of shoreline frontage with native vegetation. Emphasize planting the shoreline but they may also be planted along the side lot lines, or in front of the main dwelling, septic system, and other hardened areas.
- ☐ Maximizing building setback.
- ☐ Improving stormwater management methods (e.g., diverting water away from the waterbody and into a rain garden).
- ☐ Allowing one access point to the water through a winding narrow pathway made of porous materials (e.g., coarse gravel).
- ☐ Encouraging floating, pipe, or cantilevered docks to mitigate risk of erosion and destruction of fish spawning areas.
- ☐ Limiting dock size.
- ☐ Upgrading sewage disposal systems and moving them back at least 30 metres from the shoreline.
- ☐ Establishing "No Mow Zones".

No Mow Zones

Some site conditions may be unsuitable for planting due to their existing conditions such as shallow soil levels or rocky areas. In these cases, a "no mow zone" may be a suitable alternative to plantings. The area that is designated a "no mow zone" is to be left in its current condition, without any mowing, landscaping, or disturbances to allow the area to return to its natural state.

Note: Invasive species, which can appear in "no mow zones" and other vegetated areas, can prevent native plants from colonizing the area. It is recommended that invasive species are addressed prior to designating a "no mow zone" and the area's conditions are frequently monitored to ensure native species thrive.

As many of the above listed items as possible should be included in waterfront development applications to maximize the Environmental Net Gain on the property and ensure incremental improvements to protect the waterbody, hold the shoreline together, mitigate flood risks, provide wildlife habitat, and improve the overall natural aesthetic.

On the next pages are two resources to help a municipal planner with the review of waterfront development applications to identify suitable conditions to approve that would help achieve an Environmental Net Gain.

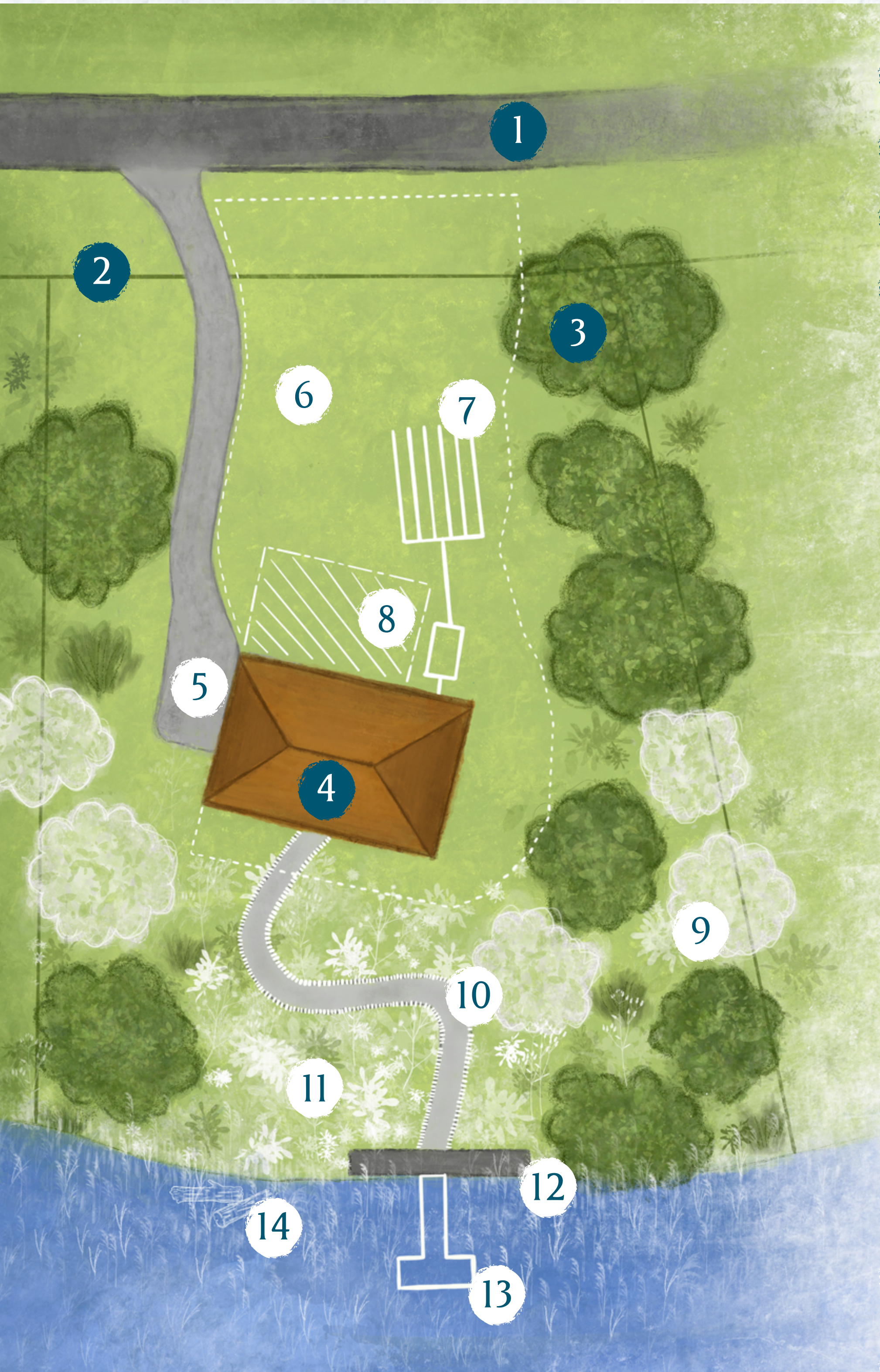
LAKEFRONT

ENVIRONMENTAL NET GAIN

Watersheds
CANADA

PLANNING FOR OUR
SHORELANDS

There are many things to consider when evaluating a waterfront redevelopment application. Below are recommended best practices for allowing development to proceed while taking steps to protect the natural environment and resilience of a waterfront property.



Existing Features

1. Road
2. Property line
3. Existing trees and vegetation
4. Dwelling

Environmental Net Gain Opportunities

5. Permeable driveway and stormwater detention measures
6. Minimized lawn area away from the shore
7. Updated waste water treatment system away from the lake
8. Proposed addition located away from the lake
9. Additional native trees and shrubs planted
10. Hard surface path is replaced with curved <1.5m wide permeable path
11. Native plants added to increase the vegetated shoreline buffer covering >75% of frontage
12. As existing concrete wall deteriorates, additional native vegetation is planted
13. Proposed floating dock
14. Maintain aquatic vegetation and fallen trees for wildlife habitat

www.watersheds.ca

PLANNING FOR OUR SHORELANDS

Watersheds CANADA

Recommended Actions for Waterfront Redevelopment Applications

This evaluation guide is to help municipal decision-makers assess redevelopment proposals through the lens of environmental sustainability. This document identifies opportunities for Environmental Net Gains over existing conditions in site plan control applications.

Note: Redevelopment is defined as an expansion to an existing structure or a rebuild of over 50% of the existing structure.

🟩 Consideration
🟦 Recommendation

🟩 Determine if there are site constraints limiting the applicant's compliance with minimum zoning standards (e.g., shoreline setback, sewage system setback).

🟦 Prohibit redevelopment from encroaching, wherever possible, into the shoreline setback (i.e., require additions to the back of the existing dwelling).

🟩 Determine if accessory structures (e.g., decks, patios, sheds, firepits, gazebos, sauna) can be relocated outside of the vegetated shoreline buffer.

🟦 Minimize accessory structures to be confined to a shoreline activity area that is no more than 25% of the water frontage. Move excess structures outside the vegetated shoreline buffer.

🟩 Determine if there is an opportunity to vegetate the shoreline. Are there grassy areas that can benefit from native planting?

🟦 Require revegetation of the shoreline with native species with a goal of vegetating 75%+ of the shoreline frontage. Designate the shoreline buffer as a "no mow zone".

🟩 In cases of significant shoreline site constraints, consider extending or restoring vegetation elsewhere on the property to compensate for environmental losses.

🟦 Require the landowner to create a planting plan as part of their site plan application (see "Shoreline Renaturalization Planting Plan Template" document).

🟩 Assess opportunities to improve stormwater management on the property to avoid erosion and surface runoff pollution.

🟦 Apply stormwater management best practices (e.g., rain garden, rain barrel, infiltration pits).

🟩 Assess existing and proposed infrastructure (e.g., sewage systems, pathways, driveway) to determine environmental impacts.

🟦 Upgrade or replace existing infrastructure where needed (e.g., faulty sewage systems, hardened to permeable surfaces)

PLANNING FOR OUR SHORELANDS

For more information, contact:

Watersheds Canada

shorelandproject@watersheds.ca

Watersheds Canada is a federally incorporated non-profit organization and registered Canadian charity (863555223RR0001). We are committed to providing programs in communities across the country to engage and help shoreline owners, students, and community groups enhance and protect the health of their lakes, rivers, and shorelines.

www.watersheds.ca

Ontario

Lakeshore Capacity Assessment Handbook: Protecting Water Quality in Inland Lakes

This document was developed to provide guidance to municipalities and other stakeholders responsible for the management of development along the shorelines of Ontario's inland lakes within the Precambrian Shield.

Preface

This Lakeshore Capacity Assessment Handbook has been prepared by the Ministry of the Environment in partnership with the ministries of Natural Resources and Municipal Affairs and Housing. It was developed to provide guidance to municipalities and other stakeholders responsible for the management of development along the shorelines of Ontario's inland lakes within the Precambrian Shield. While municipalities are not required to carry out lakeshore capacity assessment, this planning tool is strongly recommended by the Ontario government as an effective means of being consistent with the *Planning Act*, the Provincial Policy Statement (2005), the *Ontario Water Resources Act* and the federal *Fisheries Act*.

This document is based on the scientific understanding and the government policies in place at the time of publication. Questions about planning issues should be directed to the Ministry of Municipal Affairs and Housing. Scientific or technical questions dealing with water quality should be directed to the Ministry of the Environment. Questions concerning fisheries should be directed to the Ministry of Natural Resources.

Acknowledgements

This handbook is the outcome of more than three decades of scientific research and policy development. Lakeshore capacity assessment in Canada began in the 1970s with research conducted by Peter Dillon and F.H. Rigler. Researchers who contributed to the subsequent refinement of lakeshore capacity assessment and the development of the Lakeshore Capacity Model include B.J. Clark, P.J. Dillon, H.E. Evans, M.N. Futter, N.J. Hutchinson, D.S. Jeffries, R.B. Mills, L. Molot, B.P. Neary, A.M. Paterson, R.A. Reid and W.A. Scheider.

The preparation of the handbook was overseen by an inter-ministerial steering committee which included:

Ministry of the Environment: Victor Castro, Peter Dillon, Les Fitz, Fred Granek, Ron Hall, Bruce Hawkins, Heather LeBlanc, Gary Martin, Wolfgang Scheider (Chair), Doug Spry, Shiv Sud (past Chair);

Ministry of Natural Resources: John Allin, John Connolly, David Evans, Gareth Goodchild, Fred Johnson;

Ministry of Municipal Affairs and Housing: Kevin Lee

Many other provincial staff, too numerous to name individually, contributed to the development of this handbook. Technical writing assistance for the handbook was provided by Joanna Kidd from Lura Consulting and editorial assistance was provided by Carol Crittenden from Editorial Offload.

This version of the Handbook has been revised to reflect comments received during its posting on Ontario's Environmental Registry in 2008. Thanks also go to the municipal staff and the members of organizations who

assisted in the review of the handbook and provided many comments on its scope and contents. Their participation helped greatly to improve the document. These reviewers included:

- Judi Brouse – District Municipality of Muskoka
- Peter Bullock – City of North Bay
- Cliff Craig – Rideau Valley Conservation Authority
- Randy French – French Planning Services Inc.
- Roger Hogan – Former Township of Cardiff (amalgamated into the Municipality of Highlands East)
- Gerry Hunnius – Federation of Ontario Cottagers: Associations
- Neil Hutchinson – Hutchinson Environmental Sciences Ltd.
- Alex Manefski – Urban Development Institute
- Pat Martin – Municipality of Dysart et al
- Patrick Moyle – Association of Municipalities of Ontario
- Ron Reid – Federation of Ontario Naturalists
- Lorne Sculthorp – District Municipality of Muskoka

Executive summary

Purpose

This handbook has been prepared by the Ministry of the Environment in partnership with the Ministries of Natural Resources and Municipal Affairs and Housing to guide municipalities carrying out lakeshore capacity assessment of inland lakes on Ontario’s Precambrian Shield.

About lakeshore capacity assessment

Lakeshore capacity assessment (a generic term, but herein used to describe the Province’s recommended approach) is a planning tool that can be used to control the amount of one key pollutant — phosphorus — entering inland lakes on the Precambrian Shield by controlling shoreline development. High levels of phosphorus in lake water will promote eutrophication — excessive plant and algae growth, resulting in a loss of water clarity, depletion of dissolved oxygen and a loss of habitat for species of coldwater fish such as lake trout. While shoreline clearing, fertilizer use, erosion and overland runoff can all contribute phosphorus to an inland lake, the primary human sources of phosphorus are septic systems — from cottages, year- round residences, camps and other shoreline facilities. Lakeshore capacity assessment can be used to predict the level of development that can be sustained along the shoreline of an inland lake on the Precambrian Shield without exhibiting any adverse effects related to high phosphorus levels.

It should be emphasized that lakeshore capacity assessment addresses only some aspects of water quality — phosphorus, dissolved oxygen and lake trout habitat. Municipalities and lake planners also need to consider other pollutants (such as mercury, bacteria and petroleum products) and other sources of pollution (including industries, agriculture and boats). It must also be emphasized that water quality isn't the only important factor that should be considered in determining the development capacity of lakes. Factors such as soils, topography, hazard lands, crowding and boating limits may be as or more important than water quality. Finally, it’s important to emphasize that, to be effective, the technical process of carrying out lakeshore capacity assessment must be followed by implementation — in other words, the information obtained must be incorporated into municipal official plans and policies.

Benefits of lakeshore capacity assessment

Use of lakeshore capacity assessment by municipalities (along with proactive land-use controls) and enforcement of water-related regulations and bylaws will help to ensure that the quality of water in Ontario’s inland lakes is preserved. The protection of water quality will also protect environmental, recreational, economic and property values.

Lakeshore capacity assessment enhances the effectiveness of the land-use development process in many ways:

- It incorporates the concept of ecosystem sustainability in the planning process
- It is consistent with watershed planning
- It promotes land-use decisions that are based on sound planning principles
- It addresses many relevant aspects of the Provincial Policy Statement (2005), which came into effect on March 1, 2005. The Provincial Policy Statement is issued under section 3 of the *Planning Act*.
- It encourages land-use decisions that maintain or enhance water quality
- It encourages a clear, coordinated and scientifically sound approach that should reduce conflict among stakeholder groups
- It encourages a consistent approach to lakeshore capacity assessment across the province
- It is cost effective

The net effect of lakeshore capacity assessment will likely be to shift development from lakes that are already well developed to those that are less developed.

Carrying out lakeshore capacity assessment

A lake’s capacity for development is assessed with the Lakeshore Capacity Model. The model, first developed in 1975, quantifies linkages between natural sources of phosphorus to a lake, human contributions of phosphorus from shoreline development, water balance, the size and shape of a lake and the resultant phosphorus concentrations. The model uses a number of assumptions about phosphorus loading, phosphorus retention and usage figures.

The model allows the user to calculate how the quality of water in a lake will change in response to the addition or removal of shoreline development such as cottages, permanent homes and resorts. It predicts an important indicator of water quality: the total phosphorus concentration.

The model can be used to calculate undeveloped conditions of a lake, how much development can be added (in terms of the number of dwelling units) without altering water quality beyond a given endpoint, and the difference between current conditions and that endpoint.

Land use planning application and best management practices

Best management practices (BMPs) are planning, design and operational procedures that reduce the migration of phosphorus to water bodies, thereby reducing the effects of development on water quality. These BMPs apply to all lots, vacant or developed.

The maintenance of shoreline vegetation, installing vegetative buffers and minimizing the amount of exposed soil helps to reduce phosphorus loading - that is, the amount of phosphorus entering a body of water. Use of a siphon or pump to distribute septic tank effluents to the tile bed can also reduce phosphorus loading. Moreover, phosphorus loadings from septic systems can be reduced by avoiding the use of septic starters, ensuring that all sewage waste goes into the septic tank, pumping the tank out every three to five years and reducing water use.

Monitoring water quality

The predictions made by the Lakeshore Capacity Model should be validated by monitoring the quality of water in a lake. Water quality measurements should include total phosphorus, water clarity, and measurements at discrete depths of water temperature and dissolved oxygen concentrations at the end of summer. The Ministry of the Environment’s Lake Partner Program can help municipalities fulfill their monitoring requirements. Through partnerships with other agencies and a network of volunteers, the program currently collects water quality samples from more than 1,000 locations across the province.

Introduction to lakeshore capacity assessment (1.0)

Purpose of the handbook (1.1)

For many people, the image of Ontario is synonymous with the image of our northern lakes. When they think of our province, they think of anglers casting for walleye in the early morning mist, children leaping from docks into clear, sparkling waters and the rugged, tree-lined shores made famous by the Group of Seven. There are more than 250,000 inland lakes that dot Ontario's Precambrian Shield and these are an invaluable legacy for the residents of the province. Some people experience their beauty year round as residents. Others return every summer — some of them travelling great distances — for canoe tripping, fishing, cottaging, or to experience the solitude and the spiritual renewal that can be realized in these spectacular natural settings.

This handbook has been prepared as a tool to help protect the water quality of Ontario's Precambrian Shield lakes by preventing excessive development along their shores. It has been developed by the Ministry of the Environment (MOE) in partnership with the Ministry of Natural Resources (MNR) and the Ministry of Municipal Affairs and Housing (MMAH), with input from a diverse group of stakeholders. The advice in this handbook is intended for municipalities on the Precambrian Shield that have inland lakes within their boundaries. As such, it will be most useful to municipal planners, technical staff and consultants working on water quality in inland lakes. Nevertheless, cottagers' associations, residents living on lakes, conservation authorities and proponents of development should also find it informative.

The Lakeshore Capacity Assessment Handbook is a guide and resource for municipalities. Lakeshore capacity assessment will help municipalities meet their obligation under the *Planning Act* to be consistent with the Provincial Policy Statement (2005).

This handbook also incorporates a revised provincial water quality objective for phosphorus, and references a dissolved oxygen criterion developed by the Ministry of Natural Resources to protect lake trout habitat in inland lakes on the Precambrian Shield.

The handbook will become the basis for training resource managers in municipalities, the private sector and within MOE, MNR and MMAH. This will help to ensure consistent use and interpretation of lakeshore capacity assessment policies, the Lakeshore Capacity Model and its assumptions.

Outline of the handbook

The Lakeshore Capacity Assessment Handbook is organized so that more general material is presented at the beginning of the handbook and an increasing level of detail is found as one proceeds through it. The early sections are therefore suitable for general audiences, while the later chapters are targeted at more technical audiences. The greatest level of detail is found in the appendices.

Section 1.0: Provides an introduction to lakeshore capacity assessment and outlines why it is needed, what it will achieve, and what effect it will have on future lake development in the province.

Section 2.0: Examines the relationship between phosphorus, dissolved oxygen and water quality. It outlines the rationale for and approach used in the revised provincial water quality objective for phosphorus and contains a brief description of the dissolved oxygen criterion for the protection of lake trout habitat.

Section 3.0: Presents the basics of lakeshore capacity assessment. This includes a discussion on where it may be applicable, when it should be considered, what it will tell the user and what is needed to carry it out.

Section 4.0: Presents more detail on lakeshore capacity assessment and outlines how to apply the Lakeshore Capacity Model, the recommended provincial assessment tool for lakeshore capacity planning. It also addresses the updated and standardized technical assumptions used in the model, the steps involved in running it and the expected results.

Section 5.0: Provides a brief overview of land use planning application and best management practices, what they can achieve and why they are useful to municipalities (or residents and cottagers' associations) for protecting lake water quality. It also briefly addresses phosphorus abatement technologies.

Section 6.0: Focuses on monitoring water quality: why it is important, what to monitor and how to do it. It also provides an overview of MOE's Lake Partner Program.

Section 7.0: A brief conclusion.

The appendices to the handbook contain the rationale for a revised provincial water quality objective for phosphorus for Ontario’s inland lakes on the Precambrian Shield, a list of resources, and MOE technical bulletins on water quality monitoring.

What is lakeshore capacity assessment? (1.2)

At its simplest, lakeshore capacity assessment is a planning tool that is used to predict how much development can take place along the shorelines of inland lakes on the Precambrian Shield (Figure 1) without impairing water quality (i.e., by affecting levels of phosphorus and dissolved oxygen).

Development is defined herein as any activity which, through the creation of additional lots or units or through changes in land and water use, has the potential to adversely affect water quality and aquatic habitat. Development includes the addition of permanent residences, seasonal or extended seasonal use cottages, resorts, trailer parks, campgrounds and camps, and the conversion of forests to agricultural or urban land.

Figure 1. Ontario’s Precambrian Shield (shaded area)

Lakeshore capacity assessment can be used in two major ways:

1. To determine the maximum allowable development (in terms of number of dwelling units) that can occur on a lake without degrading water quality past a defined point.
2. To predict the expected effect of future development.

The goals of lakeshore capacity assessment are to help maintain the quality of water in recreational inland lakes and to protect coldwater fish habitat by keeping changes in the nutrient status of inland lakes within acceptable limits. Lakeshore capacity assessment can be carried out on any inland lake on the Precambrian Shield, although its accuracy may decrease for lakes that don't stratify during the summer months (i.e., shallow lakes), or for lakes that fall beyond the calibration range of the model (see Section 4.3 for further details).

The goals of lakeshore capacity assessment are to help maintain the quality of water in recreational inland lakes and to protect coldwater fish habitat by keeping changes in the nutrient status of inland lakes within acceptable limits.

Lakeshore capacity assessment is based on controlling the amount of one key pollutant — phosphorus — entering a lake by controlling shoreline development. Phosphorus is a nutrient that affects the growth of algae and aquatic plants. Excessive phosphorus can lead to excessive algal and plant growth, which in turn leads to unsightly algal blooms, the depletion of dissolved oxygen and the loss of habitat for coldwater fish such as lake trout — a process known as eutrophication.

As outlined in Section 2.0, phosphorus comes both from natural and human sources. In the absence of significant agricultural or urban drainage, or point sources such as sewage treatment plants, the primary human sources of phosphorus to Ontario's Precambrian Shield lakes are sewage systems from houses and cottages. Shoreline clearing, fertilizer use, erosion and overland runoff can also be important sources of phosphorus to inland lakes. Lakeshore capacity assessment helps planners understand what level of shoreline development can take place on an inland lake without appreciably altering water quality (i.e., beyond water quality guidelines or objectives for levels of phosphorus and dissolved oxygen).

MOE's mandate to protect water quality allows it to establish maximum phosphorus concentrations for individual lakes and to express these limits in terms of an allowable phosphorus load from shoreline development. Nutrient (phosphorus) enrichment may also reduce the amount of cold, well-oxygenated water available for fish requiring high levels of dissolved oxygen, such as lake trout. Development planning must protect fish habitat in accordance with the requirements of the federal *Fisheries Act* and the Department of Fisheries and Oceans policy for the management of fish habitat[1], and the Provincial Policy Statement.

Lakeshore capacity assessment is a planning tool that will help municipalities achieve a consistent approach to shoreline development on inland lakes across the province. As noted previously, MOE recommends that municipalities use lakeshore capacity assessment to ensure sustainable development of the inland lakes in their region.

Lakeshore capacity assessment alone won't guarantee good water quality and healthy fish populations

There are many other pollutants — such as mercury, fuel, and wastewater from pleasure boats, which includes dish/shower/laundry water (grey water) and sewage (black water) — and other land uses — such as industrial use, urbanization, and intensive timber harvesting and agriculture — that can degrade water quality. To protect water quality, municipalities and lake users need to have regard for federal, provincial and municipal water-related laws, bylaws and policies. Municipalities also need to develop proactive land-use controls.

Handbook users should remember that lakeshore capacity assessment, while effective at protecting some aspects of water quality, is by no means a panacea for all water quality problems in inland lakes.

Water quality is only one of many factors that influence the development capacity of inland lakes

In some cases, water quality may not be the most critical factor in determining whether a lake has reached its development capacity. The development capacity of a lake is also influenced by fish and wildlife habitat, the presence of hazard lands, vegetation, soils, topography and land capability (the suitability of land for use without permanent damage). Other factors that influence development capacity include existing development and land-use patterns, as well as social factors such as crowding, the number and type of boats in use, compatibility with surrounding land-use patterns, recreational use and aesthetics. Lakeshore capacity assessment does not address these other factors.

The technical process of carrying out lakeshore capacity assessment will not, in and of itself, protect water quality — implementation is required

The information obtained from lakeshore capacity assessment — for example, the maximum number of lots or dwelling units permitted on a lake or the names of lakes that have been determined to be at development capacity — needs to be incorporated into the policies of a municipality's official plan. The implementation of lakeshore capacity assessment is addressed in Section 3.4.

Lakeshore Capacity Assessment and Drinking Water

The outcome of the lakeshore capacity assessment will confer benefits on water quality that may, if a lake or watershed provides drinking water, also limit inputs of chemicals and pathogens to this drinking water source. A comprehensive strategy for the protection of drinking water supplies is under development. The *Clean Water*

Act, passed into law in October 2006, takes a science and watershed-based approach to drinking water source protection as part of the Ontario government's Source-to-Tap framework.

Why we need lakeshore capacity assessment (1.3)

The inland lakes on Ontario's Precambrian Shield are a major environmental, recreational and economic resource for the province. We need lakeshore capacity assessment as a tool for at least three reasons:

1. To help protect environmental resources
2. To help protect recreational and economic resources
3. To help municipal planning authorities meet their obligations under the *Planning Act*

Protecting environmental resources

Like other ecosystems, freshwater lakes are dynamic systems with an inherent resilience to stress — that is, they possess the ability to self-regulate and repair themselves. But, again like other ecosystems, inland lakes have a carrying capacity (limit) to the amount of stress they can tolerate. The near collapse of the Lake Erie ecosystem in the 1960s due to excessive phosphorus levels is one such example: a coordinated, basin-wide strategy was needed to reduce phosphorus levels and begin restoring the lake's health.

An important water quality concern related to development on Ontario's Precambrian Shield is eutrophication, which is caused by a high amount of phosphorus entering a lake. Unlike most pollutants, phosphorus isn't toxic to aquatic life. In fact, it is an essential nutrient that is supplied to the aquatic system from natural sources such as rainfall and runoff from the watershed.

However, when the amount of phosphorus entering a water body is excessive, it sets off a chain reaction. First, algae proliferate causing a loss in water clarity — the lake user may see this as greener or more turbid water, which is less aesthetically-appealing. In some cases, algal growth is dense and localized — this is called a bloom. Next, the algae die off and settle to the bottom of the lake, where bacteria begin the process of decomposition. This process consumes oxygen which, in turn, reduces the level of dissolved oxygen in the bottom waters and reduces the amount of habitat available for sensitive aquatic life such as lake trout. Lakes undergoing eutrophication may lose populations of lake trout and experience shifts in fish populations to more pollution-tolerant species.

Lakeshore capacity planning has been practiced for about 30 years in Ontario. During this time, MOE regional staff have modeled or accumulated files on more than 1,000 inland lakes. About 45 per cent of the lakes that have been determined to be at capacity to date are lake trout lakes in which a cold, well-oxygenated fish habitat is threatened by further shoreline development.

Lakeshore capacity assessment will help municipalities protect lakes that are at capacity against a further deterioration in water quality. It will also help to protect the water quality of lakes that have remaining development capacity, and help lakes to sustain healthy fisheries.

Protecting recreational and economic resources

Lakeshore capacity assessment will help to protect the significant economic values that are associated with Ontario's inland lakes:

- Ontario residents own approximately 1.2 million recreational boats.[2]
- Anglers spend approximately $1.7 billion annually in Ontario on a range of goods and services related to recreational fishing.[3]
- Ontario's Great Lakes and inland lakes support one of the largest commercial fisheries in the world, with a landed value of more than $40 million annually.[4]

- Crown lands and waters encompass approximately 87 per cent of Ontario's land mass. Many visitors engage in resource-based tourism activities on these lands including, for 1999, more than 5.6 million Canadian, American and overseas visitors. These resource-based visitors spent almost $1.1 billion in Ontario.[5]
- Of the 5.6 million resource-based trips in Ontario in 1999, 4.8 million (86 per cent) were overnight trips. Many of these visitors were engaged in water-related activities: 50 per cent participated in water sports (including swimming); 39 per cent went hunting or fishing.[6]

The *Planning Act* and the Provincial Policy Statement

Protection of matters of provincial interest is now a responsibility that is shared between the Ontario government and municipalities. MOE and other Ontario government agencies no longer assess all development applications. As a result, municipalities need better tools to meet their obligations under the Provincial Policy Statement (PPS) to protect water quality and fish habitat and to evaluate the effect of developments on the local environment. Lakeshore capacity assessment is one such tool that will help municipalities meet these obligations. Under the 2004 amendments to the *Planning Act* all planning approval authority decisions made "shall be consistent with" the PPS, which came into effect on March 1, 2005 following an extensive consultation and review. This replaced the previous wording of the *Planning Act* which stated that approval authorities, when making decisions "shall have regard to" the PPS. Copies of the PPS (2005) are readily available online and directly from the Ministry of Municipal Affairs and Housing.

It is always important to remember that the PPS (2005) must be read in its entirety. With that in mind, land-use planners must consider many matters to reach a decision that is consistent with the PPS (2005). For lake trout lakes or any other water bodies, decisions shall be consistent with, among other PPS (2005) policies, its water quality policies and fish habitat policies, including any definitions where they apply.

What lakeshore capacity assessment will achieve (1.4)

Lakeshore capacity assessment is a useful planning tool that will enhance the effectiveness of the land-use planning and development process in a number of ways. It incorporates the concept of ecosystem sustainability into the planning process.

Lakeshore capacity assessment is built upon the knowledge that inland lakes have a finite and measurable capacity for development. Central to the province's ecosystem approach to land- use planning is the concept that "everything is connected to everything else". Degradation of one element of an ecosystem (in this case, degradation of water quality) will ultimately affect other elements of the same ecosystem. Lakeshore capacity assessment is one tool that can assist in protecting the quality of water in inland lakes in the future. Protecting the quality of water in a lake will also help to protect its aquatic communities, coldwater fish habitat and the quality of water in downstream systems.

Lakeshore capacity assessment is consistent with watershed planning

The Ontario government recommends watershed planning as the preferred approach to water resource planning. Watershed planning takes a broad, holistic view of water resources and considers many factors including water quality, terrestrial and aquatic habitat, groundwater, hydrology and stream morphology (form and structure). Although lakeshore capacity assessment is more narrow in focus (as it considers only water quality), it is consistent with watershed management in that it considers upstream sources and downstream receptors when assessing the development capacity of a lake (e.g., PPS policy 2.2.1. a) which directs that planning authorities shall protect, improve or restore the quality and quantity of water by using the watershed at the ecologically meaningful scale for planning). It is a tool that will enable municipalities sharing a watershed to work together to protect the resource.

Lakeshore capacity assessment is consistent with the strategic shifts outlined in the report, Managing the Environment: A Review of Best Practices[7]

Lakeshore capacity assessment fits well with the strategic shifts outlined in the Managing the Environment report, commissioned by the Ontario government and issued in January 2001. Specifically, lakeshore capacity assessment reflects the shift towards:

- Place-based management using boundaries that make ecological sense
- Use of a flexible set of regulatory and non-regulatory tools
- A shared approach to environmental protection that includes the regulated community, non-governmental organizations, the public and the scientific/technical community

Lakeshore capacity assessment promotes land-use decisions that are based on sound planning principles and helps to address many relevant aspects of the Provincial Policy Statement (2005)

The implementation of lakeshore capacity assessment, together with the implementation of best management practices, will demonstrate sound planning principles at the municipal level by reflecting the land-use policies in a municipality's official plan. As outlined in Section 1.3, lakeshore capacity assessment supports the protection of provincial interests identified in the *Planning Act* and the Provincial Policy Statement (2005). This includes protecting water quality, natural heritage features and communities.

Lakeshore capacity assessment encourages land-use decisions that maintain or enhance water quality

While the Ontario government maintains jurisdiction and legislative authority for water quality and quantity under the *Ontario Water Resources Act* and the *Environmental Protection Act*, municipalities are strongly encouraged to consider more restrictive procedures and practices to safeguard water resources. Lakeshore capacity assessment is a proactive method by which municipalities can determine the sustainability of shoreline development on inland lakes with respect to water quality. It will help protect or enhance water quality so that permanent and seasonal residents can continue to enjoy good water clarity. It will also help to protect fish habitat and fisheries.

Lakeshore capacity assessment encourages a clear, coordinated and scientifically sound approach that will be beneficial to stakeholder groups and may avoid or reduce land use conflicts

Lakeshore capacity assessment is grounded in science that has been used for many years. It was developed by the Ontario government to guide municipalities with their planning responsibilities. It will help municipalities determine their lakeshore development capacity as they develop or update their official plans. Municipalities will then be able to set long-term planning policies before development expectations are generated and investments are made in property acquisition and subdivision design.

Lakeshore capacity assessment encourages a consistent approach across the province

The Ontario government is promoting the use of this handbook and the Lakeshore Capacity Model to encourage a consistent approach across the province.

Lakeshore capacity assessment is cost effective

Duplication of effort is avoided when municipalities carry out lakeshore capacity assessment and then develop general policies that are expressed in official plans and zoning bylaws. This is also the case when a development proposal requires a proponent to deal with more than one municipality.

What the effect will be on future lake development (1.5)

There are currently more than 220,000 residential and cottage properties on Ontario’s inland lakes.[8] Cottage development is sporadic and therefore difficult to predict. Annual demand for new lakeshore properties may increase somewhat in the future, but isn't expected to reach the high levels encountered in the late 1980s because of changes in disposable income and growing interest in recreational and retirement properties in warmer climates[9].

Municipal use of lakeshore capacity assessment — in conjunction with the revised provincial water quality objective for phosphorus for inland lakes on the Precambrian Shield — may allow for fewer new residential and cottage lots on some lakes and more on others, as compared to the existing assessment procedure. The net effect is likely to be a redirection of development from lakes that are already well developed to lakes that are less developed.

Phosphorus, dissolved oxygen and water quality (2.0)

Link between phosphorus and water quality (2.1)

Phosphorus is an essential nutrient that is supplied to aquatic systems from natural sources such as rainfall and overland runoff, as well as human sources. Unlike most aquatic pollutants, phosphorus isn't toxic to aquatic life. High levels of phosphorus, however, can set off a chain of events that can have serious repercussions on the aesthetics of recreational waters and the health of coldwater fisheries.

> The phosphorus concentration of a lake is one measure of the desirable attributes we wish to protect as the lake’s shoreline is developed. These attributes include clear water for recreation and a well-oxygenated habitat for coldwater fish.

For Ontario’s inland lakes on the Precambrian Shield, trophic (nutrient) status is determined by the level of phosphorus in the water (Table 1). Most lakes in the province of Ontario can be broadly characterized as being oligotrophic (low in nutrients) or mesotrophic (moderately nutrient-enriched), and most can accommodate small increases in phosphorus levels. However, all lakes have a finite capacity for nutrient assimilation, beyond which water quality is impaired. Excessive phosphorus loadings to a lake promote the growth of algae, sometimes leading to algal blooms on or beneath the lake’s surface. The proliferation of algae reduces water clarity, which lessens a lake’s aesthetic appeal. More serious effects may occur after the algae die and settle to the bottom. When this takes place, bacteria levels increase to decompose the algae and collectively their respiration consumes more oxygen in the water column. This means a loss of the cold, well-oxygenated habitat that is crucial to the survival of coldwater species such as lake trout. The ultimate outcome can be extirpation (local extinction) of the species.

The main human sources of phosphorus to many of Ontario’s recreational inland lakes are sewage systems from houses and cottages. Clearing the shoreline of native vegetation, use of fertilizers, stormwater runoff and increased soil erosion also can contribute significant amounts of phosphorus to a lake.

Table 1. Total phosphorus and its relationship to trophic status

Trophic status	**Total phosphorus range (µg/L)**
Oligotrophic	<10
Mesotrophic	10-20
Eutrophic	>20

MOE's mandate for protection of water quality allows it to establish maximum phosphorus concentrations for individual lakes and express these limits in terms of the allowable phosphorus load from shoreline development. Since nutrient enrichment can also reduce the amount of cold, well-oxygenated water used by fish such as lake trout, MNR has developed a new criterion for dissolved oxygen to protect lake trout habitat.

Development planning must protect fish habitat in accordance with the requirements of the federal *Fisheries Act* and Fisheries and Oceans Canada policy for the management of fish habitat[10]. Projects that may alter fish habitat fall under the jurisdiction of Fisheries and Oceans Canada for review under section 35 of the *Fisheries Act*. Fisheries and Oceans Canada has negotiated agreements with some conservation authorities to carry out these reviews at varying levels, depending on the capability of the conservation authority. Fisheries and Oceans Canada has a similar agreement with Parks Canada to carry out section 35 reviews for projects in national parks, marine conservation areas, historic canals and historic sites.

Provincial water quality objective for phosphorus (2.2)

This section of the handbook provides an overview of the relationship between phosphorus and water quality and outlines the rationale for and approach used for the development of a revised provincial water quality objective for phosphorus. More detail is found in Appendix A, Rationale for a revised phosphorus criterion for Precambrian Shield lakes in Ontario.

Existing approach

The Ontario government’s goal for surface water management is Ato ensure that the surface waters of the province are of a quality which is satisfactory for aquatic life and recreation".[11] The existing PWQO for total phosphorus was developed by MOE in 1979.[12]

It was founded on the trophic status classification scheme of Dillon and Rigler[13], and was designed to protect against aesthetic deterioration and nuisance concentrations of algae in lakes, and excessive plant growth in rivers and streams.

Interim Provincial Water Quality Objective for total phosphorus (1979)

Current scientific evidence is insufficient to develop a firm objective at this time [i.e., 1979]. Accordingly, the following phosphorus concentrations should be considered as general guidelines which should be supplemented by site-specific studies:

1. To avoid nuisance concentrations of algae in lakes, average total phosphorus concentrations for the ice-free period should not exceed 20 µg/L.
2. A high level of protection against aesthetic deterioration will be provided by a total phosphorus concentration for the ice-free period of 10 µg/L or less. This should apply to all lakes naturally below this value.
3. Excessive plant growth in rivers and streams should be eliminated at a total phosphorus concentration below 30 µg/L.

In 1992, the PWQO for total phosphorus was given interim status. This reflected both the uncertainty about the effects of phosphorus, and the fact that phosphorus isn't toxic to aquatic life. The interim PWQO doesn't explicitly distinguish between lakes in different regions of Ontario (i.e., Precambrian Shield versus southern Ontario). Instead, it sets different targets for lakes depending on whether they have naturally low productivity (total phosphorus less than 10 µg/L) or naturally moderate productivity (total phosphorus greater than 10 µg/L) (see sidebar).

In summary, the intent of the interim PWQO for total phosphorus in lakes is to:

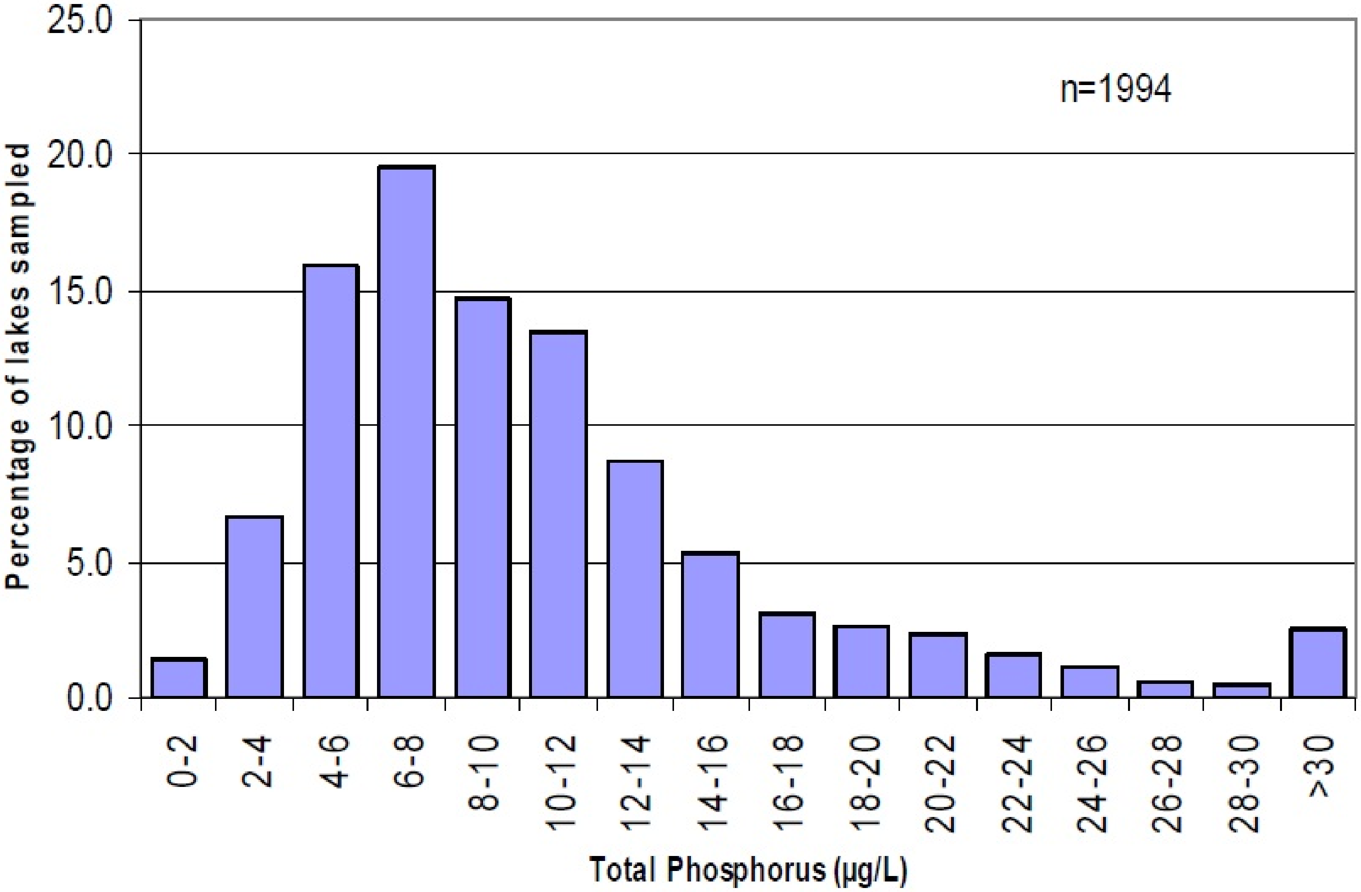
- Protect the aesthetics of recreational waters by preventing losses in water clarity
- Prevent nuisance blooms of surface-dwelling algae
- Provide indirect protection against oxygen depletion

Need for a revised approach

The need to revise the approach for managing phosphorus stems from an improved understanding of the relationship between phosphorus concentrations in water and the resulting plant and algal growth in lakes and rivers. It also reflects an improved understanding of watershed processes, biodiversity and the assessment of cumulative effects. A revised approach would ensure adoption of these considerations in the water management process.

Although the existing, two-tiered guideline for total phosphorus in lakes has performed well for more than 30 years, it fails to protect against the effects of cumulative development. Further, it doesn't protect the province's current diversity in lake water quality and its associated biodiversity. As illustrated in Figure 2, there is a wide range of nutrient levels in Ontario's inland lakes, with a prevalence of oligotrophic lakes.

Figure 2. Distribution of total phosphorus concentrations in sampled Ontario lakes



(source: MOE Inland Lakes database, March 2004)

The logical outcome of the application of the Ontario government's two-tiered 1979 phosphorus objective is that, over time, the quality of water in recreational lakes will converge on each of the two water quality objectives. This will produce a cluster of lakes slightly below 10 µg/L, and another slightly below 20 µg/L, thus reducing the diversity of water quality among lakes and, with it, the diversity of the associated aquatic communities.

Revised approach

The revised PWQO for lakes on the Precambrian Shield allows a 50 per cent increase in phosphorus concentration from a modeled baseline of water quality in the absence of human influence.

The revised approach has the following advantages:

- Each water body would have its own water quality objective, described with one number (i.e., 'undeveloped' or 'background' plus 50 per cent)
- Development capacity would be proportional to a lake's original trophic status
- Each lake would remain closer to its original trophic status classification. A lake with a predevelopment phosphorus level of 10 µg/L could be developed to 15 µg/L, maintain its mesotrophic classification, and development would not be unnecessarily constrained to 10 µg/L
- The existing diversity of trophic status in Ontario would be maintained in perpetuity

Phosphorus and dissolved oxygen (2.3)

The lake trout, Salvelinus namaycush, is found in about 2,200 lakes in Ontario, most of which are on or near the Precambrian Shield. These lakes are noted for their relatively pristine water quality: they generally have high clarity, low levels of dissolved solids, organic carbon and phosphorus, high concentrations of dissolved oxygen, cool temperatures in bottom waters year round and relatively stable water levels. Self-sustaining populations of lake trout are found in these lakes because they provide the specific, narrow environmental conditions required by this species.

Ontario's lakes were re-colonized by lake trout 10,000 years ago after the glaciers of the last Wisconsin Ice Age retreated. Populations have been largely isolated from one another since that time and adaptation to local conditions has led to genetically distinct, locally adapted stocks. The preservation of genetic diversity of the species requires conservation of individual populations through the protection of the habitat and water quality in the lakes in which they occur.

Lake trout are long-lived and late maturing, with females first spawning at six to ten years of age. This late maturation, combined with modest egg production and low recruitment rates, makes lake trout vulnerable to external factors that increase mortality. These factors include over-fishing and degradation or loss of spawning and summer habitat.

Loss of late summer habitat is influenced by phosphorus loading. In the southern part of their range, lake trout live in the hypolimnion during the summer. The hypolimnion is isolated from the atmospheric and photosynthetic supply of oxygen from the time when the lakes become thermally stratified during spring overturn until recirculation or turnover takes place in the fall. To sustain lake trout over the summer, the hypolimnion must contain enough dissolved oxygen.

When nutrient enrichment takes place as a result of shoreline development, the algae production-decomposition cycle depletes the oxygen in the deep waters of the hypolimnion.

Low concentrations of dissolved oxygen in bottom waters impair the lake trout's respiration, and therefore its metabolism, which compromises its ability to swim, feed, grow and avoid predators. Studies have shown that juvenile lake trout need at least 7 milligrams (mg) of dissolved oxygen per litre (L) of water. Measured as a mean, volume-weighted, hypolimnetic dissolved oxygen concentration (MVWHDO), this level is also sufficient to make sure that natural recruitment takes place. The Ministry of Natural Resources has thus developed a criterion of 7 mg of dissolved oxygen/L (measured as MVWHDO) for the protection of lake trout habitat (references in Appendix B). The provincial water quality objective for dissolved oxygen allows for the establishment of more stringent, site-specific criteria for the protection of sensitive biological communities.[14]

The Province recommends that generally there will be no new municipal land use planning approvals for new or more intense residential, commercial or industrial development within 300 metres of lake trout lakes where the MVWHDO concentration has been measured to be at or below 7 mg/L. This recommendation also applies to lakes where water quality modelling has determined that the development of existing vacant lots, with development approvals, would reduce the MVWHDO to 7 mg/L or less. Preservation of an average of at least 7 mg of dissolved oxygen/L in the hypolimnion of Ontario's lake trout lakes will help to sustain the province's lake trout resources. For more information on sampling oxygen and calculating the MVWHDO concentration, please see the Technical Bulletin in Appendix C.

---

[1] Department of Fisheries and Oceans. 1986. The Department of Fisheries and Oceans policy for the management of fish habitat. Department of Fisheries and Oceans. Ottawa. 28 p.

[2] Great Lakes Regional Waterways Management Forum. 1999. The Great Lakes: A waterways management challenge. Harbor House Publishers, Inc. Michigan.

[3] Ontario Ministry of Natural Resources. 2003. 2003 Recreational Fishing Regulations Summary. Queen's Printer for Ontario.

[4] Office of the Provincial Auditor of Ontario. 1999. 1998 Annual Report. Queen's Printer for Ontario.

[5] Ontario Ministry of Tourism and Recreation. 2002. An Economic Profile of Resource-Based Tourism in Ontario, 1999. Queen's Printer for Ontario.

[6] Ontario Ministry of Tourism and Recreation. 2002. An Economic Profile of Resource-Based Tourism in Ontario, 1999. Queen's Printer for Ontario.

[7] Executive Resource Group. 2001. Managing the Environment: A Review of Best Practices, Volume 1.

[8] Cottage Life Magazine. 2004. Cottage Life Advertising Brochure.

[9] Ontario Ministry of the Environment (Economic Services Branch). 1997. Economic Analysis of the Proposed Lakeshore Development Policy: Socio-economic value of water in Ontario. Queen's Printer for Ontario.

[10] Department of Fisheries and Oceans. 1986. The Department of Fisheries and Oceans policy for the management of fish habitat. Department of Fisheries and Oceans. Ottawa.

[11] Ontario Ministry of Environment and Energy. 1994. Water management: Policies, guidelines, Provincial Water Quality Objectives of the Ministry of Environment and Energy. Queen's Printer for Ontario.

[12] Ontario Ministry of Environment and Energy. 1979. Rationale for the establishment of Ontario's Provincial Water Quality Objectives. Queen's Printer for Ontario.

[13] Dillon, P.J. and F.H. Rigler 1975. A simple method for predicting the capacity of a lake for development based on lake trophic status. J. Fish. Res. Bd. Can. 32: 1519-1531.

[14] Ontario Ministry of Environment and Energy. 1994. Water management: Policies, guidelines, Provincial

Land Use Planning application and best management practice

Preface

This Lakeshore Capacity Assessment Handbook has been prepared by the Ministry of the Environment in partnership with the ministries of Natural Resources and Municipal Affairs and Housing. It was developed to provide guidance to municipalities and other stakeholders responsible for the management of development along the shorelines of Ontario's inland lakes within the Precambrian Shield. While municipalities are not required to carry out lakeshore capacity assessment, this planning tool is strongly recommended by the Ontario government as an effective means of being consistent with the *Planning Act*, the Provincial Policy Statement (2005), the *Ontario Water Resources Act* and the federal *Fisheries Act*.

This document is based on the scientific understanding and the government policies in place at the time of publication. Questions about planning issues should be directed to the Ministry of Municipal Affairs and Housing. Scientific or technical questions dealing with water quality should be directed to the Ministry of the Environment. Questions concerning fisheries should be directed to the Ministry of Natural Resources.

Acknowledgements

This handbook is the outcome of more than three decades of scientific research and policy development. Lakeshore capacity assessment in Canada began in the 1970s with research conducted by Peter Dillon and F.H. Rigler. Researchers who contributed to the subsequent refinement of lakeshore capacity assessment and the development of the Lakeshore Capacity Model include B.J. Clark, P.J. Dillon, H.E. Evans, M.N. Futter, N.J. Hutchinson, D.S. Jeffries, R.B. Mills, L. Molot, B.P. Neary, A.M. Paterson, R.A. Reid and W.A. Scheider.

The preparation of the handbook was overseen by an inter-ministerial steering committee which included:

Ministry of the Environment: Victor Castro, Peter Dillon, Les Fitz, Fred Granek, Ron Hall, Bruce Hawkins, Heather LeBlanc, Gary Martin, Wolfgang Scheider (Chair), Doug Spry, Shiv Sud (past Chair);

Ministry of Natural Resources: John Allin, John Connolly, David Evans, Gareth Goodchild, Fred Johnson;

Ministry of Municipal Affairs and Housing: Kevin Lee

Many other provincial staff, too numerous to name individually, contributed to the development of this handbook. Technical writing assistance for the handbook was provided by Joanna Kidd from Lura Consulting and editorial assistance was provided by Carol Crittenden from Editorial Offload.

This version of the Handbook has been revised to reflect comments received during its posting on Ontario's Environmental Registry in 2008. Thanks also go to the municipal staff and the members of organizations who assisted in the review of the handbook and provided many comments on its scope and contents. Their participation helped greatly to improve the document. These reviewers included:

- Judi Brouse – District Municipality of Muskoka
- Peter Bullock – City of North Bay
- Cliff Craig – Rideau Valley Conservation Authority
- Randy French – French Planning Services Inc.
- Roger Hogan – Former Township of Cardiff
  (amalgamated into the Municipality of Highlands East)
- Gerry Hunnius – Federation of Ontario Cottagers: Associations
- Neil Hutchinson – Hutchinson Environmental Sciences Ltd.
- Alex Manefski – Urban Development Institute
- Pat Martin – Municipality of Dysart et al
- Patrick Moyle – Association of Municipalities of Ontario
- Ron Reid – Federation of Ontario Naturalists
- Lorne Sculthorp – District Municipality of Muskoka

Executive summary

Purpose

This handbook has been prepared by the Ministry of the Environment in partnership with the Ministries of Natural Resources and Municipal Affairs and Housing to guide municipalities carrying out lakeshore capacity assessment of inland lakes on Ontario's Precambrian Shield.

About lakeshore capacity assessment

Lakeshore capacity assessment (a generic term, but herein used to describe the Province's recommended approach) is a planning tool that can be used to control the amount of one key pollutant — phosphorus — entering inland lakes on the Precambrian Shield by controlling shoreline development. High levels of phosphorus in lake water will promote eutrophication — excessive plant and algae growth, resulting in a loss of water clarity, depletion of dissolved oxygen and a loss of habitat for species of coldwater fish such as lake trout. While shoreline clearing, fertilizer use, erosion and overland runoff can all contribute phosphorus to an inland lake, the primary human sources of phosphorus are septic systems — from cottages, year- round residences, camps and other shoreline facilities. Lakeshore capacity assessment can be used to predict the level of development that can be sustained along the shoreline of an inland lake on the Precambrian Shield without exhibiting any adverse effects related to high phosphorus levels.

It should be emphasized that lakeshore capacity assessment addresses only some aspects of water quality — phosphorus, dissolved oxygen and lake trout habitat. Municipalities and lake planners also need to consider other pollutants (such as mercury, bacteria and petroleum products) and other sources of pollution (including industries, agriculture and boats). It must also be emphasized that water quality isn't the only important factor that should be considered in determining the development capacity of lakes. Factors such as soils, topography, hazard lands, crowding and boating limits may be as or more important than water quality. Finally, it's important to emphasize that, to be effective, the technical process of carrying out lakeshore capacity assessment must be followed by implementation — in other words, the information obtained must be incorporated into municipal official plans and policies.

Benefits of lakeshore capacity assessment

Use of lakeshore capacity assessment by municipalities (along with proactive land-use controls) and enforcement of water-related regulations and bylaws will help to ensure that the quality of water in Ontario's inland lakes is preserved. The protection of water quality will also protect environmental, recreational, economic and property values.

Lakeshore capacity assessment enhances the effectiveness of the land-use development process in many ways:

- It incorporates the concept of ecosystem sustainability in the planning process
- It is consistent with watershed planning
- It promotes land-use decisions that are based on sound planning principles
- It addresses many relevant aspects of the Provincial Policy Statement (2005), which came into effect on March 1, 2005. The Provincial Policy Statement is issued under section 3 of the *Planning Act*.
- It encourages land-use decisions that maintain or enhance water quality
- It encourages a clear, coordinated and scientifically sound approach that should reduce conflict among stakeholder groups
- It encourages a consistent approach to lakeshore capacity assessment across the province
- It is cost effective

The net effect of lakeshore capacity assessment will likely be to shift development from lakes that are already well developed to those that are less developed.

Carrying out lakeshore capacity assessment

A lake's capacity for development is assessed with the Lakeshore Capacity Model. The model, first developed in 1975, quantifies linkages between natural sources of phosphorus to a lake, human contributions of phosphorus from shoreline development, water balance, the size and shape of a lake and the resultant phosphorus concentrations. The model uses a number of assumptions about phosphorus loading, phosphorus retention and usage figures.

The model allows the user to calculate how the quality of water in a lake will change in response to the addition or removal of shoreline development such as cottages, permanent homes and resorts. It predicts an important indicator of water quality: the total phosphorus concentration.

The model can be used to calculate undeveloped conditions of a lake, how much development can be added (in terms of the number of dwelling units) without altering water quality beyond a given endpoint, and the difference between current conditions and that endpoint.

Land use planning application and best management practices

Best management practices (BMPs) are planning, design and operational procedures that reduce the migration of phosphorus to water bodies, thereby reducing the effects of development on water quality. These BMPs apply to all lots, vacant or developed.

The maintenance of shoreline vegetation, installing vegetative buffers and minimizing the amount of exposed soil helps to reduce phosphorus loading - that is, the amount of phosphorus entering a body of water. Use of a siphon or pump to distribute septic tank effluents to the tile bed can also reduce phosphorus loading. Moreover, phosphorus loadings from septic systems can be reduced by avoiding the use of septic starters, ensuring that all sewage waste goes into the septic tank, pumping the tank out every three to five years and reducing water use.

Monitoring water quality

The predictions made by the Lakeshore Capacity Model should be validated by monitoring the quality of water in a lake. Water quality measurements should include total phosphorus, water clarity, and measurements at discrete depths of water temperature and dissolved oxygen concentrations at the end of summer. The Ministry of the Environment's Lake Partner Program can help municipalities fulfill their monitoring requirements. Through partnerships with other agencies and a network of volunteers, the program currently collects water quality samples from more than 1,000 locations across the province.

Introduction to lakeshore capacity assessment (1.0)

Purpose of the handbook (1.1)

For many people, the image of Ontario is synonymous with the image of our northern lakes. When they think of our province, they think of anglers casting for walleye in the early morning mist, children leaping from docks into clear, sparkling waters and the rugged, tree-lined shores made famous by the Group of Seven. There are more than 250,000 inland lakes that dot Ontario's Precambrian Shield and these are an invaluable legacy for the residents of the province. Some people experience their beauty year round as residents. Others return every summer — some of them travelling great distances — for canoe tripping, fishing, cottaging, or to experience the solitude and the spiritual renewal that can be realized in these spectacular natural settings.

This handbook has been prepared as a tool to help protect the water quality of Ontario's Precambrian Shield lakes by preventing excessive development along their shores. It has been developed by the Ministry of the Environment (MOE) in partnership with the Ministry of Natural Resources (MNR) and the Ministry of Municipal Affairs and Housing (MMAH), with input from a diverse group of stakeholders. The advice in this handbook is intended for municipalities on the Precambrian Shield that have inland lakes within their boundaries. As such, it will be most useful to municipal planners, technical staff and consultants working on water quality in inland lakes. Nevertheless, cottagers' associations, residents living on lakes, conservation authorities and proponents of development should also find it informative.

The Lakeshore Capacity Assessment Handbook is a guide and resource for municipalities. Lakeshore capacity assessment will help municipalities meet their obligation under the *Planning Act* to be consistent with the Provincial Policy Statement (2005).

This handbook also incorporates a revised provincial water quality objective for phosphorus, and references a dissolved oxygen criterion developed by the Ministry of Natural Resources to protect lake trout habitat in inland lakes on the Precambrian Shield.

The handbook will become the basis for training resource managers in municipalities, the private sector and within MOE, MNR and MMAH. This will help to ensure consistent use and interpretation of lakeshore capacity assessment policies, the Lakeshore Capacity Model and its assumptions.

Outline of the handbook

The Lakeshore Capacity Assessment Handbook is organized so that more general material is presented at the beginning of the handbook and an increasing level of detail is found as one proceeds through it. The early sections are therefore suitable for general audiences, while the later chapters are targeted at more technical audiences. The greatest level of detail is found in the appendices.

Section 1.0: Provides an introduction to lakeshore capacity assessment and outlines why it is needed, what it will achieve, and what effect it will have on future lake development in the province.

Section 2.0: Examines the relationship between phosphorus, dissolved oxygen and water quality. It outlines the rationale for and approach used in the revised provincial water quality objective for phosphorus and contains a brief description of the dissolved oxygen criterion for the protection of lake trout habitat.

Section 3.0: Presents the basics of lakeshore capacity assessment. This includes a discussion on where it may be applicable, when it should be considered, what it will tell the user and what is needed to carry it out.

Section 4.0: Presents more detail on lakeshore capacity assessment and outlines how to apply the Lakeshore Capacity Model, the recommended provincial assessment tool for lakeshore capacity planning. It also addresses the updated and standardized technical assumptions used in the model, the steps involved in running it and the expected results.

Section 5.0: Provides a brief overview of land use planning application and best management practices, what they can achieve and why they are useful to municipalities (or residents and cottagers' associations) for protecting lake water quality. It also briefly addresses phosphorus abatement technologies.

Section 6.0: Focuses on monitoring water quality: why it is important, what to monitor and how to do it. It also provides an overview of MOE's Lake Partner Program.

Section 7.0: A brief conclusion.

The appendices to the handbook contain the rationale for a revised provincial water quality objective for phosphorus for Ontario’s inland lakes on the Precambrian Shield, a list of resources, and MOE technical bulletins on water quality monitoring.

What is lakeshore capacity assessment? (1.2)

At its simplest, lakeshore capacity assessment is a planning tool that is used to predict how much development can take place along the shorelines of inland lakes on the Precambrian Shield (Figure 1) without impairing water quality (i.e., by affecting levels of phosphorus and dissolved oxygen).

Development is defined herein as any activity which, through the creation of additional lots or units or through changes in land and water use, has the potential to adversely affect water quality and aquatic habitat. Development includes the addition of permanent residences, seasonal or extended seasonal use cottages, resorts, trailer parks, campgrounds and camps, and the conversion of forests to agricultural or urban land.

Figure 1. Ontario's Precambrian Shield (shaded area)

Lakeshore capacity assessment can be used in two major ways:

1. To determine the maximum allowable development (in terms of number of dwelling units) that can occur on a lake without degrading water quality past a defined point.
2. To predict the expected effect of future development.

The goals of lakeshore capacity assessment are to help maintain the quality of water in recreational inland lakes and to protect coldwater fish habitat by keeping changes in the nutrient status of inland lakes within acceptable limits. Lakeshore capacity assessment can be carried out on any inland lake on the Precambrian Shield, although its accuracy may decrease for lakes that don't stratify during the summer months (i.e., shallow lakes), or for lakes that fall beyond the calibration range of the model (see Section 4.3 for further details).

The goals of lakeshore capacity assessment are to help maintain the quality of water in recreational inland lakes and to protect coldwater fish habitat by keeping changes in the nutrient status of inland lakes within acceptable limits.

Lakeshore capacity assessment is based on controlling the amount of one key pollutant — phosphorus — entering a lake by controlling shoreline development. Phosphorus is a nutrient that affects the growth of algae and aquatic plants. Excessive phosphorus can lead to excessive algal and plant growth, which in turn leads to unsightly algal blooms, the depletion of dissolved oxygen and the loss of habitat for coldwater fish such as lake trout — a process known as eutrophication.

As outlined in Section 2.0, phosphorus comes both from natural and human sources. In the absence of significant agricultural or urban drainage, or point sources such as sewage treatment plants, the primary human sources of phosphorus to Ontario's Precambrian Shield lakes are sewage systems from houses and cottages. Shoreline clearing, fertilizer use, erosion and overland runoff can also be important sources of phosphorus to inland lakes. Lakeshore capacity assessment helps planners understand what level of shoreline development can take place on an inland lake without appreciably altering water quality (i.e., beyond water quality guidelines or objectives for levels of phosphorus and dissolved oxygen).

MOE's mandate to protect water quality allows it to establish maximum phosphorus concentrations for individual lakes and to express these limits in terms of an allowable phosphorus load from shoreline development. Nutrient (phosphorus) enrichment may also reduce the amount of cold, well-oxygenated water available for fish requiring high levels of dissolved oxygen, such as lake trout. Development planning must protect fish habitat in accordance with the requirements of the federal *Fisheries Act* and the Department of Fisheries and Oceans policy for the management of fish habitat[1], and the Provincial Policy Statement.

Lakeshore capacity assessment is a planning tool that will help municipalities achieve a consistent approach to shoreline development on inland lakes across the province. As noted previously, MOE recommends that municipalities use lakeshore capacity assessment to ensure sustainable development of the inland lakes in their region.

Lakeshore capacity assessment alone won't guarantee good water quality and healthy fish populations

There are many other pollutants — such as mercury, fuel, and wastewater from pleasure boats, which includes dish/shower/laundry water (grey water) and sewage (black water) — and other land uses — such as industrial use, urbanization, and intensive timber harvesting and agriculture — that can degrade water quality. To protect water quality, municipalities and lake users need to have regard for federal, provincial and municipal water-related laws, bylaws and policies. Municipalities also need to develop proactive land-use controls.

Handbook users should remember that lakeshore capacity assessment, while effective at protecting some aspects of water quality, is by no means a panacea for all water quality problems in inland lakes.

Water quality is only one of many factors that influence the development capacity of inland lakes

In some cases, water quality may not be the most critical factor in determining whether a lake has reached its development capacity. The development capacity of a lake is also influenced by fish and wildlife habitat, the presence of hazard lands, vegetation, soils, topography and land capability (the suitability of land for use without permanent damage). Other factors that influence development capacity include existing development and land-use patterns, as well as social factors such as crowding, the number and type of boats in use, compatibility with surrounding land-use patterns, recreational use and aesthetics. Lakeshore capacity assessment does not address these other factors.

The technical process of carrying out lakeshore capacity assessment will not, in and of itself, protect water quality — implementation is required

The information obtained from lakeshore capacity assessment — for example, the maximum number of lots or dwelling units permitted on a lake or the names of lakes that have been determined to be at development capacity — needs to be incorporated into the policies of a municipality's official plan. The implementation of lakeshore capacity assessment is addressed in Section 3.4.

Lakeshore Capacity Assessment and Drinking Water

The outcome of the lakeshore capacity assessment will confer benefits on water quality that may, if a lake or watershed provides drinking water, also limit inputs of chemicals and pathogens to this drinking water source. A comprehensive strategy for the protection of drinking water supplies is under development. The *Clean Water Act*, passed into law in October 2006, takes a science and watershed-based approach to drinking water source protection as part of the Ontario government's Source-to-Tap framework.

Why we need lakeshore capacity assessment (1.3)

The inland lakes on Ontario's Precambrian Shield are a major environmental, recreational and economic resource for the province. We need lakeshore capacity assessment as a tool for at least three reasons:

1. To help protect environmental resources
2. To help protect recreational and economic resources
3. To help municipal planning authorities meet their obligations under the *Planning Act*

Protecting environmental resources

Like other ecosystems, freshwater lakes are dynamic systems with an inherent resilience to stress — that is, they possess the ability to self-regulate and repair themselves. But, again like other ecosystems, inland lakes have a carrying capacity (limit) to the amount of stress they can tolerate. The near collapse of the Lake Erie ecosystem in the 1960s due to excessive phosphorus levels is one such example: a coordinated, basin-wide strategy was needed to reduce phosphorus levels and begin restoring the lake's health.

An important water quality concern related to development on Ontario's Precambrian Shield is eutrophication, which is caused by a high amount of phosphorus entering a lake. Unlike most pollutants, phosphorus isn't toxic to aquatic life. In fact, it is an essential nutrient that is supplied to the aquatic system from natural sources such as rainfall and runoff from the watershed.

However, when the amount of phosphorus entering a water body is excessive, it sets off a chain reaction. First, algae proliferate causing a loss in water clarity — the lake user may see this as greener or more turbid water, which is less aesthetically-appealing. In some cases, algal growth is dense and localized — this is called a bloom. Next, the algae die off and settle to the bottom of the lake, where bacteria begin the process of decomposition. This process consumes oxygen which, in turn, reduces the level of dissolved oxygen in the bottom waters and reduces the amount of habitat available for sensitive aquatic life such as lake trout. Lakes undergoing eutrophication may lose populations of lake trout and experience shifts in fish populations to more pollution-tolerant species.

Lakeshore capacity planning has been practiced for about 30 years in Ontario. During this time, MOE regional staff have modeled or accumulated files on more than 1,000 inland lakes. About 45 per cent of the lakes that have been determined to be at capacity to date are lake trout lakes in which a cold, well-oxygenated fish habitat is threatened by further shoreline development.

Lakeshore capacity assessment will help municipalities protect lakes that are at capacity against a further deterioration in water quality. It will also help to protect the water quality of lakes that have remaining development capacity, and help lakes to sustain healthy fisheries.

Protecting recreational and economic resources

Lakeshore capacity assessment will help to protect the significant economic values that are associated with Ontario's inland lakes:

- Ontario residents own approximately 1.2 million recreational boats.[2]
- Anglers spend approximately $1.7 billion annually in Ontario on a range of goods and services related to recreational fishing.[3]
- Ontario's Great Lakes and inland lakes support one of the largest commercial fisheries in the world, with a landed value of more than $40 million annually.[4]
- Crown lands and waters encompass approximately 87 per cent of Ontario's land mass. Many visitors engage in resource-based tourism activities on these lands including, for 1999, more than 5.6 million Canadian, American and overseas visitors. These resource-based visitors spent almost $1.1 billion in Ontario.[5]
- Of the 5.6 million resource-based trips in Ontario in 1999, 4.8 million (86 per cent) were overnight trips. Many of these visitors were engaged in water-related activities: 50 per cent participated in water sports (including swimming); 39 per cent went hunting or fishing.[6]

The *Planning Act* and the Provincial Policy Statement

Protection of matters of provincial interest is now a responsibility that is shared between the Ontario government and municipalities. MOE and other Ontario government agencies no longer assess all development applications. As a result, municipalities need better tools to meet their obligations under the Provincial Policy Statement (PPS) to protect water quality and fish habitat and to evaluate the effect of developments on the local environment. Lakeshore capacity assessment is one such tool that will help municipalities meet these obligations. Under the 2004 amendments to the *Planning Act* all planning approval authority decisions made "shall be consistent with" the PPS, which came into effect on March 1, 2005 following an extensive consultation and review. This replaced the previous wording of the *Planning Act* which stated that approval authorities, when making decisions "shall have regard to" the PPS. Copies of the PPS (2005) are readily available online and directly from the Ministry of Municipal Affairs and Housing.

It is always important to remember that the PPS (2005) must be read in its entirety. With that in mind, land-use planners must consider many matters to reach a decision that is consistent with the PPS (2005). For lake trout lakes or any other water bodies, decisions shall be consistent with, among other PPS (2005) policies, its water quality policies and fish habitat policies, including any definitions where they apply.

What lakeshore capacity assessment will achieve (1.4)

Lakeshore capacity assessment is a useful planning tool that will enhance the effectiveness of the land-use planning and development process in a number of ways. It incorporates the concept of ecosystem sustainability into the planning process.

Lakeshore capacity assessment is built upon the knowledge that inland lakes have a finite and measurable capacity for development. Central to the province's ecosystem approach to land- use planning is the concept that "everything is connected to everything else". Degradation of one element of an ecosystem (in this case, degradation of water quality) will ultimately affect other elements of the same ecosystem. Lakeshore capacity assessment is one tool that can assist in protecting the quality of water in inland lakes in the future. Protecting the quality of water in a lake will also help to protect its aquatic communities, coldwater fish habitat and the quality of water in downstream systems.

Lakeshore capacity assessment is consistent with watershed planning

The Ontario government recommends watershed planning as the preferred approach to water resource planning. Watershed planning takes a broad, holistic view of water resources and considers many factors including water quality, terrestrial and aquatic habitat, groundwater, hydrology and stream morphology (form and structure). Although lakeshore capacity assessment is more narrow in focus (as it considers only water quality), it is consistent with watershed management in that it considers upstream sources and downstream receptors when assessing the development capacity of a lake (e.g., PPS policy 2.2.1. a) which directs that planning authorities shall protect, improve or restore the quality and quantity of water by using the watershed at the ecologically meaningful scale for planning). It is a tool that will enable municipalities sharing a watershed to work together to protect the resource.

Lakeshore capacity assessment is consistent with the strategic shifts outlined in the report, Managing the Environment: A Review of Best Practices[7]

Lakeshore capacity assessment fits well with the strategic shifts outlined in the Managing the Environment report, commissioned by the Ontario government and issued in January 2001. Specifically, lakeshore capacity assessment reflects the shift towards:

- Place-based management using boundaries that make ecological sense
- Use of a flexible set of regulatory and non-regulatory tools
- A shared approach to environmental protection that includes the regulated community, non-governmental organizations, the public and the scientific/technical community

Lakeshore capacity assessment promotes land-use decisions that are based on sound planning principles and helps to address many relevant aspects of the Provincial Policy Statement (2005)

The implementation of lakeshore capacity assessment, together with the implementation of best management practices, will demonstrate sound planning principles at the municipal level by reflecting the land-use policies in a municipality’s official plan. As outlined in Section 1.3, lakeshore capacity assessment supports the protection of provincial interests identified in the *Planning Act* and the Provincial Policy Statement (2005). This includes protecting water quality, natural heritage features and communities.

Lakeshore capacity assessment encourages land-use decisions that maintain or enhance water quality

While the Ontario government maintains jurisdiction and legislative authority for water quality and quantity under the *Ontario Water Resources Act* and the *Environmental Protection Act*, municipalities are strongly encouraged to consider more restrictive procedures and practices to safeguard water resources. Lakeshore capacity assessment is a proactive method by which municipalities can determine the sustainability of shoreline development on inland lakes with respect to water quality. It will help protect or enhance water quality so that permanent and seasonal residents can continue to enjoy good water clarity. It will also help to protect fish habitat and fisheries.

Lakeshore capacity assessment encourages a clear, coordinated and scientifically sound approach that will be beneficial to stakeholder groups and may avoid or reduce land use conflicts

Lakeshore capacity assessment is grounded in science that has been used for many years. It was developed by the Ontario government to guide municipalities with their planning responsibilities. It will help municipalities determine their lakeshore development capacity as they develop or update their official plans. Municipalities will then be able to set long-term planning policies before development expectations are generated and investments are made in property acquisition and subdivision design.

Lakeshore capacity assessment encourages a consistent approach across the province

The Ontario government is promoting the use of this handbook and the Lakeshore Capacity Model to encourage a consistent approach across the province.

Lakeshore capacity assessment is cost effective

Duplication of effort is avoided when municipalities carry out lakeshore capacity assessment and then develop general policies that are expressed in official plans and zoning bylaws. This is also the case when a development proposal requires a proponent to deal with more than one municipality.

What the effect will be on future lake development (1.5)

There are currently more than 220,000 residential and cottage properties on Ontario’s inland lakes.[8] Cottage development is sporadic and therefore difficult to predict. Annual demand for new lakeshore properties may increase somewhat in the future, but isn't expected to reach the high levels encountered in the late 1980s because of changes in disposable income and growing interest in recreational and retirement properties in warmer climates[9].

Municipal use of lakeshore capacity assessment — in conjunction with the revised provincial water quality objective for phosphorus for inland lakes on the Precambrian Shield — may allow for fewer new residential and cottage lots on some lakes and more on others, as compared to the existing assessment procedure. The net effect is likely to be a redirection of development from lakes that are already well developed to lakes that are less developed.

Phosphorus, dissolved oxygen and water quality (2.0)

Link between phosphorus and water quality (2.1)

Phosphorus is an essential nutrient that is supplied to aquatic systems from natural sources such as rainfall and overland runoff, as well as human sources. Unlike most aquatic pollutants, phosphorus isn't toxic to aquatic life. High levels of phosphorus, however, can set off a chain of events that can have serious repercussions on the aesthetics of recreational waters and the health of coldwater fisheries.

> The phosphorus concentration of a lake is one measure of the desirable attributes we wish to protect as the lake’s shoreline is developed. These attributes include clear water for recreation and a well-oxygenated habitat for coldwater fish.

For Ontario’s inland lakes on the Precambrian Shield, trophic (nutrient) status is determined by the level of phosphorus in the water (Table 1). Most lakes in the province of Ontario can be broadly characterized as being oligotrophic (low in nutrients) or mesotrophic (moderately nutrient-enriched), and most can accommodate small increases in phosphorus levels. However, all lakes have a finite capacity for nutrient assimilation, beyond which water quality is impaired. Excessive phosphorus loadings to a lake promote the growth of algae, sometimes leading to algal blooms on or beneath the lake’s surface. The proliferation of algae reduces water clarity, which lessens a lake’s aesthetic appeal. More serious effects may occur after the algae die and settle to the bottom. When this takes place, bacteria levels increase to decompose the algae and collectively their respiration consumes more oxygen in the water column. This means a loss of the cold, well-oxygenated habitat that is crucial to the survival of coldwater species such as lake trout. The ultimate outcome can be extirpation (local extinction) of the species.

The main human sources of phosphorus to many of Ontario’s recreational inland lakes are sewage systems from houses and cottages. Clearing the shoreline of native vegetation, use of fertilizers, stormwater runoff and increased soil erosion also can contribute significant amounts of phosphorus to a lake.

Table 1. Total phosphorus and its relationship to trophic status

Trophic status	**Total phosphorus range (µg/L)**
Oligotrophic	<10
Mesotrophic	10-20
Eutrophic	>20

MOE's mandate for protection of water quality allows it to establish maximum phosphorus concentrations for individual lakes and express these limits in terms of the allowable phosphorus load from shoreline development. Since nutrient enrichment can also reduce the amount of cold, well-oxygenated water used by fish such as lake trout, MNR has developed a new criterion for dissolved oxygen to protect lake trout habitat.

Development planning must protect fish habitat in accordance with the requirements of the federal *Fisheries Act* and Fisheries and Oceans Canada policy for the management of fish habitat[10]. Projects that may alter fish habitat fall under the jurisdiction of Fisheries and Oceans Canada for review under section 35 of the *Fisheries Act*. Fisheries and Oceans Canada has negotiated agreements with some conservation authorities to carry out these reviews at varying levels, depending on the capability of the conservation authority. Fisheries and Oceans Canada has a similar agreement with Parks Canada to carry out section 35 reviews for projects in national parks, marine conservation areas, historic canals and historic sites.

Provincial water quality objective for phosphorus (2.2)

This section of the handbook provides an overview of the relationship between phosphorus and water quality and outlines the rationale for and approach used for the development of a revised provincial water quality objective for phosphorus. More detail is found in Appendix A, Rationale for a revised phosphorus criterion for Precambrian Shield lakes in Ontario.

Existing approach

The Ontario government’s goal for surface water management is Ato ensure that the surface waters of the province are of a quality which is satisfactory for aquatic life and recreation".[11] The existing PWQO for total phosphorus was developed by MOE in 1979.[12]

It was founded on the trophic status classification scheme of Dillon and Rigler[13], and was designed to protect against aesthetic deterioration and nuisance concentrations of algae in lakes, and excessive plant growth in rivers and streams.

Interim Provincial Water Quality Objective for total phosphorus (1979)

Current scientific evidence is insufficient to develop a firm objective at this time [i.e., 1979]. Accordingly, the following phosphorus concentrations should be considered as general guidelines which should be supplemented by site-specific studies:

1. To avoid nuisance concentrations of algae in lakes, average total phosphorus concentrations for the ice-free period should not exceed 20 µg/L.

2. A high level of protection against aesthetic deterioration will be provided by a total phosphorus concentration for the ice-free period of 10 µg/L or less. This should apply to all lakes naturally below this value.
3. Excessive plant growth in rivers and streams should be eliminated at a total phosphorus concentration below 30 µg/L.

In 1992, the PWQO for total phosphorus was given interim status. This reflected both the uncertainty about the effects of phosphorus, and the fact that phosphorus isn't toxic to aquatic life. The interim PWQO doesn't explicitly distinguish between lakes in different regions of Ontario (i.e., Precambrian Shield versus southern Ontario). Instead, it sets different targets for lakes depending on whether they have naturally low productivity (total phosphorus less than 10 µg/L) or naturally moderate productivity (total phosphorus greater than 10 µg/L) (see sidebar).

In summary, the intent of the interim PWQO for total phosphorus in lakes is to:

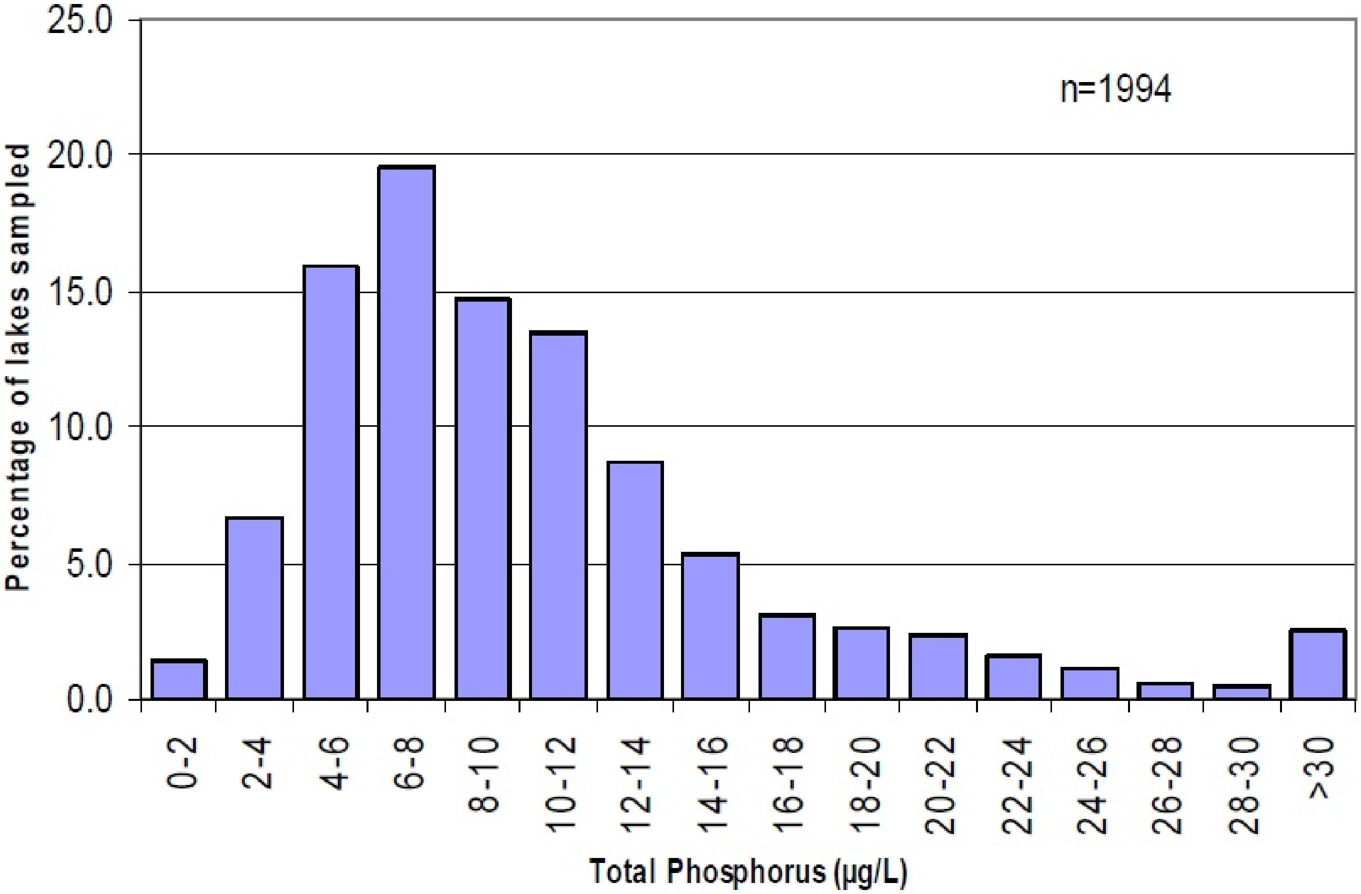
- Protect the aesthetics of recreational waters by preventing losses in water clarity
- Prevent nuisance blooms of surface-dwelling algae
- Provide indirect protection against oxygen depletion

Need for a revised approach

The need to revise the approach for managing phosphorus stems from an improved understanding of the relationship between phosphorus concentrations in water and the resulting plant and algal growth in lakes and rivers. It also reflects an improved understanding of watershed processes, biodiversity and the assessment of cumulative effects. A revised approach would ensure adoption of these considerations in the water management process.

Although the existing, two-tiered guideline for total phosphorus in lakes has performed well for more than 30 years, it fails to protect against the effects of cumulative development. Further, it doesn't protect the province’s current diversity in lake water quality and its associated biodiversity. As illustrated in Figure 2, there is a wide range of nutrient levels in Ontario’s inland lakes, with a prevalence of oligotrophic lakes.

Figure 2. Distribution of total phosphorus concentrations in sampled Ontario lakes



(source: MOE Inland Lakes database, March 2004)

The logical outcome of the application of the Ontario government's two-tiered 1979 phosphorus objective is that, over time, the quality of water in recreational lakes will converge on each of the two water quality objectives. This will produce a cluster of lakes slightly below 10 µg/L, and another slightly below 20 µg/L, thus reducing the diversity of water quality among lakes and, with it, the diversity of the associated aquatic communities.

Revised approach

The revised PWQO for lakes on the Precambrian Shield allows a 50 per cent increase in phosphorus concentration from a modeled baseline of water quality in the absence of human influence.

The revised approach has the following advantages:

- Each water body would have its own water quality objective, described with one number (i.e., 'undeveloped' or 'background' plus 50 per cent)
- Development capacity would be proportional to a lake's original trophic status
- Each lake would remain closer to its original trophic status classification. A lake with a predevelopment phosphorus level of 10 µg/L could be developed to 15 µg/L, maintain its mesotrophic classification, and development would not be unnecessarily constrained to 10 µg/L
- The existing diversity of trophic status in Ontario would be maintained in perpetuity

Phosphorus and dissolved oxygen (2.3)

The lake trout, Salvelinus namaycush, is found in about 2,200 lakes in Ontario, most of which are on or near the Precambrian Shield. These lakes are noted for their relatively pristine water quality: they generally have high clarity, low levels of dissolved solids, organic carbon and phosphorus, high concentrations of dissolved oxygen, cool temperatures in bottom waters year round and relatively stable water levels. Self-sustaining populations of lake trout are found in these lakes because they provide the specific, narrow environmental conditions required by this species.

Ontario's lakes were re-colonized by lake trout 10,000 years ago after the glaciers of the last Wisconsin Ice Age retreated. Populations have been largely isolated from one another since that time and adaptation to local conditions has led to genetically distinct, locally adapted stocks. The preservation of genetic diversity of the species requires conservation of individual populations through the protection of the habitat and water quality in the lakes in which they occur.

Lake trout are long-lived and late maturing, with females first spawning at six to ten years of age. This late maturation, combined with modest egg production and low recruitment rates, makes lake trout vulnerable to external factors that increase mortality. These factors include over-fishing and degradation or loss of spawning and summer habitat.

Loss of late summer habitat is influenced by phosphorus loading. In the southern part of their range, lake trout live in the hypolimnion during the summer. The hypolimnion is isolated from the atmospheric and photosynthetic supply of oxygen from the time when the lakes become thermally stratified during spring overturn until recirculation or turnover takes place in the fall. To sustain lake trout over the summer, the hypolimnion must contain enough dissolved oxygen.

When nutrient enrichment takes place as a result of shoreline development, the algae production-decomposition cycle depletes the oxygen in the deep waters of the hypolimnion.

Low concentrations of dissolved oxygen in bottom waters impair the lake trout's respiration, and therefore its metabolism, which compromises its ability to swim, feed, grow and avoid predators. Studies have shown that juvenile lake trout need at least 7 milligrams (mg) of dissolved oxygen per litre (L) of water. Measured as a mean, volume-weighted, hypolimnetic dissolved oxygen concentration (MVWHDO), this level is also sufficient to make sure that natural recruitment takes place. The Ministry of Natural Resources has thus developed a criterion of 7 mg of dissolved oxygen/L (measured as MVWHDO) for the protection of lake trout habitat (references in Appendix B). The provincial water quality objective for dissolved oxygen allows for the establishment of more stringent, site-specific criteria for the protection of sensitive biological communities.[14]

The Province recommends that generally there will be no new municipal land use planning approvals for new or more intense residential, commercial or industrial development within 300 metres of lake trout lakes where the MVWHDO concentration has been measured to be at or below 7 mg/L. This recommendation also applies to lakes where water quality modelling has determined that the development of existing vacant lots, with development approvals, would reduce the MVWHDO to 7 mg/L or less. Preservation of an average of at least 7 mg of dissolved oxygen/L in the hypolimnion of Ontario's lake trout lakes will help to sustain the province's lake trout resources. For more information on sampling oxygen and calculating the MVWHDO concentration, please see the Technical Bulletin in Appendix C.

---

[1] Department of Fisheries and Oceans. 1986. The Department of Fisheries and Oceans policy for the management of fish habitat. Department of Fisheries and Oceans. Ottawa. 28 p.

[2] Great Lakes Regional Waterways Management Forum. 1999. The Great Lakes: A waterways management challenge. Harbor House Publishers, Inc. Michigan.

[3] Ontario Ministry of Natural Resources. 2003. 2003 Recreational Fishing Regulations Summary. Queen's Printer for Ontario.

[4] Office of the Provincial Auditor of Ontario. 1999. 1998 Annual Report. Queen's Printer for Ontario.

[5] Ontario Ministry of Tourism and Recreation. 2002. An Economic Profile of Resource-Based Tourism in Ontario, 1999. Queen's Printer for Ontario.

[6] Ontario Ministry of Tourism and Recreation. 2002. An Economic Profile of Resource-Based Tourism in Ontario, 1999. Queen's Printer for Ontario.

[7] Executive Resource Group. 2001. Managing the Environment: A Review of Best Practices, Volume 1.

[8] Cottage Life Magazine. 2004. Cottage Life Advertising Brochure.

[9] Ontario Ministry of the Environment (Economic Services Branch). 1997. Economic Analysis of the Proposed Lakeshore Development Policy: Socio-economic value of water in Ontario. Queen's Printer for Ontario.

[10] Department of Fisheries and Oceans. 1986. The Department of Fisheries and Oceans policy for the management of fish habitat. Department of Fisheries and Oceans. Ottawa.

[11] Ontario Ministry of Environment and Energy. 1994. Water management: Policies, guidelines, Provincial Water Quality Objectives of the Ministry of Environment and Energy. Queen's Printer for Ontario.

[12] Ontario Ministry of Environment and Energy. 1979. Rationale for the establishment of Ontario's Provincial Water Quality Objectives. Queen's Printer for Ontario.

[13] Dillon, P.J. and F.H. Rigler 1975. A simple method for predicting the capacity of a lake for development based on lake trophic status. J. Fish. Res. Bd. Can. 32: 1519-1531.

[14] Ontario Ministry of Environment and Energy. 1994. Water management: Policies, guidelines, Provincial

Basics of Assessing Lakeshore Capacity Model

Basics of assessing lakeshore capacity (3.0)

When lakeshore capacity assessment should be considered (3.1)

Lakeshore capacity assessment is a scientifically-established and recommended tool for municipalities to use on a routine basis as part of their ongoing land-use planning process. Triggers to carry out lakeshore capacity assessment may include the following:

- When developing or updating official plans
- If significant improvements to road access to a lake are being considered, or have occurred, increasing the use of residences from seasonal to extended seasonal or permanent
- If development (i.e., new planning approvals) are being considered within 300 metres of a lake or a permanently flowing stream within its watershed[15]
- If significant or unusually large amounts of development are proposed for a lake beyond the 300 metre boundary
- If water quality problems (such as elevated levels of phosphorus, loss of water clarity, or algal blooms) are noted
- If lake trout populations are present
- If changes in fisheries have been noted, especially diminishing populations of coldwater species such as lake trout
- If cottagers or year-round residents raise concerns about the effects of development on water quality

What lakeshore capacity assessment will tell you (3.2)

The Lakeshore Capacity Model will estimate a lake's development capacity and compare its current level of development to this estimate. If the lake hasn't attained its development capacity, the model will also estimate the additional amount of development it can tolerate. This will allow a municipality to decide how many residential and cottage lots, or other uses, should be permitted on the lake. Municipalities with lake trout lakes should note that dissolved oxygen may be a more stringent criterion than phosphorus for limiting development on these lakes to protect fish habitat.

What is needed to carry out a lakeshore capacity assessment? (3.3)

Expertise needed

Resource managers, planners and environmental engineers carrying out lakeshore capacity assessment on inland lakes will require some level of familiarity with environmental resource management, the overall land-use development process, and the Lakeshore Capacity Model. Some municipalities may have staff with this expertise; others won't. Local conservation authorities may have experts on staff that could be of assistance.

Most resource managers, planners and environmental engineers with a basic understanding of aquatic science can be trained to use the Lakeshore Capacity Model in less than a week.

Alternately, there are consultants familiar with lakeshore capacity assessment and the model that could provide municipalities with their expertise.

Information needed

This section provides an overview of the information needed to run the Lakeshore Capacity Model. The minimum information required to run the LCM is:

- Lake name
- Lake latitude and longitude, defined as the point where the outflow leaves the lake (degrees, minutes, seconds)
- Lake area (hectares)
- Local catchment or watershed area[16], excluding both the lake area and the area of any upstream lakes and their watershed(s) (hectares)
- Current shoreline development status of all lots (i.e., the number of cottages and resort units and the nature of their usage: permanent/seasonal/extended seasonal); this information should also include vacant lots of record
- Land-use data for the watershed (i.e., the percent of the watershed that is composed of wetlands, agricultural or urban land use)
- Categorization of the hypolimnion as anoxic or oxic at the end-of-summer (see Technical Bulletin in Appendix C for more information on sampling deepwater oxygen in lakes)
- Observed or measured total phosphorus concentrations to evaluate the model's performance

If you wish to model oxygen conditions and/or to evaluate lake trout habitat and the effect of development on lake trout habitat, further information is required:

- Detailed morphometric/bathymetric data (areas within each contour interval in hectares)
- Water temperature profiles from August and September to determine the depth of the hypolimnion at the end of summer stratification (metres)
- Dissolved oxygen profiles to evaluate the model's performance
- Maximum fetch (maximum distance across the lake through the deepest location in kilometres)

Additional information that will improve the accuracy of the model’s predictions includes:

- Detailed site specific information to assess whether there is potential for the long-term attenuation of phosphorus in watershed soils (see Section 5.2 for additional information)

Information sources

The Government of Ontario’s Lakeshore Capacity Model uses input data from sources such as topographic maps, geological maps, fishing maps (e.g., bathymetric maps, aquatic habitat inventory and lake files available from MNR for all significant cottage lakes in the province), MOE's lake files, and additional information that has been built into the model.

Shoreline development is the critical managed parameter. Information can be obtained from the assessment rolls of municipalities, lake residents' associations or direct counts. At a cost, the Municipal Property Assessment Corporation can provide assessment data that identify waterfront lots and second-tier development. In areas of the province where they exist, conservation authorities can also be a source of information on water quality in lakes and tributaries.

The following table provides some additional information regarding the possible sources of input data for the Lakeshore Capacity Model:

Table 2: Information on sources of input data for the Lakeshore Capacity Model

Information Required	Source	General Quality of Source
Lake name	MNR, MOE, Municipality, Geographical Information Systems (GIS), Gazetteer of Ontario	Good
Lake latitude and longitude	GIS, Web-based mapping programs (e.g., Google Earth)	Good
Lake area	MNR, MOE, GIS	Good
Local catchment or watershed area	MNR, MOE, GIS	Good
Current shoreline development status	Municipal tax roll information	Good
Current shoreline development status	Municipal Property Assessment Corporation (MPAC)	Good, GIS expertise is required
Current shoreline development status	Municipal Affairs and Housing	Good, where information is available

Information Required	**Source**	**General Quality of Source**
Current shoreline development status	Cottagers' Associations	Quality and availability varies
Current shoreline development status	Web-based mapping programs	Good, but resolution may vary regionally; usage estimates are not available using this source
Land-use data for the watershed	GIS	Quality varies; percent wetland area values are often underestimated
Land-use data for the watershed	Information that has been verified on the ground by measurement	Good, but requires technical expertise
Categorization of the hypolimnion as oxic or anoxic	MNR, MOE, Municipality	Good if recommended sampling protocols are followed (Appendix C)
Observed or measured total phosphorus concentrations	MNR, MOE, Municipalities, Cottagers' Associations	Good if recommended sampling and analytical protocols are followed (Appendix C). Analysis should be completed by a reputable lab with suitable detection limits for low-level phosphorus concentrations (see Section 6.5)

Implementing lakeshore capacity assessment (3.4)

The Implementation of effective lakeshore capacity assessment will require a coordinated and cooperative approach by the various agencies involved to develop and implement the planning and regulatory tools that are needed. It is expected that implementation will be phased in, in a manner that reflects differing levels of municipal organization and the ability of municipalities to develop or acquire the expertise needed to do the assessment.

Adoption of appropriate policies in official plans and zoning bylaws

It is recommended that municipalities and planning boards update the policies in their official plans to implement lakeshore capacity assessment. Reforms made to the *Planning Act* in 2007 require municipalities to update their official plan not less frequently than every five years after the plan comes into effect, followed by an update of the accompanying zoning by-law within three years after the new official plan is in effect. These may include policies and standards that identify:

- Water quality objectives required to protect water quality and fish habitat
- Where lakeshore capacity assessments need to be completed and/or lake capacity limits need to be established prior to additional development approvals
- Where lakeshore capacity assessments have been completed and/or lake capacity limits have been established and:
    - Which lakes, if any, have reached their development capacity
    - Which lakes haven't reached their development capacity and what additional application requirements, approval considerations and/or development conditions may be required to protect their water quality and coldwater fish habitats

Where the catchment area of a lake is shared with another planning authority, official plans should establish a mechanism for allocating development capacity in cooperation with the neighbouring jurisdiction(s) to make sure that the water quality objectives of the lake are met.

Establishment of appropriate review mechanisms for new development

All planning authorities that have been delegated or assigned responsibility for the approval of new development through mechanisms such as official plans, official plan amendments, zoning bylaws, severances and subdivision plans should ensure as part of their review that:

- New planning approvals will meet all the policies of the official plan, including water quality objectives
- Where no policies on water quality exist in an official plan, the limits specified in this handbook and the provincial water quality objectives be used as a basis for defining water quality limits
- Where appropriate, a Lakeshore Capacity Model is used and development capacity limits are established
- Development doesn't exceed the capacity of the lake
- Appropriate design and construction conditions are incorporated as conditions of approval to minimize the effect of development on water quality and fish habitat
- All planning decisions shall be consistent with the Provincial Policy Statement (2005)

Modeling, setting capacity limits and allocating development capacity

In reviewing new developments, municipal planning authorities are encouraged to:

- Use the Lakeshore Capacity Model to establish development capacity limits, where necessary
- Set development capacity limits for lakes within their jurisdiction
- Allocate lakeshore development capacity among landowners and developers within the catchment area of a lake
- Cooperate in the allocation of development capacity where the catchment area of a lake is shared with an adjacent planning authority or authorities

Municipalities and planning boards are viewed as the most appropriate level of government to carry out these responsibilities. They're in the best position to identify and set development limits at the local level in the context of other social, economic and environmental considerations. This may require municipalities to train staff, hire consultants or work with conservation authorities to use the Lakeshore Capacity Model, set development capacities and translate them into development potential. Costs for such activities can often be recouped from the applicants as part of the development review process.

Upper-tier municipalities with planning and engineering staff are viewed as having the responsibility and capacity to carry out this role. The Ontario government encourages these jurisdictions to assume responsibility for the entire process of lakeshore capacity planning with some ongoing technical assistance and training from the province.

Planning authorities who make decisions on plans of subdivision, plans of condominium, severance applications or other *Planning Act* proposals, are expected to make decisions on the suitability of severance applications based on planning direction received from the municipalities or planning boards in which they are located, as well as technical information received from the Province.

Provincial role

The Ontario government, through MOE and MNR, will provide technical support to municipal planning authorities by:

a. Providing educational/outreach materials on the application of the Lakeshore Capacity Model

b. Providing municipalities with existing information on lake trout habitat and lakes at or near development capacity
c. Providing technical advice or support to municipalities on lakeshore capacity assessment, when asked
d. Providing technical advice to municipalities on site-specific applications of the Lakeshore Capacity Model on a limited, short-term basis until the municipalities have fully assumed these responsibilities

In areas with no municipal organization, the Province will continue to apply the Lakeshore Capacity Model and establish lakeshore capacity limits.

Watershed planning

Ecosystem-based watershed planning is used to assess long-term changes and cumulative effects, and overcomes the limitations of administratively-defined planning boundaries. The Ontario government recognizes the watershed as the ecologically meaningful scale for planning. This is a policy of the Provincial Policy Statement (2005) and is consistent with the principles of source water protection.

The PPS (2005) also states that a coordinated, integrated and comprehensive approach should be used when dealing with planning matters which cross municipal boundaries. The watershed is an appropriate arena for this inter-municipal coordination — especially as applied to inland lakes and river systems. Conservation authorities are watershed-based and already provide inter-municipal coordination in various parts of the province.

---

[15] The use of the 300-metre distance is described in Section 4.3 of the handbook. The area within 300 metres of a lake or permanently flowing stream is considered to be the area of influence for phosphorus loading, (i.e., the area within which phosphorus from septic systems may move to the lake or stream).

[16] Catchment area and watershed area are treated as synonyms herein, and exclude the lake surface area. Catchment or watershed area is defined as the area of land that drains water, sediment and dissolved materials to a common receiving body or outlet. The local catchment or watershed area excludes the catchment areas of upstream lakes.

Applying the Lakeshore Capacity Model

Applying the lakeshore capacity model (4.0)

Elements of the model (4.1)

The Ontario government's Lakeshore Capacity Model quantifies the linkages between the natural contributions of phosphorus to a lake, the contributions of phosphorus to a lake from shoreline development, the water balance of a watershed, the size and shape of a lake and the resultant phosphorus concentration. A schematic of the model is given in Figure 3.

Figure 3. Ontario government's Lakeshore Capacity Model

The model allows the user to calculate how the water quality of a lake will be affected by the addition or removal of shoreline developments (such as permanent homes, seasonal cottages, resorts, campsites) and point source discharges (such as sewage treatment plants). It can calculate the natural, undeveloped condition of a lake, the amount of development (in terms of number of dwellings) the lake could sustain without changing its total phosphorus concentration past a given point, and the difference between existing conditions and that tolerance point. The model also allows the user to theoretically modify the land-use and development parameters of upstream lakes to estimate the effect of potential development on downstream lakes in the watershed.

How the model was developed (4.2)

The Dillon-Rigler model, published in 1975[17], was the first model to specifically address the relationship between the eutrophication of Ontario's Precambrian Shield lakes and the density of development along their shorelines. Its rapid acceptance by the international scientific community led to the development of the Ontario government's Lakeshore Capacity Study (1976-1980) in the belief that substantial predictive relationships might be developed for other responses of lakes to shoreline development. The Lakeshore Capacity Study was coordinated by the Ministry of Municipal Affairs and Housing and published in 1986[18]. It produced predictive models for land-use (MMAH), fisheries exploitation and wildlife (MNR), microbiology and water quality (MOE), as well as a capacity model that integrated all of these components (MMAH). Although several of these models were very useful, MOE's water quality model was the only one that management agencies adopted for routine use.

MOE's Lakeshore Capacity Model is based on the total phosphorus concentration or trophic status of a lake. It provides an accurate and quantitative linkage between the level of shoreline development and the level of phosphorus in a lake. This output can subsequently be used to predict the impacts of development on water clarity and deepwater oxygen content.

Over time, resource managers in MOE's regional offices, other government agencies in Canada and the United States, and the scientific and consulting communities have adopted the Lakeshore Capacity Model as an assessment tool. Although the model was accepted as a useful planning approach, the Ontario government never formalized its implementation. As a consequence, resource managers developed their own modifications to the model to address local concerns and interpretations. By the early 1990s, it became apparent that these informal implementation arrangements were no longer suitable; significant variations of the model were in use across the province, leading to a fragmented approach to water quality protection and confusion among stakeholders.

With the MOE's corporate adoption of watershed planning in 1993, a process leading to the formalization of lakeshore capacity assessment in policy commenced. This handbook is a result of this process. It was developed to give clear and consistent guidance to municipal planning authorities (as well as developers and lake residents),and to provide effective succession training to ministry staff, municipal staff and consultants.

Assumptions built into the model (4.3)

The Lakeshore Capacity Model includes several assumptions and coefficients. These numeric data represent the unknown and variable conditions in a lake or watershed. In the past, resource managers often adapted these variables to fit local conditions or to achieve certain management goals.

The mathematical assumptions in the Lakeshore Capacity Model have been refined over the past 25 years. Those presented herein reflect the current position of the MOE, and are based on the recent peer-reviewed scientific evidence. They also reflect MOE's commitment to a precautionary approach, as outlined in the Ministry's Statement of Environmental Values. This approach supports the use of conservative assumptions to protect the environment when there is uncertainty in the science. Resource materials related to the assumptions are listed in Appendix B, Lakeshore capacity assessment resources.

Definition of shoreline development

The original Lakeshore Capacity Study (1986) defined shoreline development as the total number of units to be situated within 300 metres of the lake or any inflowing stream of the lake. Herein, the definition of development is broadened to include any activity which, through the creation of additional lots or units or through changes in land and water use, has the potential to adversely affect water quality and aquatic habitat. Development includes the addition of permanent residences, seasonal or extended seasonal use cottages, resorts, trailer parks, campgrounds and camps, and the conversion of forests to agricultural or urban land. It also recommended that consideration be given to any proposed large-scale alterations in land use (e.g., clearcutting of forest, dredging or filling of lowland areas) which may affect the TP input from the terrestrial watershed.

A watershed represents the total land area that contributes drainage to a lake. In some cases, significant portions of the watershed may be situated numerous kilometres from the lake they drain into. For management purposes, the 300 metre distance from the shoreline of the lake or any inflowing stream of the lake will continue to be used as the primary influence area. This 300 metre zone is immediately adjacent to the lake and is therefore considered sensitive in terms of lake water quality protection. On a case-by-case basis, large-scale developments (e.g., subdivisions) or any other significant land use activities which may affect the TP input from the terrestrial watershed beyond 300 metres may also be considered.

Phosphorus loadings to septic systems

Since the Lakeshore Capacity Model was first developed in the 1970s, the water usage rates for recreational lakes have increased due, in part, to the increased use of washing machines and dishwashers. These changes have been partially offset by decreases in the phosphorus content of detergents. The model now assumes that 0.66 kilograms of phosphorus is contributed per capita per year to septic systems (Paterson et.al. 2006, Appendix B). This loading is considered to be the most appropriate coefficient in cases where detailed site-specific measurements haven't been made.

In general, reduced phosphorus loading rates should only be used for calculating lakeshore capacity where:

- The sewage effluent is received and treated in a municipally or provincially operated system designed to produce lower per unit phosphorus loading levels; if this system discharges into the lake being modeled, its total phosphorus load should be accounted for as a point source when modeling;
- The sewage effluent is transported, treated and discharged outside the catchment area of the lake in accordance with regulatory requirements.

Other sources of phosphorus from shoreline development

The Lakeshore Capacity Model focuses on phosphorus from septic systems as the major, human contributor to lake loadings. In recent years, as lake developments have become more urban with extensive cleared areas, gardens and turf grass, overland runoff has also been recognized as an additional contributor of phosphorus.

The model assumes an overland run-off loading to lakes of 0.04 kilograms of phosphorus per lot per year. This is calculated by multiplying the export coefficient for phosphorus from pasture land (9.8 $mg/m^2/yr$; Dillon et.al. 1986, Appendix B) by the mean size of lots in the District of Muskoka and the County of Haliburton (3798 m^2, n>1000; Paterson et.al. 2006, Appendix B). Additional sources of phosphorus such as sewage treatment plants, golf courses, intensive agriculture or timber harvesting, and lake sediments may also contribute significant nutrient loads to lakes. In cases where these loads have been quantified through direct measurement, they may be input into the Lakeshore Capacity Model as additional loads.

Retention of phosphorus from septic systems

The degree to which septic system phosphorus may be retained in watershed soils has been the subject of considerable scientific debate over the past two decades. While the Ontario Ministry of the Environment has recognized that the degree of retention may vary with soil type and grain size[19], it has consistently held the position that all of the P deposited in septic systems will eventually migrate to lake ecosystems. This reflects the predominance of thin, organic or sandy soils and tills on the Precambrian Shield, the fractured nature of the bedrock, and the predominance of aging septic systems that were designed for hydraulic purposes (i.e., to ensure fast infiltration) rather than for nutrient retention. Furthermore, at the time of model development, there was no scientific evidence that phosphorus could be retained in watershed soils over the long-term.

Subsequent studies, however, have shown that the movement of phosphorus from septic tank- tile bed systems may be retained to some degree in certain soil types[20,21]. In response to this new science, the Ministry has developed criteria (Section 5.2) that can be used to assess the likelihood of P retention at a site over the long-term (i.e., decades). These criteria were developed after organizing technical workshops on the topic, liaising with technical experts, reviewing relevant peer-review studies from Ontario and elsewhere, and following the completion of technical reports by Dr. W.D. Robertson (Department of Earth Sciences, University of Waterloo) examining the fate of P in septic system plumes at sites on the Precambrian Shield.

A review of the peer-reviewed literature and the Robertson reports indicates that eight septic system plumes located within the Precambrian Shield in Ontario have been the subject of detailed field studies[22]. Of these, significant (> 90%), long-term (decadal-scale) retention of P has been demonstrated at half of the sites (Muskoka, Harp, Lake Joseph and Nobel). However, the Harp site was not investigated in detail because of monitoring difficulties (Zanini et.al. 1998)[23], and the Nobel plume is described by Robertson (2003) as distinct from the other sites because its septic system receives only "blackwater". Thus, only two of the aforementioned sites (one quarter of the sites on the Precambrian Shield in Ontario with detailed monitoring networks) provide field evidence of significant, long-term retention of P.

It is worth noting that the two sites showing long-term P retention (Muskoka, Lake Joseph) have native soils in excess of six meters. In contrast, all of the monitoring sites that have native soils of less than three meters show elevated concentrations of phosphate in groundwater (Delawana, Sturgeon Bay), have uncertainty in how they were monitored (Harp), or have uncertainty regarding the location of the P plume (Killarney). Poor attenuation at these sites, and the apparent loss of the plume core zone at the Killarney site, has been attributed to a variety of factors including the presence of thin soils, reducing conditions that develop in saturated soils, or chemical interference from water treatment apparatus. The above findings remind us that we must be cautious on the issue of P retention, and that failure to do so may place sensitive lakes at an unacceptable level of risk.

Thus, the recommended approach for applying phosphorus retention factors reflects the type of information that is available on the factors that influence the movement of phosphorus in soils. There are two basic approaches:

Use of phosphorus retention factors

1. In areas of the province where soils are thin or absent, and bedrock is exposed or fractured, site-specific information may show that very little phosphorus is retained, and modelers should use a 100 per cent loading coefficient within 300 m of the shoreline or inflowing tributary.
2. At sites where deeper native soils are present, planning authorities or development proponents may consider undertaking detailed site-specific studies to assess phosphorus distribution, migration velocity and long-term retention. This information should be made available to the local planning authority for review and consideration (see Section 5.2). In such cases, MOE will provide interpretation and guidance on the requirements of site-specific studies. Following approval, the resulting retention factor may be used in the model to reduce the input of P loading from septic systems.

Site engineering and vegetated buffers as nutrient sinks

In urban areas, techniques such as stormwater detention ponds, constructed wetlands and infiltration areas can be used to reduce the concentration of nutrients in overland runoff. For lakeshore properties, techniques such as shoreline naturalization and vegetated buffer strips have been accepted in many jurisdictions as sound management practices. However, there is not enough information to reliably predict the level of nutrient control that may be achieved through such techniques, or their long-term effectiveness at reducing phosphorus loading. Accordingly, the Lakeshore Capacity Model makes no allowances for mitigation of overland runoff through site engineering and vegetated buffers. It is recommended, however, that further studies be done to quantify the effectiveness and longevity of such techniques.

Rivers, wetlands and phosphorus transport

The Lakeshore Capacity Model assumes that all the phosphorus leaving one lake will be transported downstream to the next lake. Questions have been raised about the potential for phosphorus retention in wetlands and river channels. Evidence to date doesn't support the idea of phosphorus retention in either wetlands or river channels on a long-term basis. In both rivers and riverine wetlands, phosphorus retention is seasonal, with retention in the summer and export during high flow periods in the spring and fall. Accordingly, the current model doesn't include the possibility of phosphorus retention along river systems between lakes. This assumption may be revisited in the future as more information is gathered.

Usage rate of shoreline properties

One of the critical unknown variables in the Lakeshore Capacity Model is the usage rate of shoreline properties: how many days a year a property is occupied and by how many people. Usage rates vary dramatically with factors such as distance to major population centres and rate of conversion of seasonal residences to permanent use. Some indication of current usage rates may be obtained from surveys, tax records, lake residents' associations, topographic maps or aerial photos, although uncertainties are associated with all these information sources. Estimating future usage rates is more difficult. Estimating usage rates for uses other than year-round residences and seasonal cottages (such as resorts) is also challenging. The current MOE position is that the provincial standard usage rates should remain in effect (Table 3).

Table 3. Standard usage rates for lakeshore residences

Type of shoreline residence	Usage rate (capita years per year)
Seasonal	0.69
Extended seasonal	1.27
Permanent	2.56

Usage rates can be modified based on local survey data. MOE also recommends that lake managers develop and update registries of development for each lake. In cases where usage rates are unknown and where there is no winter road access, MOE recommends using the seasonal rate of 0.69 capita years per year as a default. The extended seasonal rate of 1.27 capita years per year should be used for other non-permanent developments that have reliable year-round access.

MOE also recommends that specific phosphorus loading and/or usage rates be used for youth camps, resorts, permanent trailer parks, and campgrounds/tent trailers/RV parks:

Phosphorus loading / usage rates

Youth camps

Each camper = 125 g per year

Resorts (serviced, housekeeping cabins or meal plan)

Each resort unit = 1.18 capita years per year; or
Each guest = 308 g per year; or
If staff are considered, the resort contribution can be estimated using the extended seasonal usage figure of 1.27 capita years per year per unit

Trailer parks

Each site or hook up = 0.69 capita years per year

Campgrounds / Tent trailers / RV parks

With septic system to service pump outs, comfort and wash stations: Each campsite = 0.37 capita years per year

With vaulted (i.e., pumped out) outhouses and grey water treatment only: Each campsite = 0.175 capita years per year

To allocate remaining development (existing vacant lots plus new severances) where usage patterns are known, managers should use a hybrid usage factor: the existing ratio of seasonal / extended seasonal / permanent residences, and their respective standard usage factors.

Watershed-based planning issues

Lakeshore capacity assessment is consistent with watershed planning in that it considers phosphorus loading on a watershed basis. All lakes in a watershed have to be taken into account and modeled to make accurate predictions. Failure to model all lakes in a watershed may result in: 1) an overestimate of the concentration of phosphorus in the target lake because, with no accounting for retention by upstream lakes, the phosphorus export from the entire watershed will be added to the target lake; or 2) an underestimate of the P concentration in the target lake because the phosphorus load from nutrient-rich lakes upstream is not considered. In practice, lakes that are less than 25 hectares in size aren't considered unless they have significant shoreline development. Wetlands aren't modeled as separate water bodies.

Watershed-based planning can be applied in three different ways, depending upon the situation:

Application of watershed-based planning

1. First time modeling, no lakes known to be at capacity

   All upstream sources of phosphorus must be accounted for in a lake’s budget. Development capacity must allow for human sources of phosphorus from upstream. In this case, the watershed includes all lakes greater than 25 hectares in size, and smaller lakes with significant development, up to the headwaters of that catchment.

2. Risk-based decision making

   When a lake is getting close to capacity, managers should review the implications of further upstream development, taking into consideration the amount of sampling that has been done:

   - How much development capacity is left upstream?
   - What type of development is planned for the future?

  - How much will full development upstream drive a target lake past its water quality objective?
  - What resource is at risk if an objective is exceeded (e.g., clarity, dissolved oxygen)?
3. When a lake reaches capacity

   In this situation, MOE recommends using a less restrictive definition of a watershed as a balance between environmental protection and economic development. In this case, the watershed includes the lake that has reached capacity and extends upstream to the point where cumulative in-lake retention of phosphorus exceeds 80 per cent.

Lakeshore capacity assessment should be based on phosphorus loadings for the entire watershed so that phosphorus offset trading, remediation and mitigation can be incorporated if they become established practices in the future.

Comparisons between modeled estimates and measured water quality values

There will always be some discrepancy between modeled estimates and measured water quality values. This can occur because current development may not yet be expressed as changes in trophic status due to the lag time that exists between construction and phosphorus loading. Discrepancies may also result from use of inappropriate coefficients, inaccurate water quality data, or an insufficient sampling period (Table 4).

Table 4. Possible reasons for a poor prediction of measured TP concentrations using the model

Common reasons for over-prediction of measured TP	**Common reasons for under-prediction of measured TP**
• A lag time in the movement of phosphorus from septic systems to lakes - the impact has not yet been realized in the lake • Site conditions favour the long-term retention of phosphorus in watershed soils, and anthropogenic contributions of phosphorus are overestimated • There are significant groundwater inputs to the lake, diluting phosphorus concentrations in the lake • The lake is modeled as being anoxic, when it is oxic during the end-of-summer period • Inaccurate input coefficients are used (e.g., runoff values, usage values, lake area) • The lake falls outside the calibration and test range of the modes (e.g., lakes with very small surface areas) • Measured phosphorus data are of poor quality	• There is a significant internal load of phosphorus to the lake that the model does not account for • The portion of the catchment that is estimated as wetland area (i.e., % wetlands) is underestimated • The amount of cleared land is underestimated • The lake is modeled as being oxic, when it is anoxic during the end-of-summer period • Inaccurate input coefficients are used (e.g., runoff values, usage values, lake area) • The lake falls outside the calibration and test range of the model (e.g., shallow lakes where there is a significant internal load of phosphorus to the water column) • Measured phosphorus data are of poor quality

MOE recommends that total phosphorus be used as the parameter for comparison of model results with measured values. The sampling period must be long enough to enable the long-term mean to be estimated to within 20 per cent with 95 per cent confidence. In most cases, this means that at least two years of spring overturn measurements or one year with at least five measurements of volume-weighted phosphorus concentrations should be used (see Section 6.2, Table 5). Measurements should be summarized using an arithmetic mean for comparison purposes.

If the modeled estimates and measured values are within 20 per cent of each other, then they aren't considered to be significantly different. If the modeled estimates and measured values differ by more than 20 per cent, then lake managers should inspect the measured record for quality and the data used in the model for accuracy, consider alternative coefficients that may be more accurate, and consult other water quality measurements (i.e., Secchi depth and oxygen-temperature profile records).

Following a review of the model coefficients and monitoring data, predicted and measured values may still differ by more than 20 per cent. A test of the Lakeshore Capacity Model across many watersheds in Ontario suggests that, in general, the following lake types may not model well, because they fall beyond the calibration and test range of the model:

- Shallow lakes (lakes with mean depth < 5 metres): The lakeshore capacity model was calibrated on Precambrian Shield lakes that thermally stratify during the ice-free season. The model assumes a constant to estimate the rate of loss of phosphorus to lake sediments (i.e., the settling velocity, or mass transfer coefficient). This constant is modified depending on whether or not a lake's hypolimnion is oxic or anoxic in late summer. For shallow lakes, the default values may overestimate the loss of phosphorus to sediments, as it does not account for P re-suspension during wind events.
- Tea-stained lakes (dissolved organic carbon concentrations > 10 mg/L): The model has not been calibrated for lakes that are highly coloured due to humic and fulvic acids. These lakes are common in northern Ontario, and may have relatively high background phosphorus concentrations.
- Lakes with small surface areas (< 25 ha): For very small lakes, minor differences in surface area can have a large impact on the model output. For example, the difference in surface area between a 25 and 20 ha lakes is small in absolute terms, but represents a 20% difference in relative size. This change in the model input may result in a significant increase in predicted P.

What if the model fails?

The Ministry recommends that the Lakeshore Capacity model be used to manage the effects of shoreline development and land-use change on P concentrations in Precambrian Shield lakes. As outlined in Appendix A, this approach allows resource managers and planning authorities to assess changes relative to lake-specific PWQOs for phosphorus, to assess future risks from the cumulative effects of development, and to protect the trophic diversity of lakes across the province. However, in some cases the model may not predict phosphorus concentrations within acceptable limits, putting into question its applicability. In these cases, it is recommended that the interim PWQO for phosphorus be followed as a guideline (Section 2.2).

In both cases, a total phosphorus concentration of 20 µg/L will be used as the upper limit to protect against nuisance algal blooms. In situations where a lake is naturally above 20 µg/L (e.g., highly coloured, tea-stained lakes), Regional MOE staff may use discretion to allow a limited amount of new development (e.g., < 10 lots), provided the lake is not sensitive, and downstream lakes are not designated at-capacity.

Changes to model assumptions

Over the past 30 years, some of the original assumptions and coefficients of the Lakeshore Capacity Model have been modified based on new scientific evidence. With the shift to municipalities for many responsibilities in land-use planning and in recognition of the need for a stable planning environment, questions have been raised about how best to continue with the process of updating assumptions. MOE recommends establishing a working group with representation from MOE, MNR, MMAH, municipalities and the private sector to periodically review major scientific advances and to discuss challenges to the model. Based on this information, the workgroup would consider if changes to the model are warranted.

Overview of the Lakeshore Capacity Model (4.4)

The Lakeshore Capacity Model will assess the lakeshore capacity of a specific lake. The model was developed and calibrated for Precambrian Shield lakes in south-central Ontario, but has been tested and used in lakes across the entire Precambrian Shield. At the end of the assessment process, the user will have had the opportunity to determine the amount of development — whether seasonal, permanent, resort or point source that each lake in a watershed could accommodate while adhering to its water quality targets.

Using the Lakeshore Capacity Model to assess the development capacity of a lake

1. Modeling begins at the top of the watershed and continues downstream until the target lake is reached. The model is used to track phosphorus sources and the transport of phosphorus from one lake to the next downstream lake.
2. The model calculates the total phosphorus (TP) concentration of a lake by calculating what the TP concentration would have been without shoreline development (the predevelopment concentration) and adding this amount to the current estimated TP contribution from shoreline development.
3. The model can also be used to calculate the response of water quality to increases in shoreline development as well as the amount of additional development the target lake could tolerate while still adhering to its desired water quality targets. The model will also illustrate how changes in the upper watershed would influence the quality of water in downstream lakes.
4. The user can compare the model results with the provincial water quality objectives for total phosphorus. The user can then determine the amount of development that could occur while still enabling these objectives to be met.
5. The model translates water quality objectives (as µg/L phosphorus) into total allowable phosphorus load. The total allowable phosphorus load can either be expressed in kilograms or as the number of allowable cottages, permanent residences or resort units.

The Lakeshore Capacity Model is an assessment tool that is intended to be used by resource managers to predict the response of water quality to shoreline development. The municipal bodies surrounding the lake or the watershed are responsible for implementing the model predictions and allocating lakeshore capacity after the assessment has been completed.

Land use planning applications and best management practices (5.0)

Why use best management practices? (5.1)

Best management practices (BMPs) are practices that can help to reduce the migration of phosphorus from septic system effluents to water bodies, thereby reducing the effects of shoreline development on lake water quality. Coupled with lakeshore capacity assessment, BMPs will help municipalities maintain good lake water quality. On their own, BMPs can help to reduce the adverse effects of shoreline development on inland lakes.

Best management practices can take many forms. One category involves practices that can be implemented during the planning and construction phase of shoreline development and especially during the design and construction of septic systems. Other practices relate to the ongoing maintenance of a septic system and other operating practices of the cottage or homeowner. An overview of BMPs that lessen phosphorus migration is provided below. Sources of more detailed information on BMPs are listed in Appendix B.

As noted in Section 4.3, BMPs such as shoreline naturalization and vegetated buffer strips have been accepted in many jurisdictions as sound management practices for lakeshore properties. However, there is insufficient information on these techniques to reliably predict the level of nutrient control that may be achieved or their long-term effectiveness at reducing phosphorus loading. This is why the Lakeshore Capacity Model makes no allowances for mitigation of overland runoff through site engineering and vegetated buffers.

Involving residents and cottagers' associations in the voluntary adoption and promotion of BMPs is a useful way to introduce the notion of lake stewardship (caring for lakes). Where they exist, conservation authorities often have programs or communications materials that promote the use of BMPs.

Development and planning considerations (5.2)

This Handbook is a beneficial planning tool for approval authorities (municipalities, planning boards and MMAH) to use when reviewing planning applications adjacent to water bodies. A qualified consultant will likely undertake the modeling and provide interpretations and recommendations. This will assist decision makers when reviewing planning applications involving shoreline development.

Shoreline setbacks "in general"

The Ontario Building Code (OBC) sets a province-wide uniform standard requiring that there be a minimum of 15 metres clearance between a Class 4 or 5 Sewage System and any lakes, pond, spring, river or stream (as well as other water sources such as wells or reservoirs). This requirement is intended to mitigate pathogens that are harmful to humans from entering water bodies. There are no requirements in the building code that apply specifically to phosphorus.

To address possible impacts of development on fish habitat, municipalities may enact zoning bylaws setting out setbacks or other zoning provisions. These could, for example, set out setbacks greater than 15 metres or zone the shoreline to restrict locating of buildings or structures. Such bylaws would be established through the planning process under the *Planning Act*.

Throughout the Precambrian Shield soil cover is typically thin and fractured bedrock is common. For lakes in this environment, irrespective of whether or not they are at capacity for shoreline development, MOE and MNR recommends a minimum of 30 metre setback or a 30 metre non- development zone from water bodies. If natural heritage features are identified on or adjacent to a lot then additional appropriate setbacks or restrictive development zones might be required. Cottagers and lake residents are encouraged to provide as great a setback as possible to minimize the impact of development on lakes.

Vegetation and site preparation

Phosphorus is an essential element required to support plant growth. What is not broadly accepted scientifically, however, is the amount of phosphorus that is removed permanently by a vegetative buffer that may exist at the shoreline of the proposed lot. Because of this uncertainty, further studies should be completed to quantify the effectiveness and longevity of such techniques. Thus, as a default in Lakeshore Capacity modeling, the Handbook does not consider a retention rate for phosphorus for vegetative buffers. However, the model is flexible and a coefficient of this nature could be added in the future if new science supports its use; a vegetated buffer is still considered to be a Best Management Practice. For example, MNR recommends that generally 30 metres of natural vegetation be maintained or rehabilitated adjacent to fish habitat for its protection (Natural Heritage Reference Manual, 2nd Edition).

Where natural vegetation exists at the juncture of land and water, it should be maintained. Where this doesn't occur naturally, or has been removed, a vegetative buffer (riparian zone) of shrubs and ground cover can be planted along a shoreline bank. Preserving aquatic vegetation and retaining shoreline woodlots will also help to reduce phosphorus loadings. To capture and infiltrate runoff, infiltration trenches with filter fabric and crushed stone may be placed along the drip line of the cottage or house instead of traditional gutters and downspouts.

Septic system design

Cottagers and lake residents may take measures they consider will lessen the impact of their on-site sewage treatment on the environment as long as these measures do not impact negatively on any of the approved and

OBC-required features of the sewage system. For example, acidic sites on non-calcareous sands (sands with low % calcium carbonate), may provide better phosphorus retention than sites on calcareous sands. Another example is the use of a siphon or pump to reduce phosphorus loading by providing an even distribution of septic tank effluents to the tile bed. Until a technology is proven effective over the long term, however, the phosphorus removal rate cannot be factored into the lakeshore capacity modeling.

What is a lake at capacity?

Lakes can be modeled to determine what their carrying capacities are with respect to phosphorus loading from shoreline development. Modeling takes into account vacant lots of record, incorporates assumptions that are inherent in the calculation of 'background' or 'undeveloped' conditions, and can be predictive with respect to any remaining capacity of the lake. See section 2.0 for a discussion on the link between phosphorus, dissolved oxygen, water quality, and lakeshore capacity. (See also Appendix A and references in Appendix B).

As set out in Section 2.2, the revised Provincial Water Quality Objectives (PWQO) for lakes on the Precambrian Shield allows a 50 per cent increase in phosphorus concentration from a modeled baseline of water quality in the absence of human influence. Based on this test, a lake would be 'at capacity' with respect to phosphorus if the modeling process determined that the existing development, including vacant lots of record, exceeded the modeled 'background' or 'undeveloped' concentration of (total) phosphorus, plus 50%.

In some cases, a lake may be considered to be 'at capacity' based on modeling results, but be 'below capacity' based on measured phosphorus concentrations, or vice versa. Because of natural variability in phosphorus concentrations over time, and inaccuracies in some model coefficients when applied to lakes across the Precambrian Shield, there is some error associated with the model predictions. Thus, we recommend that in cases where the predicted value is within 10% of the revised PWQO for total phosphorus (i.e., between background + 40% and background + 60%), that some flexibility be allowed when making management decisions. For example, further consideration should be given to a lake's sensitivity[24] to anthropogenic development and to other potential threats to water quality. If a lake has a history of nuisance algal blooms, or has undergone noticeable aesthetic changes in recent years (e.g., changes to water clarity), these observations should be considered as part of the overall management strategy for a lake.

The PWQO for dissolved oxygen allows for the establishment of more stringent criteria for the protection of specific, biologically-sensitive communities. A small percentage of all lakes provide suitable lake trout habitat. Low concentrations of dissolved oxygen in deeper water impair lake trout respiration, and therefore its metabolism, which compromises its ability to swim, feed, grow, and avoid predators. Studies have shown that juvenile lake trout need at least 7 milligrams (mg) of dissolved oxygen per Litre (L) of water to thrive and reproduce. The Ministry of Natural Resources consequently adopted a criterion of 7 mg/L dissolved oxygen measured as mean volume-weighted hypolimnetic concentration at the end-of-summer, to protect lake trout habitat. This is considered to be a scientifically established standard (for purposes of the PPS, 2005). For more information on this criterion, and how it is measured, please see references in Appendix B.

To protect natural heritage features, including fish habitat, policy 2.1.6. of the PPS (2005) includes direction that development and site alteration shall not be permitted on adjacent lands to the natural heritage features and areas unless the ecological function of the adjacent lands has been evaluated and it has been demonstrated that there will be no negative impacts on the natural features or on their ecological functions. Further to this, policy 2.1.5. of the PPS (2005) provides that development and site alteration shall not be permitted in fish habitat except in accordance with provincial and federal requirements. Provincial and federal requirements are defined in the PPS (2005) as legislation and policies administered by the federal and provincial governments for the purpose of protection of fish and fish habitat, and related, scientifically- established standards such as water quality criteria for protecting lake trout populations.

Requirements and restrictions for development on lakes at capacity

The following applies to lakes that have been modeled to be at-capacity for phosphorus (i.e., phosphorus concentrations exceed 'background' or 'undeveloped' concentrations + 50%), or have modeled or measured dissolved oxygen concentrations that are less than MNR's criterion for lake trout lakes (i.e., less than 7 mg/L dissolved oxygen, measured as mean volume-weighted hypolimnetic dissolved oxygen concentration at end-of-summer). Where these circumstances exist, new lot creation and other planning approvals should only be allowed:

- to separate existing habitable dwellings, each of which is on a lot that is capable of supporting a Class 4 sewage system, provided that the land use would not change and there would be no net increase in phosphorus loading to the lake;
- where all new tile fields would be located such that they would drain into a drainage basin which is not at capacity; or
- where all new tile fields would be set back at least 300 metres from the shoreline of lakes, or such that drainage from the tile fields would flow at least 300 metres to the lake[25]; and,

The following additional site-specific criteria can be applied where new development is proposed on at-capacity lakes and where certain municipal planning tools and agreements are in place such as a Development Permit System under the *Planning Act*, and/or site plan control under the *Planning Act*, and site alteration and tree-cutting by-laws under the *Municipal Act*:

- where a site-specific soils investigation prepared by a qualified professional[26] has been completed showing the following site conditions:
  - the site where the septic tile-bed is to be located, and the region below and 15 metres down-gradient of this site, toward the lakeshore or a permanently-flowing tributary, across the full width of the tile bed, consist of deep (more than three metres), native and undisturbed, non-calcareous (<1% $CaCO_3$ equivalent by weight) overburden with acid-extractable concentrations of iron and aluminum of >1% equivalent by weight (following Robertson 2005, 2006, Appendix B). Soil depth shall be assessed with test pits and/or boreholes at several sites. Samples for soils chemistry should be taken at a depth adjacent to, or below, the proposed tile bed; and
  - an unsaturated zone of at least 1 ½ metres depth exists between the tile bed and the shallowest depth (maximum) extent of the water table. The position of the water table shall be assessed with test pits during the periods of maximum soils saturation (e.g., in the spring, following snowmelt, or late fall)

Given that some relevant measures are not applicable law under the Ontario Building Code, agreements pursuant to the *Planning Act* that are registered on title will be needed to ensure the following for each lot created:

- design of the septic system shall include pump-dosing or equivalent technology to uniformly distribute septic effluent over the tile bed;
- no add-on system components such as water-softening apparatus, to ensure the proper functioning of the septic tank-tile bed system over the long-term;
- provision of a 30-metres minimum undisturbed shoreline buffer and soils mantle, with the exception of a pervious pathway;
- preparation of a stormwater management report and a construction mitigation plan (including phosphorus attenuation measures such as directing runoff and overland drainage from driveways, parking areas, other hard surfaces to soak away pits, infiltration facilities);
- location of the tile bed, in accordance with the recommendations of the site-specific soils investigation;
- long-term monitoring – for research purposes – of the sewage disposal system and reports to the planning approval authority and the Ministry of Environment. Monitoring would commence from the time of installation of the sewage treatment systems and proceed for at least 10 years. This monitoring will, at a minimum, include:
  - sampling locations immediately below the tile bed, down-gradient of the tile bed, and at least one site up-gradient of the tile bed;

  - collection of groundwater samples by a certified professional. All samples should be field filtered (0.45 µm) prior to atmospheric exposure. Samples for PO_4^{3-} (or TP) and Fe should be acidified in the field (pH < 2) with HCl or H_2SO_4, and analysed within two weeks of collection; and
  - chemical analyses should also include pH, chloride, total or dissolved phosphorus, nitrate, ammonium and iron;
  - sampling to occur annually (mid-summer) for the first five years, and once (mid-summer) every five years thereafter

BMPs for maintenance and operation (5.3)

Inspection and Regulation

Septic systems are regulated by provisions in the Building Code. Systems are required to perform based on the standard or requirements in place when the system was approved for use. If a system is not performing to the standard required of it and an inspector believes the system presents a health hazard, remedial steps may be required of the owner to bring the septic system into compliance.

Septic system operation and maintenance

Septic systems contained on one lot with a designed sewage flow of not more than 10,000 litres per day are regulated through the *Building Code Act* (1992) and the Building Code, which are administered by the Ministry of Municipal Affairs and Housing. The Building Code contains technical requirements that must be met when constructing a new septic system, or when extending, repairing or altering an existing system. The Code also mandates that owners of septic systems operate and maintain their systems in accordance with requirements to which they were designed. Under the act, enforcement bodies have the authority to determine whether existing systems are unsafe, to issue orders where unsafe conditions are found and, in extreme conditions, to remediate dangerous situations at the owner’s expense.

All household sewage waste should be discharged into its septic tank. Wastewater (grey water) from laundry and saunas shouldn't be discharged directly into the drain field as the detergent and soap scum will quickly clog soil pores and cause the septic system to fail.

Starters shouldn't be added to septic systems as enough bacteria are available in the wastes that are flushed into the septic tank. Septic systems should be pumped out every three to five years to remove solids and scum. While the tank is being pumped out, the cover should be removed to make sure that all solids are pumped out. Pumping through the inspection port may clog the outlet baffle with scum and grease.

Water conservation

Excessive water use is the most common cause of septic failure. Residents should be encouraged to reduce as much as possible the amount of water they use for bathing, laundry and flushing the toilet.

Shoreline vegetation

Surface waters can be contaminated by soil particles that have been washed or blown into the water. In addition to reducing water clarity, these particles may also carry phosphorus into the water. Residents can minimize soil erosion by retaining a vigorously growing filter zone (or buffer) of native grasses, trees and shrubs beside the lake and along any streams that empty into the lake. Residents can also reduce erosion by maintaining native vegetation throughout their properties to minimize areas of exposed soil. The use of native vegetation as a ground cover instead of a lawn is especially beneficial as it doesn't require the application of pesticides and phosphorus-rich fertilizers that can add to water quality problems. Minimizing the amount of impermeable surfaces such as concrete or asphalt will reduce stormwater runoff and its erosive effects.

Phosphorus abatement technologies (5.4)

In recent years, interest has grown in the potential to reduce phosphorus loadings to inland lakes by using technologies such as different filter media for septic systems. Currently, approval of conventional septic systems is carried out under the Ontario Building Code. This statute sets out septic system requirements including distance from water and size.

The Lakeshore Capacity Model takes into account the phosphorus load from conventional sewage treatment systems. The model allows for the phosphorus load to be varied if phosphorus abatement or phosphorus removal technologies are used. Currently, the Ontario government hasn't acknowledged any technologies as being suitable to be installed with, or instead of, small-scale subsurface sewage treatment systems for individual dwellings, cottages or other small buildings.

---

[17] Dillon. P.J. and F.H. Rigler. 1975. A simple method for predicting the capacity of a lake for development based on lake trophic status. J. Fish. Bd. Can. 32: 1519-1531.

[18] Ontario Ministry of Municipal Affairs and Housing (Research and Special Projects Branch). 1983-1986.

Lakeshore Capacity Study. Queen’s Printer for Ontario:

- Committee Report
- Land use (Downing, J.C. 1986. Ministry of Municipal Affairs and Housing)
- Fisheries (McCombie, A.M. 1983. Ministry of Natural Resources)
- Microbiology (Burger, C.A. 1983. Ministry of the Environment)
- Trophic Status (Dillon, P.J., Nicholls, K.H., Scheider, W.A, Yan, N.D. and Jeffries, D.S. 1986. Ministry of the Environment)
- Wildlife (Euler, D.L. 1983. Ministry of Natural Resources)
- Integration (Teleki, G. 1986. Ministry of Municipal Affairs and Housing)

[19] Dillon, P.J., K.H. Nicholls, W.A. Scheider, N.D. Yan, and D.S. Jeffries. 1986. Lakeshore Capacity Study – Trophic Status. Ont. Min. Muncip. Affairs Tech. Report. Table 29.

[20] Robertson W.D., S.L. Schiff and C.J. Ptacek, 1998. Review of phosphate mobility and persistence in 10 septic system plumes. Groundwater. 36: 1000-1010.

[21] Robertson, W.D. 2003. Enhances attenuation of septic system phosphate in noncalcareous sediments. Groundwater. 41: 48-56.

[22] References in footnotes 19 and 20, and: Robertson, W.D. Robertson. 2005. 2004 Survey of phosphorus concentrations in five central Ontario septic system plumes. Technical Report prepared for the Ontario Ministry of the Environment, Dorset Environmental Science Centre. 24 pp.; and Robertson, W.D. 2006. Phosphorus distribution in a septic system plume on thin soil terrain in Ontario cottage country. Technical Report prepared for the Ontario Ministry of the Environment, Dorset Environmental Science Centre. 16 pp.

[23] Zanini, L., Roberston, W.D., Ptacek, C.J., Schiff, S.L., and Mayer, T. 1998. Phosphorus characterization in sediments impacted by septic effluent at four sites in central Canada. Journal of Contaminant Hydrology. 33: 405-429.

[24] Sensitivity can be broadly defined as the degree of change in phosphorus (P), relative to background conditions, that a lake experiences with shoreline development. The relative sensitivities of lakes within a watershed can be tested by adding a set P load to all lakes, standardized to lake area, and comparing the resultant changes in predicted P concentrations.

[25] Sewage effluent travels from the infiltration bed to the receiving water body in both the unsaturated and saturated zone of the sub-surface. Most commonly, the effluent pathway within the unsaturated zone is considered to be directly downward. After reaching the water table, effluent is transported with local groundwater along the groundwater gradient, which is generally in the direction of the shortest linear distance to the receiving water body. The effluent pathway may vary from the above definition under the following circumstances: 1) the effluent flow path may vary from vertical in the vadose zone if site conditions promote horizontal flow. These conditions may include topographic influences or hydraulic variations in subsurface stratigraphy. The potential for horizontal flow should be evaluated on a site specific basis; and 2) the effluent flow path in the saturated zone may vary from the shortest distance to the receiving water body. This may occur because of topographic or bedrock structural features (e.g., orientation of dominant fracture patterns). In such cases, the inference of a groundwater flow direction that is not directly to the receiving water body must be supported by hydrogeological data. This may require the identification of the groundwater gradient through measured potentiometric surface elevations at several piezometers and, or characterization of structural geology.

[26] Qualified professional is defined here as a licensed member of the Association of Professional Geoscientists of Ontario or the Professional Engineers of Ontario who is qualified to practice geoscience.

Monitoring Lake water quality

Monitoring lake water quality (6.0)

Why monitoring is important (6.1)

As noted in Section 3.4, although the Lakeshore Capacity Model makes reliable predictions when properly applied, it should be validated by water quality monitoring. Monitoring water quality in a lake over time will allow municipalities to follow trends, determine whether the lake systems are behaving as predicted and detect any unforeseen problems as they emerge.

The following sections provide an overview of monitoring. More detailed information on what and how to monitor is available from MOE.[27] Historical information on a lake's water quality may also exist at MOE (e.g., through the Lake Partner Program, see Section 6.3) or at the local conservation authority. For more about acquiring such information, see Appendix B, Lakeshore capacity assessment resources.

What should be monitored? (6.2)

The most useful estimate of trophic status, considering ease of collection and temporal variability, is total phosphorus (TP). For the purpose of using the Lakeshore Capacity Model, the optimal method of assessing the trophic status of a lake is to collect several years of TP data at spring overturn. Alternately, a lake can be characterized by using whole-lake, volume-weighted, ice-free means of TP (Table 5). Epilimnetic TP data (i.e., samples taken from the warm, wind-circulated upper layer of a thermally stratified lake) aren't as suitable for use in the Lakeshore Capacity Model.

In lakes that support populations of lake trout, dissolved oxygen is a critical measure. Levels of dissolved oxygen are usually at their minimum just before fall turnover and monitoring usually focuses on this time period. To better understand seasonal changes, spring profiles can also be taken to determine the degree of mixing. Several years of data, taken at multiple depths, are needed to make sure that atypical profiles aren't being used to represent long-term average conditions.

Table 5. Optimal sampling strategies for the most commonly used trophic status indicators[28]

Indicator	**Derivation**	**Sample method**	**Samples per year - 95% confident of being within 10% mean**	**Samples per year - 95% confident of being within 20% mean**	**Number of years - 95% confident of being within 10% mean**	**Number of years - 95% confident of being within 20% mean**	**Time**
TP(so)*	usually single sample	5 m composite	1[1]	1[1]	10	2	during spring turnover prior to thermal stratification
TP(if)*	average of all samples collected for ice-free period	composites when lake is mixed volume weighted during stratification	9-13 (bi-weekly)	4-5 (monthly)	5	1	between ice out and freeze up
TP(epi)*	average of all samples collected during stratification	epilimnetic composite	19	5	7	2	during thermal stratification
Chl a(ss)*	average of all samples collected during stratification (e.g. through self help programs)	euphotic zone composites	less than for Chl a(if); should use Chl a(if) if spring/fall blooms expected	less than for Chl a(if); should use Chl a(if) if spring/fall blooms expected	less than for Chl a(if); should use Chl a(if) if spring/fall blooms expected	less than for Chl a(if); should use Chl a(if) if spring/fall blooms expected	during thermal stratification
Chl a(if)*	average of all samples collected for ice-free period	euphotic zone composites	10	5	>5	2-5	between ice out and freeze up
Oxygen	usually profile data	oxygen meter with some Winkler test samples to confirm	sample frequency based on final use of data	sample frequency based on final use of data	sample frequency based on final use of data	sample frequency based on final use of data	key period just prior to fall de-stratification
Secchi	individual observations	Secchi disc	11-17 (weekly)	3-4 (monthly)	2-5	1	ice-free period

---

* so = spring overturn;
if = ice free;
epi = epilimnetic;
ss = summer stratified.

[1] usually only enough time for one visit.

Lake Partner Program (6.3)

The Ministry of the Environment’s Lake Partner Program works in partnership with the Federation of Ontario Cottagers' Associations, the Lake of the Woods District Property Owners Association and many other organizations to foster lake stewardship by increasing the public’s awareness of the links between phosphorus and water clarity in Ontario lakes.

The program uses volunteers to collect total phosphorus (TP) and water clarity data for lakes throughout Ontario and cooperates with many science partners (including other MOE departments and municipalities) to provide accurate TP monitoring for specific lakes of interest. The program has been quite successful: in 2004, water quality information was collected from more than 1,000 locations scattered throughout the major cottage areas of the province (Figure 4).

Lakes on the Precambrian Shield are sampled once each spring for TP, while water clarity is measured monthly with a Secchi disc during the ice-free period (May through October). Off-shield lakes are sampled monthly for both TP and water clarity during the ice-free period.

The TP samples are analysed by MOE to an average precision of approximately 0.7 µg/L, which is sensitive enough to detect between-year differences in spring turnover concentrations for individual lakes. The numbers are also precise enough to test the performance of the Lakeshore Capacity Model or for use as input to hypolimnetic oxygen models.

The Lake Partner Program is based out of the Ministry’s Dorset Environmental Science Centre. Annual reports for the program are made available to volunteers, science partners and the public in hard copy or electronically via the ministry’s website (See Lake Partner Program Map). Inquiries about the Lake Partner Program can be made by calling 1-800-470-8322 or by emailing lakepartner@ontario.ca.

Figure 4. Lake Partner Program: Sample locations in 2004

.

How chemical analysis should be done (6.5)

Phosphorus occurs naturally in many forms. Both organic and inorganic phosphorus are present as dissolved, colloidal and particulate fractions in lake water samples. The analysis of total phosphorus (TP) in a lake water sample is the best test to yield precise results for phosphorus.

Total phosphorus can be accurately measured even at low microgram per litre (µg/L) levels if certain precautions are taken. To obtain acceptable phosphorus results, it is best to use the classic colourimetric method: reduced phospho-antimonyl-molybdate (heteropolyblue) complexing reaction with subsequent colourimetric measurement. This reaction is specific to the orthophosphate form and is stable and relatively interference-free (when arsenate and silicate concentrations are both less than 10 µg/L). Phosphorus analysis by inductively-coupled plasma emission isn't recommended because the level of detection is generally 50 µg/L or greater. This isn't sensitive enough for modeling the trophic status of Precambrian Shield lakes.

The colourimetric method is amenable to automation, making large numbers of analyses possible. It is straightforward and quick, giving reliable results if done by a trained analyst. Sample pre-treatment is further simplified through the use of an autoclave and acid digestion with persulfate oxidation. This digestion converts all phosphorus fractions (total phosphorus) to orthophosphate.

The optimal method of TP analysis for the purpose of the Lakeshore Capacity Model also includes the collection of duplicate lake water samples directly into the autoanalyzer tubes to minimize container effects.

The laboratory at MOE's Dorset Environmental Science Centre specializes in low-level phosphorus analysis and can be contacted for information on this procedure. The ministry's Laboratory Services Branch can also be contacted to provide information on methods to determine both total and soluble phosphorus at higher concentrations for a nominal fee (about $35 currently). Contacts for the ministry are listed in Appendix B. There are also several commercial labs in the province that can carry out TP analysis using the colourimetric method.

---

[27] Ontario Ministry of Environment and Energy. 1992. Measuring the trophic status of lakes: sampling protocols. Queen's Printer for Ontario.

[28] Ontario Ministry of Environment and Energy. 1992. Measuring the trophic status of lakes: sampling protocols. Queen=s Printer for Ontario.

Conclusion and Appendices

Conclusion (7.0)

Lakeshore capacity assessment is a tool to help municipalities and other agencies with responsibility for land-use planning to develop inland lakes in a sustainable manner. Used in concert with other federal, provincial and municipal water-related laws, regulations and bylaws, lakeshore capacity assessment will help to ensure that the province's inland lakes on the Precambrian Shield will continue to have good water quality and healthy fish communities for generations to come.

This Lakeshore Capacity Assessment Handbook was developed, along with the Lakeshore Capacity Model, to help municipalities to meet their obligations under the *Planning Act* and the Provincial Policy Statement (2005). Cooperation among agencies, municipal planning authorities, residents' and cottagers' associations, developers and the public will help to achieve sustainable development of Ontario's inland lakes.

Appendix A

Rationale for a revised phosphorus criterion for Precambrian shield lakes in Ontario.

Abstract

Ontario should revise the existing provincial water quality objective (PWQO) for total phosphorus in surface waters. The existing, two-tiered, numeric guideline overprotects some lakes, fails to adequately protect others, produces unwarranted asymmetries in shoreline development potential and does not protect against a cumulative loss of diversity in the resource as a whole. A new, interim PWQO is proposed for lakes on the Precambrian Shield. This revised PWQO allows a 50 per cent increase in phosphorus concentration from a modeled baseline of water quality in the absence of human influence. The proposed objective prevents cumulative losses of water clarity, is detectable with a modest sampling effort, maintains the existing diversity in lake water quality and incorporates the regionally specific objectives of other jurisdictions into a single numeric criterion. The same principles should be considered in a future review of the PWQO for phosphorus in off-Shield lakes and rivers.

Document inquiries to:
Tim Fletcher, Team Leader
Standards Development Branch
Ecological Standards
Phone: 416-327-5002
Fax: 416-327-6421
E-mail: tim.fletcher@ontario.ca

With contributions from:

- Ron Hall – Formerly MOE
- Peter Dillon – Formerly MOE
- Ken Nicholls – Formerly MOE
- Ian Smith – Standards Development Branch, MOE
- Adam Socha – Formerly of Standards Development Branch, MOE
- Conrad de Barros – Operations Division, Eastern Region, MOE
- Shiv Sud – Formerly of the Environmental Partnerships Branch, MOE

For critical review we wish to thank:

- Dr. Joe Kerekes – Canadian Wildlife Service, Environment Canada, Dartmouth, NS
- Dr. Rick Nordin – British Columbia Ministry of the Environment, Victoria, BC
- Greg Searle – Wisconsin Department of Natural Resources, Madison, WI, USA

Additional contributors:

- Neil Hutchinson – Gartner Lee, Markham, ON (formerly MOE)
- Doug Spry – Environment Canada, Hull, QC (formerly MOE)

Existing PWQO for total phosphorus (1.0)

The existing provincial water quality objective (PWQO) for total phosphorus was developed by MOE in 1979. It draws on the trophic status classification scheme of Dillon and Rigler (1975) to protect against aesthetic deterioration and nuisance concentrations of algae in lakes and excessive plant growth in rivers and streams. The rationale (MOE 1979) acknowledges that elemental phosphorus can be toxic but that, since it is rare in nature, its toxicity is rarely of concern. Instead, the purpose of this water quality objective is to protect the aquatic ecosystem from non-toxic forms of phosphorus:

> …phosphorus must be controlled, however, to prevent any undesirable changes in the aquatic ecosystem due to increased algal growth… *MOE 1979*

The 1979 PWQO for phosphorus reflects the uncertainty regarding the effects of phosphorus and acknowledges the differences in the management of toxic and non-toxic pollutants. The PWQO does not explicitly distinguish between lakes in different regions of Ontario (i.e., Precambrian Shield versus southern Ontario) but, instead, categorizes lakes of low and moderate productivity into two corresponding levels of water quality. It is still in use today and reads:

> Current scientific evidence is insufficient to develop a firm objective at this time. Accordingly, the following phosphorus concentrations should be considered as general guidelines which should be supplemented by site- specific studies:
>
> [For lakes:]
>
> To avoid nuisance concentrations of algae in lakes, average total phosphorus concentrations for the ice-free period should not exceed 20 µg/L.
>
> A high level of protection against aesthetic deterioration will be provided by a total phosphorus concentration for the ice-free period of 10 µg/L or less. This should apply to all lakes naturally below this value.
>
> [For rivers and streams:]

> Excessive plant growth in rivers and streams should be eliminated at a total phosphorus concentration below 30 µg/L.

The need for phosphorus management (2.0)

The Government of Ontario's goal for surface water management is:

> …to ensure that the surface waters of the province are of a quality which is satisfactory for aquatic life and recreation…*MOEE 1994*

In Ontario, phosphorus is managed to protect the clarity of its recreational waters from unacceptable increases in turbidity caused by algal growth in the water column and to prevent the formation of nuisance blooms of algae on the water's surface. Although water clarity is also reduced by its content of dissolved organic carbon (DOC), which stains the water brown, DOC in Precambrian Shield waters is controlled by natural factors and is not readily amenable to management. Phosphorus concentrations will have little influence on the clarity of lakes with high DOC levels but may still have to be considered for the protection of other attributes.

The process of decomposition of organic matter consumes oxygen from a lake and so, at some point, the stimulation of excess algal growth by increasing phosphorus concentrations may decrease the amount of dissolved oxygen that is available to aquatic life. In addition, phosphorus may be released from the bottom sediments of lakes during periods of anoxia (oxygen deprivation), which further enriches the lake water. Although Ontario has a separate PWQO for dissolved oxygen, the relationship between phosphorus and oxygen is implicit in any lake management activities and should, at least, be considered in formulating the PWQO.

In summary, the PWQO for total phosphorus is intended to:

- Protect the aesthetics of recreational waters by preventing losses in water clarity
- Prevent nuisance blooms of surface algae
- Maintain the existing diversity in water clarity in Precambrian Shield lakes
- Provide indirect protection against oxygen depletion

Need for revision (2.1)

The total phosphorus PWQO serves as the cornerstone for making lake management decisions and achieving the necessary balance between health of the aquatic system and development in a watershed. The PWQO must, therefore, be based on the most current, scientifically sound information. The existing rationale states that the PWQO was developed and used despite incomplete knowledge of relationships between phosphorus concentrations in water and the corresponding plant and algal growth in lakes and rivers (MOE 1979). It was therefore later revised to an interim PWQO (MOEE 1994). Evaluation of the scientific advances since that time is necessary to ensure that the interim PWQO reflects current scientific understanding and to determine whether a revision in its status is warranted.

The rationale for revisiting the PWQO for phosphorus does not lie exclusively in better information on its effects as a pollutant. Instead, improved understanding of watershed processes, biodiversity and the assessment of cumulative effects over the past 20 years have lead to the corporate adoption of these considerations into the water management process (MOEE 1994). This has revealed several shortcomings with the existing, two-tiered guideline of 10 µg/L for "a high level of protection against aesthetic deterioration" and 20 µg/L "to avoid nuisance concentrations of algae". Although these numeric objectives are designed to maintain water clarity and aesthetic values and have performed well for more than 20 years, they fail to protect against the cumulative effects of development and do not protect the existing diversity in water quality across the province and the associated biodiversity.

In 1996, Ontario decided to review its PWQO for total phosphorus. The bulk of Ontario's 226,000 lakes (Cox 1978) lie on the Precambrian Shield and the scientific basis for a new PWQO had previously been developed for these lakes (Hutchinson et al. 1991). Accordingly, the three-year review process targeted Precambrian Shield lakes first, with off-Shield lakes, the Great Lakes, and streams and rivers to be reviewed later.

Total phosphorus and the PWQO development process (3.0)

Ontario's PWQO development process is intended to deal specifically with toxic substances. It uses published studies on the effects of pollutants to estimate a safe concentration for indefinite exposure (MOEE 1992). The only data which are mandatory for PWQO development are data on toxicity, bioaccumulation and mutagenicity (the capability of mutation). Information on aesthetic impairment, such as taste and odour, may also be considered but is not mandatory. The protocol for the Government of Ontario's water quality objective development process (MOEE 1992) requires a minimum dataset and specifies both the number and quality of studies which are required for development of a PWQO. If either the mandatory elements are not fulfilled or the minimum dataset does not exist, then an interim PWQO is developed with the intent to upgrade it to a full PWQO when the data become available.

The interim status of the existing PWQO for total phosphorus should not, however, be interpreted solely as a reflection of incomplete knowledge at the time of its formulation. Development of a PWQO for total phosphorus is distinctly different from the development of a PWQO for toxic substances. Phosphorus' lack of toxicity and the insufficient knowledge of its effects should not provide the rationale for its interim status. It is therefore inappropriate to adhere strictly to the established procedures (MOEE 1992). Instead, those reviewing the status of the phosphorus criterion should consider the following:

- The detrimental effects of phosphorus are indirect and not a result of toxicity
- Some effects of phosphorus are aesthetic and so its management requires an element of subjectivity
- Our knowledge of the effects of small increases in phosphorus on the aquatic ecosystem are incomplete
- Factors such as dissolved organic carbon and the biotic community may modify the detrimental effects of phosphorus on the environment.

Toxicity and PWQO development (3.1)

Although pollutants such as copper or zinc are required nutrients at trace levels, they become toxic at concentrations slightly above ambient levels. As a result, the health of aquatic organisms, and hence the ecosystem, is maintained at low ambient concentrations but declines rapidly with even slight increases in concentration (Figure 1).

Phosphorus is a major nutrient. The first responses of an aquatic system to phosphorus additions — increased productivity and biomass — are beneficial and concentrations can increase substantially with no direct adverse effects. Beyond a certain point, however, further additions stimulate indirect detrimental effects which ultimately decrease system health. It is therefore a more difficult proposition to derive safe levels for phosphorus than it is for toxic pollutants.

Other considerations addressed in PWQO development (3.2)

Figure 1. Generalized responses of an ecosystem to toxic and non-toxic pollutants

The first responses of a lake to enrichment — decreased water clarity and increased algal biomass — are aesthetic and of concern only to humans. Assessment of aesthetic effects is highly subjective, however, and perceived changes in water clarity are based largely on what one is used to (Smeltzer and Heiskary 1990). The development of a phosphorus objective must therefore acknowledge an element of subjectivity in dealing with human concerns and consider that aesthetic effects begin where a change in water clarity is first noticeable to the human eye or where the average water clarity first exceeds natural variation.

The biotic effects of incremental phosphorus enrichment remain poorly understood. Some — such as the formation of nuisance blooms of blue-green algae and their associated toxicity — are well known but, with few exceptions, are not a consideration at the phosphorus concentrations observed in Precambrian Shield lakes. Effects of small changes in phosphorus concentration may well be beneficial to the productivity of the aquatic system, but the effects on diversity and system function have not been studied.

In contrast, the effects of phosphorus enrichment on the oxygenated hypolimnetic habitat of many cold water species (e.g., the lake trout, Salvelinus namaycush) are known and can be addressed objectively (MacLean et.al. 1990). Dissolved oxygen concentrations are explicitly protected by the Ontario PWQO for dissolved oxygen (MOEE 1994) or by specific guidelines for fish habitat which are administered by agencies such as the Ministry of Natural Resources. They are not intended as a direct consideration in phosphorus objective development. Nevertheless, recent advances in oxygen-phosphorus models (i.e., Molot et.al. 1992) allow for a direct estimation of the effect of phosphorus concentrations on dissolved oxygen in lakes. Any protection of dissolved oxygen which is achieved, even indirectly, by the phosphorus objective is beneficial.

Management of phosphorus as a method of controlling algal biomass, water clarity and dissolved oxygen is the central presumption behind setting safe limits. Total phosphorus concentrations set the upper limits on algal yields in lake water. The relationship between algal yield and water clarity is well established and these indicators are all predictably related (Dillon and Rigler 1975, Volleinweider and Kerekes 1980, Canfield and Bachmann 1981). Although natural levels of dissolved organic carbon may alter these relationships, the effects are predictable, have been quantified (Dillon et.al. 1986) and have been considered in this rationale document.

Nevertheless, in recent years, some challenges have emerged as to the adequacy of phosphorus-loading models for managing trophic status (Mazumder and Lean 1994) and some controversies have developed regarding the importance of nutrient loading (bottom up) versus biotic interactions (top down) in controlling algal growth in lakes (DeMelo et.al. 1992, Carpenter and Kitchell 1992). These criticisms, however, address only the unexplained variance in the phosphorus/chlorophyll/water clarity relationship and have not produced convincing arguments against, or alternatives to, its use. Biotic models are best viewed as complementary explanations of the same phenomena (Carpenter and Kitchell 1992) and not as alternatives to that relationship. Management of biotic factors to control water clarity is hampered by incomplete understanding, large and unpredictable variance in the natural system and the mandate of the Ministry of the Environment to manage sources of nutrients and their concentrations in the water. As such, "the prudent lake manager…might be best advised to focus first on nutrient abatement and then on biomanipulation" (DeMelo et.al. 1992). The PWQO for total phosphorus therefore provides the basis to maintain desirable levels of phosphorus in Ontario's surface waters through the control of nutrient loading only.

The sources of phosphorus to the aquatic environment also influence the derivation of a PWQO. With the exception of sewage treatment plant discharges, non-point sources of phosphorus are the most important contribution to nutrient enrichment of Precambrian Shield surface waters. These include changes in land use, septic systems from residential and cottage development, agriculture, timber harvest and urbanization. In many cases, these sources are diffuse and develop over extended periods of time. There may also be delays of up to decades between the addition of phosphorus sources to a watershed (i.e., septic systems), its movement from the source to surface water (Robertson 1995) and its expression as a change in trophic status. Shoreline residential development in particular represents a significant contribution to the eutrophication of Ontario's Precambrian Shield lakes (Dillon et.al. 1986).

As a result, phosphorus management in Ontario requires the extensive use of nutrient-loading models. These provide instantaneous estimates of the long-term, steady-state response of surface waters to non-point sources of phosphorus. They operate on the fundamental principles of areal loading of phosphorus to a lake's surface (Volleinweider 1976, Volleinweider and Kerekes 1980) and can consequently be adapted to a variety of sources.

There are, therefore, elements of uncertainty which are unique to the development of a PWQO for naturally occurring, non-toxic, non point-source pollutants such as phosphorus. Some may be resolved as models are further refined or as scientific understanding is further developed. Subjective elements of uncertainty, such as aesthetics, typically cannot be addressed in the conventional PWQO development process (currently only the aesthetics of taste and odour are considered). In addition, management of the pollutants that may take decades to manifest their effect on the aquatic system necessitates the use of models to predict such future effects.

New considerations for PWQO development (4.0)

Managing to preserve diversity in trophic status (4.1)

The existing numeric objectives for total phosphorus ignore fundamental differences between lake types and their nutrient status in the absence of human influences. Ontario's Precambrian Shield lakes now span a range of phosphorus concentrations from oligotrophic to mesotrophic, however, the distribution favours an abundance of higher quality, oligotrophic lakes (Figure 2). Within this range, however, there is still a large diversity of water clarity, controlled by both total phosphorus concentrations and dissolved organic carbon (Dillon et al. 1986).

Figure 2. Distribution of total phosphorus concentrations in sampled Ontario lakes

(source: MOE Inland Lakes database, March 2004)

The logical outcome of the current two-tiered PWQO is that, over time, all recreational waters will converge on each of the two water quality objectives. This will produce a cluster of lakes slightly below 10 µg/L and another slightly below 20 µg/L — this means that the provincial diversity in lake water quality will decrease along with the diversity of the associated aquatic communities.

The second shortcoming is that, over time, some lakes would sustain unacceptable changes in water quality while others would be unaffected, producing both ecological and economic asymmetries as their shorelines are developed. A lake with a natural phosphorus concentration of 4 µg/L is a fundamentally different from a lake at 9 µg/L. Both lakes, however, would be allowed to increase to 10 µg/L under the existing PWQO. One lake would experience no perceptible change (9 to 10 µg/L) and be overprotected, but the other (4 to 10 µg/L) would be under-protected and would change dramatically. In both cases, human perceptions of aesthetics would be ignored in the objective. Allocation of phosphorus loadings between these two lakes would be unfair as well; the high phosphorus lake could sustain a greater change than the low phosphorus lake, but would be restrained to a much lower load.

A final concern is that the existing PWQO does not explicitly consider the effect of phosphorus on hypolimnetic oxygen or aquatic biota. It does, however, make reference to site-specific studies in the assessment process.

In summary, the existing numeric objectives are too stringent for some lakes and do not protect others adequately. Allocation of phosphorus loadings is unnecessarily restricted in some lakes and overly generous in others. Neither biotic nor aesthetic attributes are adequately protected. Over time, Ontario's diversity in lake trophic status will decrease.

Environmental baselines and measured water quality (4.2)

An emerging concern in environmental assessment is the need for a standard baseline for comparison against environmental change. The existing PWQO is interpreted through measurements of present and past water quality. Detecting change is thus difficult for non-point additions which may occur over large areas and extended time periods. Phosphorus measurements made in the period between development of a non-point source and its expression as a change in trophic status will therefore underestimate the effect and may wrongfully lead to the conclusion that the lake has not responded to the phosphorus loading.

The incremental nature of watershed development results in a slow and gradual increase in trophic status. The high degree of seasonal and annual variance in lake phosphorus levels (Clark and Hutchinson 1992) means that changes may not be detectable without an intensive monitoring program that requires the collection of many samples and uses a precise and replicable analytical method.

Finally, a slow increase in trophic status over a generation may not be noticed by human observers. Environmental change which occurs during one generation becomes the status quo for the next. Over a long period, therefore, any assessment baseline which is based on measurements of total phosphorus will increase.

In summary, any phosphorus objective which relies exclusively on measured water quality will suffer from:

- Detection problems due to natural variance and analytical problems
- The lag time between addition of phosphorus to a watershed and its expression in a lake
- Failure to detect incremental changes in water quality
- Human perceptual conditioning which reduces the apparent change in water quality over time

As a result, a rising assessment baseline and incremental decreases in water quality will slowly degrade the quality of lake water past any objective. Effects will accumulate by virtue of delay in their expression, repetition over time and space, extension of the boundary of the effects by the transport of phosphorus downstream or by triggering indirect changes in the system such as the release of phosphorus from sediments during anoxic periods. Non-point source phosphorus loading is thus an excellent example of a pollutant which produces cumulative effects on the aquatic environment. The emergence and validation of mass balance phosphorus models for lakes, however, offers an opportunity to correct some of the disadvantages of water quality measurements and conventional assessment techniques.

Phosphorus criteria in other jurisdictions (5.0)

A brief survey of jurisdictions across Canada and the U.S. states bordering the Great Lakes shows different approaches to establishing criteria for surface water quality and to managing contributions of phosphorus to surface waters.

Canada (5.1)

In February, 2004, the National Guidelines and Standards Office of Environment Canada published the Canadian Guidance Framework for the Management of Phosphorus in Freshwater Systems. The Framework offers a tiered approach in which phosphorus concentrations should not exceed pre-determined trigger ranges, and phosphorus concentrations should not increase more than 50% over a system-specific baseline (reference) condition. The trigger ranges are based on the range of phosphorus concentrations in water that define the reference trophic status for a site. If the upper limit is exceeded, or is likely to be exceeded, further assessment is required, and a management decision may be required.

Québec (5.1.1)

The Province of Québec uses the 20 and 30 µg/L phosphorus values that are also in use in Ontario (but not the 10 µg/L value), however there is no indication of implementation approaches yet. Québec has begun to review the approaches of other jurisdictions with the goal of updating its own during the next three years and has expressed particular interest in the approach being considered in Ontario (D. Nadeau, Ministère du Loisir, de la Chasse et de la Pèche, Direction régionale de l'Abitibi-Temiscamingue, Noranda, QC pers. comm.)

British Columbia (5.1.2)

British Columbia uses criteria for surface water quality which vary as a function of the type of aquatic system and its intended use (Table 1).

Table 1. Phosphorus objectives for the Province of British Columbia

Water use	**Characteristics: Phosphorus (µg/L)***	**Characteristics: Chlorophyll a (mg/m^2)****
Drinking water (lakes)	10 max	none proposed
Aquatic life (streams)	none proposed	100 max
Aquatic life (lakes only—with salmonids as the predominant fish species)	5 to 15 inclusive	none proposed
Recreation: streams only	none proposed	50 max
Recreation: lakes only	10 max	none proposed

---

* Total phosphorus in lakes is either the spring overturn concentration, if the residence time of the epilimnetic water is greater than six months, or the mean epilimnetic growing-season concentration, if the residence time of the epilimnetic water is less than six months

** Chlorophyll a criteria in streams apply to naturally growing periphytic algae

Manitoba (5.1.3)

The Province of Manitoba has two phosphorus criteria for surface water: one for flowing waters of 50 µg/L and one for lakes of 25 µg/L. Manitoba will be reviewing these criteria in the next two years.

Alberta (5.1.4)

The Province of Alberta generally uses 50 µg/L as an objective for phosphorus in surface water.

United States (5.2)

The U.S. Environmental Protection Agency (USEPA) has decided not to develop a national standard for phosphorus in surface water. Instead, the USEPA provides guidance to states to develop their own methods to assess trophic status and to develop criteria for surface water quality.

Criteria are intended to guide resource assessment, establish management priorities, evaluate projects and assist with long-range planning. The USEPA is emphasizing non-traditional indicators of enrichment, such as regional biological criteria and land-use changes, as well as the more conventional indicators, such as total phosphorus and water clarity. Biological indicators are showing particular promise. Methods of nutrient classification will emphasize differences between regions of the U.S. based on the size, and the nutrient and watershed status of water bodies and will advise on consistent means of gathering, storing and evaluating data, all with the intent of moving beyond classification to improve the resource (George Gibson, USEPA, Annapolis, MD. pers. comm. Nov. 14, 1996).

Minnesota (5.2.1)

Table 2. State of Minnesota: Most sensitive lake uses by ecoregion and corresponding phosphorus criterion (Heiskary and Wilson 1988)

Ecoregion	**Most Sensitive Use**	**P Criterion**
Northern lakes and forests	Drinking water supply	< 15 µg/L
Northern lakes and forests	Cold water fishery	< 15 µg/L
Northern lakes and forests	Primary contact recreation and aesthetics	< 30 µg/L

Ecoregion	**Most Sensitive Use**	**P Criterion**
North central hardwood forests	Drinking water supply	< 30 µg/L
North central hardwood forests	Primary contact recreation and aesthetics	< 40 µg/L
Northern glaciated plains	Recreation and aesthetics - full support - partial support	- < 40 µg/L for full support - < 90 µg/L for partial support
Western corn belt plains	Drinking water supply	< 40 µg/L
Western corn belt plains	Primary contact recreation and aesthetics - full support - partial support	- < 40 µg/L for full support - < 90 µg/L for partial support

The State of Minnesota uses an ecoregion approach in which eutrophication standards vary with the region (i.e., the natural water quality) (Table 2). Criteria were developed to meet specific uses, such as fishery protection and swimming, and are based on reference lakes and public perceptions of water quality. They are not formal standards (which are legally binding in the U.S.) but are used for setting goals and priorities. As a starting point, if the concentration of phosphorus in a lake is better than the criterion for that ecoregion, then efforts will be made to protect it. If the concentration of phosphorus is greater than the criterion, then site-specific assessments may be done to ensure that the criterion is appropriate before corrective actions are taken.

Phosphorus criteria are related to summer chlorophyll a concentrations and acceptable chlorophyll concentrations are quite variable. In the areas of the northern lakes and forests, 10 µg/L would be considered to be a mild bloom, whereas 70 to 90 µg/L would be the norm in more southerly agricultural areas. Minnesota has also produced some guidelines which relate phosphorus concentrations to the probability of severe summer blooms and is starting work on phosphorus criteria for rivers and streams (Heiskary 1997).

Wisconsin (5.2.2)

The State of Wisconsin is in the final stages of developing phosphorus standards based on the ecoregion approach. It has used 14 years of monitoring data to establish three phosphorus regions for the state, each of which is characterized by statistically distinct water quality. It has relied on the best professional judgment of water quality experts to establish the background water quality of various types of water bodies in each region. The phosphorus objectives were chosen as the average of the lowest 25 per cent of measured phosphorus concentrations for each lake type in each region, rounded down to the nearest multiple of five (Table 3). Separate standards were developed for impoundments and natural lakes. Exceeding the standard is interpreted as a trigger for further evaluation (Searle 1997).

Table 3. State of Wisconsin: Ambient water quality criteria for phosphorus – Natural lakes

Region	**Drainage/ mixed (µg/L)**	**Drainage/ stratified (µg/L)**	**Seep/ mixed (µg/L)**	**Seep/ stratified (µg/L)**
North	15	10	10	10
Central	5	5	5	5
South	25	15	15	10

Table 3. State of Wisconsin: Ambient water quality criteria for phosphorus – Impoundments

Region	**Mixed (µg/L)**	**Stratified (µg/L)**

Region	Mixed (µg/L)	Stratified (µg/L)
North	20	10
Central	5	10
South	25	10

Maine (5.2.3)

The State of Maine has developed a non-degradation approach to phosphorus management. The existing phosphorus concentration of a lake and its sensitivity to loadings are used to establish a lake-specific allowable phosphorus increase. Lakes are classified into categories ranging from outstanding water quality to poor/restorable, and to low, medium and high levels of protection based on considerations such as usage and unique qualities. Acceptable increases are very stringent, ranging from 0.5 µg/L of total phosphorus for outstanding quality/high protection to 2 µg/L for good quality/low protection lakes. A watershed model is then used to allocate development to achieve the water quality goal. Very generous use is made of mitigation techniques such as buffer strips, storm water detention ponds and septic system setbacks in an attempt to control phosphorus export from new development in the watershed. Specific mitigation techniques will vary with the degree of protection required and each technique has a quantitative export coefficient to estimate the effect of the development on water quality (Dennis et.al. 1992).

Vermont (5.2.4)

The State of Vermont has focused on site-specific management of enriched lakes (e.g., Lake Champlain) in the past. It has recently completed an intensive study of Lake Champlain and developed separate phosphorus objectives for 13 basins of the lake. These range from 10 to 25 µg/L, compared to current levels of 9 to 58 µg/L which exceed the objective in eight of the 13 basins. Vermont is now considering developing standards for all lakes in the state (Smeltzer 1997 and pers. comm.).

Other states (5.2.5)

Some jurisdictions, such as Michigan and Pennsylvania, have not developed surface water criteria, but rely solely upon effluent concentrations, discharge loadings or best management practices.

Great Lakes (5.2.6)

The Great Lakes Water Quality Agreement (1987) states that:

> The concentration should be limited to the extent necessary to prevent nuisance growths of algae, weeds and slimes that are or may become injurious to any beneficial water use.

Fourteen impairments to beneficial uses are listed in the agreement. The agreement also contains lake-specific target loads and restrictions on sewage treatment plant discharges: 1 mg/L total phosphorus in the basins of lakes Superior, Michigan and Huron and 0.5 mg/L for plants in the basins of lakes Erie and Ontario. Several narrative statements regulate phosphorus loadings from industrial discharges to the maximum extent possible.

Summary (5.3)

All jurisdictions have attempted to deal with regional variance in natural or background water quality in various ways and to accommodate different criteria for different uses. One cannot judge the success of each approach but, in all cases, the intent is reasonable and achievable. Jurisdictions in which water quality is similar to Ontario’s have developed similar objectives but, in many cases, use a series of regional or use-specific objectives.

The State of Maine, unlike other jurisdictions, has tied very specific implementation details to its phosphorus objectives. Maine's objectives, like Ontario's proposed objective, appear to address shoreline development as the most important water quality stressor. It has combined very restrictive allowable increases in phosphorus concentrations to very permissive assumptions regarding the efficacy of techniques for mitigating phosphorus export. Ontario, in contrast, is proposing to allow for a generous proportional increase, combined with restrictive assumptions regarding mitigation — this approach is described in the following section (Section 6.0).

Proposal for a revised PWQO for Precambrian shield lakes (6.0)

Recent advances in phosphorus modeling, the understanding of watershed dynamics and the assessment of cumulative effects have been used to develop a new PWQO for Ontario's Precambrian Shield lakes. The proposal encompasses two innovations:

1. The use of models to establish a baseline for changes in trophic status
2. A proportional increase from that baseline due to phosphorus loadings from human activities

This approach would allow each Precambrian Shield to have its own numeric water quality target. The challenge now lies in expanding this understanding beyond shoreline development in Precambrian Shield lakes (for which it was originally developed) to apply it to all the waters of the province, including off-Shield lakes, the Great Lakes, and rivers and streams.

Modeled assessment baseline (6.1)

The basis of the revised PWQO is increased reliance on water quality modeling in the objective setting process. Recent advances in trophic status models allow us to calculate the predevelopment phosphorus concentrations of inland lakes (Hutchinson et al. 1991). This is done by modeling the total phosphorus budget for the lake, comparing the predicted concentration to a reliable water quality measurement and subtracting that portion of the budget which is attributable to human activities. Further work is necessary for water bodies lying off the Precambrian Shield, but the basic premise is applicable to any water body where a phosphorus budget can be calculated.

The main advantage of the modeling approach is the establishment of a constant assessment baseline. A modeled predevelopment baseline is based on an undeveloped watershed so it will not change over time. This serves as the starting point for all future assessments. Every generation of water quality managers will therefore have the same starting point for decision- making, instead of a steadily increasing baseline of phosphorus measurements.

The ministry therefore proposes a PWQO for total phosphorus which is based on a modeled predevelopment phosphorus concentration. This will provide water quality managers with a:

- Constant assessment baseline
- Buffer against incremental loss of water quality
- Buffer against variable water quality measurements

The predevelopment phosphorus concentration should not be interpreted as a PWQO. Pristine phosphorus levels have not existed in Ontario for more than a century and their attainment is not cost effective in a heavily developed society. The modeled predevelopment concentration only serves as the starting point for the PWQO and as a reference point for future changes.

A model-based objective would have two additional advantages. First, the modeled response of the watershed to future changes is instantaneous. It applies new development directly against capacity, without the intervening decades it takes for phosphorus to move into a lake and be expressed as a measured change in water quality. Second, Ontario's trophic status model is based on entire watersheds, so it allows explicit consideration of downstream phosphorus transport in the assessment.

Proportional increase (6.2)

The second component of the objective is a proportional increase from the modeled predevelopment condition. The proportional increase accommodates regional variation in natural or background water quality through the use of a lake-specific numeric objective for each Precambrian Shield lake. It is, in fact, a broader — yet simpler — application of the regionally specific, multi-tiered objectives proposed in other jurisdictions as a means of accommodating regional variation in background water quality (e.g., Minnesota and Wisconsin).

Ontario is proposing an allowable increase of 50 per cent above the predevelopment level. Under this proposal, a lake which was modeled to a predevelopment phosphorus concentration of 4 µg/L would be allowed to increase to 6 µg/L. Predevelopment concentrations of 6, 10 or 12 µg/L would increase to 9, 15 and 18 µg/L, respectively. A cap at 20 µg/L would still be maintained to protect against nuisance algal blooms.

There are numerous advantages to this approach:

- Each water body would have its own water quality objective that would be described with one number (i.e., predevelopment plus 50 per cent).
- Development capacity would be proportional to a lake's original trophic status.
- As a result, each lake would maintain its original trophic status classification. A 4 µg/L lake could be developed to 6 µg/L and would maintain its classification as oligotrophic. A 10 µg/L lake could be developed to 15 µg/L, maintain its mesotrophic classification and development would not be unnecessarily constrained to 10 µg/L.
- The existing diversity of trophic status in Ontario would be maintained forever, instead of a future set of lakes at 10 µg/L and another at 20 µg/L.

Rationale for a 50 per cent increase (6.3)

Water clarity (6.3.1)

Water clarity in Ontario's Precambrian Shield lakes is controlled by both dissolved organic carbon (DOC) and phosphorus (Dillon et.al. 1986). Any phosphorus objective should therefore consider DOC as well as phosphorus in its derivation. Molot and Dillon (pers. comm.) used 14 years of data (1976-1990) from lakes in south central Ontario to produce the following relationship, summarized in Figure 3.

$SD = 6.723 - (0.964 \times DOC) + (9.267 \div TP_{ep})$

Where:

SD = Secchi depth (water transparency)
DOC = dissolved organic carbon
TPep = total phosphorus concentration in the epilimnetic waters of the lake

Figure 3 shows that the rate of loss of water clarity with phosphorus increase is greatest between 4 and 10 µg/L, suggesting that the existing PWQO of 10 µg/L allows the greatest effects in the most sensitive, high-quality lakes.

Figure 4 shows the response of water clarity to various proportional increases in total phosphorus concentration predicted for various DOC levels using the same equation. Responses have been grouped to include all lakes with initial phosphorus concentrations between 2 and 14 µg/L, so a 50 per cent increase represents final values of 3 to 21 µg/L. There is no clear threshold of changed water clarity — a point where further increases in phosphorus would induce a markedly severe change. Instead, there is a gradual loss of water clarity as phosphorus concentrations are increased from 10 to 100 per cent. The allowable percentage increase cannot, therefore, be determined on the basis of water clarity alone.

Figure 3. Relationship of predicted water clarity to total phosphorus and dissolved organic carbon (DOC) concentrations in Precambrian Shield lakes in south-central Ontario.

Figure 4. Predicted response of Secchi depth to 10 to 100 per cent increases in total phosphorus concentration from initial values of 2 to 14 µg/L at dissolved organic carbon (DOC) levels of 2, 4, 6 and 7 mg/L.

Detection of change in phosphorus and water clarity (6.3.2)

The average coefficient of variation in Secchi depth for a series of southern Ontario Precambrian Shield lakes was 17 per cent to 21 per cent during a 14-year period of record (Clark and Hutchinson 1992). A change of 25 per cent in water clarity would therefore represent a significant, detectable departure from natural variation. Based on the data from Figure 4, a 50 per cent increase in phosphorus concentration produces, on average, a 25 per cent loss in Secchi depth across the range of initial phosphorus (2 to 14 µg/L) and DOC (2 to 7) concentrations (Table 4). In addition, a 50 per cent increase protects the clearest and most desirable water clarity and allows a greater proportional change only in those lakes with high DOC where this parameter (rather than the phosphorus/chlorophyll relationship) is the limiting factor (Table 4).

Table 4. Average loss in Secchi depth with a 50 per cent increase in total phosphorus concentration as a function of dissolved organic carbon (DOC) concentration*

DOC	% Loss in water clarity
2	14
4	18
6	27
7	41
Average	25.3

---

* The 50 per cent increase in TP is taken from a starting range of 2 to 14 µg/L to produce final values of 3 to 21 µg/L.

Hutchinson et al. (1991) reported a natural coefficient of variation in total phosphorus concentrations in south central Ontario lakes of about 20 per cent. Detection of a 20 per cent change in total phosphorus requires only two years of spring overturn measurements or one year of four to five measurements in the ice-free season (Clark and Hutchinson 1992). A phosphorus objective 50 per cent greater than the predevelopment conditions would therefore be detectable with even the most rudimentary sampling program and would limit changes in water clarity to an average of 25 per cent, a level just beyond the range in natural Secchi depth variation.

Protection of dissolved oxygen (6.3.3)

Although dissolved oxygen concentration is not intended to be a direct consideration in phosphorus objective development, any indirect protection of this parameter that results from the maintenance of the phosphorus objective is beneficial. Implementation procedures for Ontario's PWQOs allow more stringent applications to protect beneficial uses in specific locations (MOEE 1994). In the case of phosphorus, more stringent applications are used most often to assist the Ministry of Natural Resources (MNR) with the protection of fish habitat in lakes inhabited by lake trout. Protection of lake trout is not, however, an explicit requirement of the PWQO for total phosphorus. Instead, habitat may be considered through the effect of phosphorus on dissolved oxygen content.

Dissolved oxygen concentrations are explicitly protected by Ontario's existing PWQO for dissolved oxygen of 6 mg/L at 10°C for most biological species present in the cold water layer (hypolimnion) of thermally stratified lakes (MOEE 1994). For oxygen-sensitive species such as lake trout, a more specific water quality objective may be required (MOEE 1994). MNR has adopted a dissolved oxygen criterion of 7 mg/L for the protection of lake trout.

Oxygen-phosphorus models (i.e., Molot et al. 1992) have been incorporated into Ontario's phosphorus model for the direct estimation of the effect of phosphorus on dissolved oxygen. These models can be used to identify those situations in which more stringent protection is required and for the explicit consideration of the lake trout habitat in routine management applications. They predict the effect of phosphorus on the hypolimnetic oxygen profile at the critical end-of-summer period, when lakes are warmest and oxygen depletion is near its maximum.

The revised PWQO for total phosphorus does appear to provide some indirect protection of hypolimnetic oxygen. The effect of a 50 per cent increase in phosphorus on dissolved oxygen was modeled using four stratified lake types, spanning a range from highly sensitive (shallow and small) to least sensitive (deep and large). Responses were expressed as volume-weighted average hypolimnetic oxygen concentration and as the volume of hypolimnion exceeding the PWQO of 6 mg/L. On average, limiting the increase in phosphorus to background plus 50 percent protects dissolved oxygen in any lake which is larger than 67 hectares, at least 28 metres deep, and has less than 12 µg/L of predevelopment phosphorus. Some portion of the hypolimnion remained at 6 mg/L of dissolved oxygen or better in all such lakes modeled. Lakes with predevelopment concentrations of 7 µg/L or less were particularly well protected, but the 50 per cent increase did not protect lakes with natural total phosphorus concentrations of 12 µg/L or more because of their higher initial phosphorus levels.

Future PWQO development activities (7.0)

This proposal for an interim PWQO for phosphorus applies only to inland lakes on the Precambrian Shield. A full revision of the PWQO for phosphorus in all surface waters should address the following:

- Evaluation of new science relating phosphorus effects to changes in ecosystem responses including dissolved oxygen levels
- Evaluation of the proposed PWQO for off-Shield lakes, especially in southern Ontario
- Evaluation of the proposed PWQO with regard to dystrophic lakes, particularly those in northern Ontario (these lakes are highly coloured due to humic and fulvic acids and typically have relatively high background phosphorus concentrations which may not provoke typical eutrophication responses)
- Evaluation of the approach used for Precambrian Shield lakes for its applicability to rivers and streams
- Review of the objectives for the Great Lakes and modifications, if required
- Evaluation of the role of introduced (exotic) species such as zebra mussels and the spiny water flea on ecosystem changes relating to phosphorus effects

References (8.0)

Canfield, D.E. Jr. And R.W. Bachmann. 1981. Prediction of total phosphorus concentrations, chlorophyll a and Secchi depths in natural and artificial lakes. Can. J. Fish. Aquat. Sci. 38: 414-423.

Carpenter, S.R. and J.F. Kitchell. 1992. Trophic cascade and biomanipulation: interface of research and management — a reply to the comment by DeMelo et.al. Limnol. Oceanogr. 37: 208-213.

Clark, B. and N.J. Hutchinson. 1992. Measuring the trophic status of lakes: sampling protocols. Ontario Ministry of the Environment. September 1992. PIBS 2202. ISBN 0-7778-0387-9. 36 p.

Cox, E.T. 1978. Counts and measurements of Ontario lakes 1978. Fisheries Branch, Ontario Ministry of Natural Resources. 114 p.

DeMelo, R., R. France and D.J. McQueen. 1992. Biomanipulation: hit or myth? Limnol. Oceanogr. 37: 192-207.

Dennis, J., J. Noel, D. Miller and C. Eliot. 1992. Phosphorus Control in Lake Watersheds: A Technical Guide to Evaluating New Development. Maine Department of Environmental Conservation. Revised September 1992. 111 p.

Dillon, P.J. and F.H. Rigler. 1975. A simple method for predicting the capacity of a lake for development based on lake trophic status. J. Fish. Res. Bd. Can. 32: 1519-1531.

Dillon, P.J., K.H. Nicholls, W.A. Scheider, N.D. Yan and D.S. Jeffries. 1986. Lakeshore Capacity Study: Trophic Status. Final Report. Ontario Ministry of Municipal Affairs. May 1986. ISBN 0-7743-8077- 2. 89 p.

Heiskary, S.A. and C.B. Wilson. 1988. Minnesota Lake Water Quality Assessment Report. Minnesota Pollution Control Agency, St. Paul. 63 p.

Heiskary, S.A. 1997. The Minnesota ecoregion and attainable trophic state approach. pp. 8-15 in: Smeltzer, E. U.S. Environmental Protection Agency Lake Nutrient Criteria Guidance Manual Appendix — Case Studies. Draft 7/31/97.

Hutchinson, N.J., Neary, B.P. and P.J. Dillon. 1991. Validation and use of Ontario’s trophic status model for establishing lake development guidelines. Lake Reserv. Manage. 7: 13-23.

International Joint Commission. 1987. Revised Great Lakes Water Quality Agreement of 1978. 130 p.

MacLean, N.G., J.M. Gunn, F.J. Hicks, P.E. Ihssen, M. Malhiot, T.E. Mosindy and W. Wilson. 1990. Environmental and genetic factors affecting the physiology and ecology of lake trout. Lake Trout Synthesis — Physiology and Ecology Working Group. Ontario Ministry of Natural Resources. Toronto. 84 p.

Mazumder, A. and D.R.S. Lean. 1994. Consumer-dependent responses of lake ecosystems to nutrient loading. J. Plankton Research 16: 1567-1580.

MOE. Ontario Ministry of the Environment. 1979. Rationale for the establishment of Ontario’s Provincial Water Quality Objectives. Queen’s Printer for Ontario. 236 p.

MOEE. Ontario Ministry of Environment and Energy. 1992. Ontario’s Water Quality Objective Development Process. Queen’s Printer for Ontario. 42 p. + app.

MOEE. Ontario Ministry of Environment and Energy. 1994. Water Management: Policies, Guidelines, Provincial Water Quality Objectives of the Ministry of Environment and Energy. Queen’s Printer for Ontario. July 1994. 32 p. PIBS 3303E. ISBN 0-7778-3494-4.

Molot, L.A., P.J. Dillon, B.J. Clark and B.P. Neary. 1992. Predicting end-of-summer oxygen profiles in stratified lakes. Can. J. Fish. Aquat. Sci. 49: 2363-2372.

Robertson, W.D. 1995. Development of steady-state phosphate concentrations in septic system plumes. J. Contam. Hydrology. 19: 289-305.

Searle, G. 1997. Wisconsin Lake Phosphorus Criteria. pp. 25-29 in: Smeltzer, E. U.S. Environmental Protection Agency Lake Nutrient Criteria Guidance Manual Appendix — Case Studies. Draft 7/31/97.

Smeltzer, E. and S.A. Heiskary. 1990. Analysis and applications of lake user survey data. Lake and Reserv. Manage. 6: 109-118.

Smeltzer, E. 1997. Total phosphorus criteria for Lake Champlain (Vermont, New York and Québec) pp. 29-35 in: Smeltzer, E. U.S. Environmental Protection Agency Lake Nutrient Criteria Guidance Manual Appendix — Case Studies. Draft 7/31/97.

Vollenweider, R.A. 1976. Advances in defining critical loading levels for phosphorus in lake eutrophication. Mem. Ist. Ital. Idrobiol. 44: 53-83.

Vollenweider, R.A. and J. Kerekes. 1980. Synthesis Report. Co-operative Programme on Monitoring of Inland Waters (Eutrophication Control). Rep. Technical Bureau, Water Management Sector Group, Organization for Economic Co-operation and Development (OECD), Paris. 290 p.

Appendix B

Watershed management

Watershed Academy Web:

- Free distance learning modules on key watershed management topics from the Office of Water at the United States Environmental Protection Agency.

North American Lake Management Society:

- The society’s mission is to forge partnerships among citizens, scientists and professionals to foster the management and protection of lakes and reservoirs.

The Source Water Protection Primer

- Available from Pollution Probe website

Best management practices

The Shore Primer: A cottager’s guide to a healthy waterfront

- Available from Cottage Life magazine and Fisheries and Oceans Canada.

Living by Water Project:

- National partnership initiative offering programs, projects and resources on shoreline living.

University of Minnesota:

- Minnesota Shoreland Management Resource Guide
- The Onsite Sewage Treatment Program

A Guide to Operating and Maintaining Your Septic System

- Available from the Ontario Ministry of Municipal Affairs & Housing

Lakeshore Capacity Model: Coefficients, assumptions and validation

Dillon, P.J., and L.A. Molot. 1996. Long-term phosphorus budgets and an examination of a steady-state mass balance model for central Ontario lakes. Water Research. 30: 2273-2280.

Dillon, P.J. and F.H. Rigler. 1975. A simple method for predicting the capacity of a lake for development based on lake trophic status. J. Fish. Res. Bd. Can. 32: 1519-1531.

Dillon, P.J., R.A. Reid and H.E. Evans. 1993. The relative magnitude of phosphorus sources for small, oligotrophic lakes in Ontario, Canada. Verh. Internat. Verein. Limnol. 25: 355-358.

Dillon, P.J., W.A. Scheider, R.A. Reid and D.S. Jeffries. 1994. Lakeshore Capacity Study: Part 1 — Test of effects of shoreline development on the trophic status of lakes. Lake and Reserv. Manage. 8:121-129.

Dillon, P.J., K.H. Nicholls, W.A. Scheider, N.D. Yan, D.S. Jeffries. 1986. Lakeshore Capacity Study: Trophic status. Ontario Ministry of Municipal Affairs and Housing.

Hutchinson, N.J., B.P. Neary and P.J. Dillon. 1991. Validation and use of Ontario's trophic status model for establishing lake development guidelines. Lake and Reserv. Manage. 7(1):13-23.

Paterson, A.M., P.J. Dillon, N.J. Hutchinson, M.N. Futter, B.J. Clark, R.B. Mills, R.A. Reid, and W.A. Scheider. 2006. A review of components, coefficients, and technical assumptions on Ontario's Lakeshore Capacity Model. Lake and Reserv. Manage. 22(1): 7-18.

Robertson, W.D. 2005. 2004 survey of phosphorus concentrations in five central Ontario septic system plumes. Technical Report prepared for Ontario Ministry of the Environment.

Robertson, W.D. 2006. Phosphorus distribution in a septic system plume on thin soil terrain in Ontario cottage country. Technical Report prepared for Ontario Ministry of the Environment.

Lake monitoring

Information on the Lake Partner Program for monitoring water quality in Ontario lakes is available from:

Ontario Ministry of the Environment
Dorset Environmental Science Centre
Lake Partner Program
P.O. Box 39
Bellwood Acres Road
Dorset, ON P0A 1E0
Tel: 1-800-470-8322
Fax: 705-766-2254
E-mail: lakepartner@ontario.ca
Web: Ministry of the Environment website - Lake Partner

Methods for phosphorus analysis

The MOE's Dorset Environmental Science Centre can provide information on methods for low-level phosphorus testing:

Don Evans
Ontario Ministry of the Environment
Dorset Environmental Science Centre
P.O. Box 39

Bellwood Acres Rd.
Dorset, ON P0A 1E0
Tel: 705-766-0632
Fax: 705-766-2254
Email: don.evans@ontario.ca

The MOE's Laboratory Services Branch can provide methods to determine both total and soluble phosphorus for a nominal fee (about $35-$50):

Laboratory Services Branch
Quality & Reference Services
Ontario Ministry of the Environment
125 Resources Road
Toronto, ON M9P 3V6
Tel: 416-235-6311
Fax: 416-235-6312

Dissolved oxygen criterion

EBR Decision Notice: Proposal for a dissolved oxygen criterion for the protection of lake trout habitat:

- The proposed uniform, standard, dissolved oxygen criterion to determine development capacity on inland lake trout lakes on the Precambrian Shield for use by MNR field staff and municipalities.

Effects of hypoxia on scope-of-activity of lake trout: defining a new dissolved oxygen criterion for protection of lake trout habitat

Appendix C

Strategies and parameters for trophic status and water quality assessment

Technical Bulletin No. DESC-4

Trophic status

The concentration of nutrients (phosphorus and nitrogen) in a lake directly influences algal growth, water clarity, and other in-lake processes such as hypolimnetic oxygen depletion and growth of near-shore periphyton and rooted aquatic plants. The evaluation of trophic status is, therefore, often a prerequisite to the management of a water body. Evaluation of trophic status is especially important if nutrient loading to the water body is expected to change or if there are recent signs of increased eutrophication.

Trophic status is commonly measured (or monitored) using at least one of three parameters. These are transparency (Secchi depth), chlorophyll a, and total phosphorous (TP) concentration. Dissolved oxygen which is also considered an indicator of trophic status is addressed in another report.

Transparency is a sensitive indicator of long-term changes in trophic status. It has been shown that Secchi disc measurements are less subject to within- year variability than either chlorophyll a or phosphorous measurements and as such can provide a better monitoring tool for early detection of eutrophication. Transparency observations, however, may be influenced by factors other than those related to trophic status (e.g., dissolved organic carbon (DOC)) and should, therefore, be interpreted together with TP and/or chlorophyll a data, especially for between-lake comparisons.

Chlorophyll a often is collected as an indicator of trophic status primarily because a change in algal biomass is the most evident result of a change in the trophic status of the lake. Chlorophyll a, however, tends to show a great deal of seasonal and inter-annual variation, especially in more eutrophic systems. As these seasonal patterns cannot be represented by a single or even several observations, it is often necessary to collect numerous samples throughout the year to determine meaningful 'ice free average' concentrations. It is, on average, necessary to collect more than 10 samples per season to derive averages which are within 20% of the seasonal mean (95% confidence) and 30 to 50 samples to be within 10% of the seasonal mean. Based on data from Dorset lakes, establishing a long- term mean will require one to four years of data collection to be within 20% of the long-term mean and three to 16 years to be within 10%. Generally, the more eutrophic the system the more years of data that will be required. In addition, chlorophyll a samples tend to be perishable and very susceptible to a number of 'handling' problems between the time of sampling and analysis of the sample. While there may be merit in quoting individual chlorophyll a concentrations to quantify the extent of an algal bloom or to indicate how high or low concentrations are in general, it is both costly and labour-intensive to use chlorophyll as a tool to reflect trophic status.

Total phosphorus, the basis for most trophic status models, including the MOEE Lakeshore Capacity Model, is the most reliable indicator of trophic status. Average TP concentrations in a lake can be estimated by measuring a single spring turnover concentration and long-term average numbers can be determined with the collection of only several years of turnover data. Two years of data records will provide results within 20% of the long-term mean (95% confidence), but approximately seven years are required to be within 10% of the long-term mean (provided the lake is not undergoing significant changes in nutrient level). Some researchers report 'ice free average TP concentrations' which require the collection of up to ten samples each year and the use of volume-weighted distinct 'layer' samples while the lake is stratified. These observations will yield reliable long-term averages in fewer years than spring turnover samples, but this advantage generally does not justify the extra effort required to collect the data. The recommended method for determining the trophic status of a lake is therefore based on the collection of spring overturn TP data over several years. These are usually collected as composites of the top 5 m of water at the deepest location in the lake. Samples are best collected after the lake has had an opportunity to mix for several days (temp >4E). Thermal stratification may occur rapidly after turnover, but chemical stratification does not occur as quickly so that surface TP concentrations are usually similar to spring overturn concentrations for several weeks after thermal stratification occurs. Generally, spring TP concentrations can be collected any time when surface water temperatures are between 5 and 10E. Caution is required with respect to the type of sample containers used. Details of this concern and outlines of other sampling protocols can be obtained by contacting the Dorset Research Centre.

Field programs that require staff to visit a lake several times each year (at least monthly) would also benefit by collecting Secchi disc observations at each visit. This would allow the addition of 'ice free average' transparency data to the database which would allow the observation of long-term trends in trophic status.

Water quality assessment

It is desirable to collect water quality data to describe chemical or physical characteristics of a lake for reasons other than trophic status. Concerns over acidification, for example, require the collection of pH, alkalinity, sulphate, and other related parameters. When comparative studies are undertaken, it is useful to group lakes on the basis of concentrations of major ions or to distinguish the dystrophic (brown water) lakes in the data set by observing DOC or colour. Each research related use for the database may require the collection of additional parameters and it may become difficult to choose tests that both fulfil the current project needs and provide background information for future research.

Parameters collected by the Ministry of the Environment and Energy (MOEE) which can be used as a guideline for describing the general water quality of a water body include: pH, alkalinity, total Kjeldahl nitrogen, nitrate, ammonia, iron, conductivity, colour, dissolved inorganic and organic carbon, calcium, sulphate, and total phosphorus. Secondary parameters collected less often include: aluminum, fluoride, manganese, chloride, potassium, magnesium, silica, and sodium.

Similar to the sampling strategies outlined for the determination of trophic status, these parameters can be measured with minimal effort at spring turnover with 5 m composite samples. The data obtained from a single visit when the lake is 'mixed' will be more valuable than several years of data that may include several visits per season if those sample dates are at times when distinct samples do not represent the whole lake. Small lakes will require measurements at only one mid-lake station while large lakes or lakes with localized influences may require the establishment of several sampling locations. More extensive collections of information from distinct layers during stratification or at other times of the year will only be necessary if specific, complex interpretations are required.

The number of years of water quality data that are required is parameter specific. The use of a single number for complex analysis or for input to models should consider between year or seasonal variability on a parameter by parameter basis. It is, however, common to accept the water quality description of a water body based on the results of the most recent visit without concern for the year to year variance associated with the individual parameters.

Sample container and submission protocols vary with each parameter and should be verified through contact with MOEE labs or by contacting MOEE field staff at the Dorset Research Centre.

For further information, contact:
B. Clark
Phone: 705-766-2150
Fax: 705-766-2254
Email: clarkbe@ene.gov.on.ca

Hypolimnetic oxygen: data collection strategies for use in predictive models

Technical Bulletin No. DESC-5

Data collection strategies for predictive models

Hypolimnetic oxygen concentrations are a key element of habitat quality for many cold-water species. These include fish such as lake trout and whitefish as well as many invertebrates including Copepods and Mysis that are important food for fish. Oxygen concentration profiles are typically measured at the deepest location in the lake, usually on a monthly basis throughout the open water season. These types of data are difficult to interpret because concentrations change both spatially and temporally in a specific year and also tend to show considerable inter-annual variation.

One method of addressing a great deal of this variation is to examine only end-of-summer or end-of-stratification oxygen profiles. This eliminates the need to evaluate seasonal changes in the profile and concentrates on the "worst case" profiles at the time of year when oxygen concentrations in the hypolimnion are at the open- water minimum. When attempting to characterize lakes in this manner, it is preferable to use average profiles which are derived from several years of data to offset the effects of inter-annual variation. This approach will allow the description of average conditions in a lake’s hypolimnion at the end of summer (early in September) and compare between-lake differences under similar conditions.

In 1992, a model* which predicts steady state, end-of-summer oxygen profiles for small oligotrophic lakes was developed as an additional component of the ministry’s Lakeshore Capacity Model (LCM). The oxygen model uses lake morphometry and epilimnetic phosphorus concentration to predict end-of-summer oxygen concentrations of each stratum in the hypolimnion. An example is shown in Fig. 1. The model requires total phosphorus (TP) as one of its parameters, and can therefore be used to predict the effects of shoreline development on hypolimnetic oxygen.

Recent efforts to validate the model indicate that it will predict end-of-summer profiles for lakes with a broader range of size and trophic status than those that were used to formulate the model.

Morphometry plays a major role in determining hypolimnetic oxygen concentrations. With the model, oxygen profiles can be predicted using as a minimal, a lake morphometric map and a modelled TP value (if no measured TP data exist). It is preferable to use long-term mean spring overturn TP.

To use the model for predicting the effects of changes in trophic status, it is preferable to average several years of oxygen profiles from the time period spanning two weeks either side of the first week in September. The model is then used to predict how changes in TP concentrations would effect the measured (not modelled) long-term average profile. This approach maintains the unique shape and magnitude of the lake's end-of-summer oxygen profile. Operation of the model is straightforward and it can be obtained as a spread sheet from the Dorset Research Centre.

From a data collection standpoint, this approach to oxygen monitoring suggests that field crews concentrate on the collection of end-of-summer profiles specifically between August 15 and September 15. Temperature profiles should also be collected to determine hypolimnetic boundaries. Data bases, for example, could benefit more from the collection of oxygen profiles from several different lakes circa early September than from a series of monthly observations from the same lake over the course of a summer. In other words, in this case, a survey approach would be more useful than a monitoring program.

Determining hypolimnetic volume-weighted oxygen concentration

There are several methods used to quantify cold-water fish species habitat based on oxygen concentrations. For lake trout, optimal habitat has been described as having greater than 6 mg L-1 oxygen at less than 10°C. Usable habitat has expanded boundaries at greater than 4 mg L-1 oxygen and less than 15°C. These guidelines can be used to generate habitat "volumes". However, these may be difficult to interpret since similar "volumes" between lakes may represent different proportions of total lake volumes.

The proposed use of end-of-summer, volume-weighted hypolimnetic oxygen concentrations to define lake trout habitat would eliminate many of these problems. Lakes with large volumes of oxygenated water would not have their average greatly affected by small volumes of depleted water near the bottom. Lakes with small and enriched hypolimnia would be affected to a greater degree by increased depletion in bottom waters. It is suggested for lake trout that these values remain above 7 mg L-1 oxygen.

Calculating volume-weighted hypolimnetic oxygen requires morphometric data and at least one end-of-summer oxygen profile (Aug 15 - Sept 15). Ideally, oxygen profiles from several years would be used to reflect long-term average conditions. Area and depth information from morphometric maps should first be converted to ha and m if originally in acres and feet. This will yield contour areas in ha for uneven numbers of m but these can be converted to 1 or 2 m contour areas by one of two methods:

1. Metres and ha are plotted and the individual areas for each stratum are simply read from the axis of the graph.
2. Individual pairs of adjacent points in ha and m are used to interpolate areas for the intervals that fall within the depth range spanned by the pair of points. This can be done through simple linear interpolation or by doing a linear regression on two pairs of points. However, it is important to note that entire sets of hypolimnetic depth/area data cannot be regressed as a single group of numbers because the relationship is almost always curvilinear. Individual contour areas are then converted to volumes by the formula:

Where:

V
is volume in $m^3 \times 10^4$

A_t
is the area in ha of the top of the stratum

A_b
is the area in ha of the bottom of the stratum

m
is the depth of the stratum in m

The volume of each stratum of the hypolimnion is then expressed as a fraction of the total hypolimnetic volume and multiplied by the oxygen concentration observed for that stratum. These individual concentrations are summed to yield volume-weighted average oxygen as shown in the example below.

Volume-weighted average oxygen

Stratum	**Volume ($10^3 m^3$)**	**A-Volume as fraction of total Volume**	**B-Dissolved oxygen (mg L^{-1})**	**A * B**
14-16m	1500	0.49	10.0	4.9
16-18m	1000	0.33	8.0	2.6
18-20m	400	0.13	6.0	0.78
20-22m	150	0.05	1.0	0.05

Total of A * B is volume weighted oxygen concentration 8.33.

It should be noted that volume-weighted oxygen concentration calculations yield a single number which may respond differently from lake to lake to changes in trophic status. The number should be interpreted together with other physical and chemical information relating to the lake in question. However, it is a simple and useful measure related directly to lake trout habitat.

* Footnote: Details of the oxygen model have been published in: Molot, L.A., P.J. Dillon, B.J. Clark, and B.P. Neary. 1992. Predicting end-of-summer oxygen profiles in stratified lakes. Can. J. Fish. Aquat. Sci. 49:2363-2372.

For further information, contact:
B. Clark
Phone: 705-766-2150
Fax: 705-766-2254
Email: clarkbe@ene.gov.on.ca

The trouble with chlorophyll: cautions regarding the collection and use of Chlorophyll data

Technical Bulletin No. DESC-10

Resource managers and researchers from many agencies commonly use chlorophyll as a trophic status indicator. Although variation in chlorophyll concentration tends to be the most evident consequence of changes in trophic status, there are problems involved with using this test as a basis for either setting trophic status objectives or detecting long-term change. These problems can be summarized as follows:

- the collection and submission of chlorophyll samples require precautions that are complex compared to other trophic status parameters
- changes in analytical methods may disrupt long-term chlorophyll data sets.
- significant seasonal and inter-annual variation in chlorophyll requires the collection of large numbers of samples over many years.
- many different chlorophyll pigments are commonly measured, i.e.: Chl a, b, c, chl a corrected etc., concentrations of these pigments may not correspond to actual phytoplankton cell densities.

Data collection

Chlorophyll samples must be collected into opaque bottles and immediately fixed with magnesium carbonate ($MgCO_3$ ensures that the sample remains 'basic' to avoid conversion of primary pigments to phaeopigments under acidic conditions). They must then be kept cool and filtered as soon as possible. The filtrate must be frozen and transported to the lab without being allowed to thaw. This makes the remote collection of samples difficult or impossible such that, from the onset, chlorophyll data can present uncertainties if the samples have not been collected under strictly controlled conditions.

Chlorophyll samples are often collected as euphotic zone composites and reported as ice-free means. The euphotic zone, usually approximated as twice the Secchi disc visibility, is sometimes well mixed since much of this layer is composed of epilimnion. However algal cells will often stratify dramatically below the epilimnion and this can occur even in mixed layers (Fig. 1). This means that chlorophyll concentrations based on euphotic zone composite samples may vary based simply on the physical collection methods i.e.: how the water is combined in proportion from given depths. This is very relevant in situations where the depth of the euphotic zone relative to the thermocline changes over time.

Figure 1: Vertical distribution of Chl a in Plastic Lake.

Changes in analytical methods

The reported concentrations of chl a have been subject to methods changes at the MOEE laboratories. The long-term data base has been most notably broken due to changes in the methods that occurred in 1985. At that time, a switch to nylon filters increased extraction efficiencies of the acetone. This resulted in an increase in post '85 values. Although it may be possible to 'align' the data before 1985 to match current values, there is no single correction factor that can be applied to these data. Data base managers who have chlorophyll values spanning 1985 should refer to the documentation referring to the methods changes which was published by the Lab Services Branch in 1985.

Seasonal and inter-annual variation

The largest problem with the interpretation of chlorophyll data is associated with seasonal and inter-annual variation. Chlorophyll concentrations vary significantly on a seasonal basis within lakes and often show different seasonal patterns between lakes (Fig. 2). In addition there is a great amount of long-term, or between-year variation in the ice-free means for individual lakes. (Fig. 3) This makes it necessary to collect numerous samples each year to derive ice-free means that are close to the actual value, and many years of this type of data are required to estimate the long-term mean (Table 1). Thus it is difficult to assess whether observed changes in chlorophyll are actually reflecting long-term change or whether they are simply noise based on the collection of too few samples each year or too few years of data being used to detect the change. Development objectives for individual lakes that are based on chlorophyll will therefore be difficult to assess since it will be imposible to tell the difference between the actual surpassing of objectives and simple variation based on the collection of too few samples. These problems tend to increase in severity with increasing trophic status such that the situations that require the most attention, i.e.: more enriched systems, also tend to require the most samples to describe accurately.

Figure 2: Seasonal changes in chl a for Gravenhurst Bay, Chub, Dickie and Red Chalk lakes in 1993.

Figure 3: Long-term variation in ice-free chl a for Gravenhurst Bay and South Bay (Lake Muskoka).

Table 1: Number of chlorophyll samples required each year and the number of years of data required to be within specified percents of the actual mean. Number of years of data is based on seasonal means that are approx. within 20%.

% of mean	**# samples/year: 10**	**# samples/year: 20**	**# samples/year: 50**	**# years: 10**	**# years: 20**	**# years: 50**
Blue chalk	55	14	2	3	1	1
Harp	59	15	2	7	2	1
Dickie	126	32	5	16	4	1

Cell density vs. pigment concentration

Finally, the whole picture is further complicated by the fact that chlorophyll concentrations are not always tied to phytoplankton cell densities. The actual concentration of chlorophyll in algal cells is determined by incident radiation, species composition, nutrient supply and certain aspects of algal physiology. These determinants have a seasonal component such that the correspondence between chlorophyll a and algal cell densities is not constant. These relationships can further be specific to different chlorophyll pigments. In most cases chlorophyll a or a version of chlorophyll a corrected for phaeopigments is used to represent the phytoplankton community. Sometimes chl b or chl c are quoted but often the relationship between the concentrations of specific pigments and the concentrations of algal cell in the lake do not correspond because the cells in greatest abundance do not contain pigments that are being measured. Also, algal communities are changing seasonally back and forth between those that contain the investigator’s pigment of choice and those that do not.

Conclusions and Recommendations

When all of these problems are considered it makes it difficult to recommend chlorophyll as a trophic status indicator in situations where small amounts of data are collected. Most of the problems outlined above are amplified by the collection of too little data. This is not to say that chlorophyll data should not be collected. A great deal of usefull data exists that show the effects of phosphorus load reductions, zebra mussels, etc. on chlorophyll concentrations. These are generally based on large data sets that are not plagued by seasonal or inter-annual variation.

Since virtually none of the same problems outlined for the collection of chlorophyll data apply to the collection of total phosphorus data it is probably better to use total phosphorus as an indicator of trophic potential in situations where minimal data sets are being collected.

Lastly, the cost of monitoring the trophic status of a lake based on spring turnover TP would be a fraction of that involved with using chlorophyll. Spring turnover total phosphorus based trophic status estimates would require only one visit to each lake per year. Since ice-free mean chlorophyll estimates require at least 6 or 7 visits per year and considering that the chlorophyll test is approx 4 times as expensive as a TP test, the relative difference in test costs alone would be in the neighbourhood of 25 times. When staff and transportation costs are considered the numbers become significantly different. Cost aside, the results would be much more reliable when based on total phosphorus such that it would be recommended in almost every case to base trophic status estimates on total phosphorus. If information about the phytoplankton community must be collected, managers should consider collecting seasonal composite phytoplankton enumeration samples. Generally, weekly, bi-weekly or monthly phytoplankton samples are collected and fixed with Lugols fixative. These may be combined at the ennumeration Lab in Rexdale and counted to provide seasonal, mean, phytoplankton cell densities. These numbers will relate better to trophic status than will chlorophyll estimates (Fig. 4) and the costs will still be approximately half.

Figure 4: relationship between total phosphorus and chlorophyll a (left) and phytoplankton cell volume (right).

Details about estimating the trophic status of a lake based on total phosphorus are available in STB Tech. Bull. DESC-4.

For further information, contact:
B. Clark
Phone: 705-766-2150
Fax: 705-766-2254
Email: clarkbe@ene.gov.on.ca

Appendix D

Long-term monitoring of trophic status: The value of total phosphorus concentration at spring overturn

Technical Bulletin No. DESC-25

There are many reasons to measure the nutrient status of a water body. It may be done as part of an initiative to control nutrient inputs in an effort to reduce nuisance levels of aquatic plants or algae. In some cases, measurements are taken as part of a self-regulation program designed to monitor inputs to surface waters. In most cases, however, the nutrient status of a water body is measured to detect long-term changes in water quality (the nutrient status) of the water body.

The three most common measures of the nutrient status of a water body are TP (total phosphorus), chlorophyll a and Secchi depth. In Ontario, Secchi depth is often controlled by DOC rather than by chlorophyll and the chlorophyll measurements themselves are costly and must be pooled in large numbers to yield meaningful ice-free means (see Techbull DESC-10). For these reasons, TP is the recommended parameter to monitor long-term changes in trophic status. This is supported by the fact that TP is almost always the limiting nutrient for algal growth in Ontariolakes. In addition, TP surveys are easy andcomparatively inexpensive to conduct.

Once the decision has been made to monitor long-term changes in TP, decisions must be made with respect to the type of sampling regime that will be followed. Since seasonal variation in TP would rarely be of interest, it is, in most cases, desirable to obtain some number that describes an annual average condition such that the individual annual means can be monitored through time.

There are many different ways to combine TP samples to derive some measure of an annual mean. Monthly samples can be pooled to derive an "ice-free mean" but care must be taken when combining these numbers to produce "means" that can be validly compared to the numbers derived by similar studies elsewhere. For example, individual surface water samples when taken as 5 metre composites or euphotic zone composites when pooled will give an ice free epilimnetic or euphotic zone (annual) mean. This number will be different from numbers generated by other programs that volume weight the stratified season samples taken from all layers of the lake to accurately produce a "whole-lake" ice free annual mean. For these reasons it is often safer to collect TP samples at spring overturn to detect long-term trends. Certainly, it is better to have a single, reliable spring-overturn number than it is to average several samples that have been collected in a helter skelter fashion at other times of the year. The DESC database clearly shows that long-term average TP concentrations derived for a given lake using spring turnover samples are very closely corelated to those derived using ice- free means by volume weighting. (Fig. 1).

$TP_{if} = 0.96 TP_{so} + 0.31$

$r^2 = 0.93$

Figure 1. The relationship between long term mean TP derived using spring turnover and ice-free mean data for the lakes in the Dorset database.

Note: Volume weighting is used to collect data for all parameters for use in mass balance calculations at the DESC and probably would not be conducted if the only goal was to monitor changes through time in whole lake TP concentrations.

Previous calculations based on DESC data have shown that a reliable long-term mean can be derived with 2-4 years of spring turnover data. The ice-free, volume-weighted means will provide a reliable long-term mean sooner i.e., within 1-3 years but the extra effort and cost is usually not justified. In fact, for many lakes, the long-term trend is described as well or better by spring turnover TP than by ice-free volume weighted means (Fig. 2).

Figure 2. Annual TP expressed as spring overturn concentrations and as ice free means (mean of monthly volume weighted concentrations) for Blue Chalk Lake.

Spring turnover TP concentrations should be taken as some form of surface water composite (i.e., 5 m composite bottle sample) from the deepest location in the lake(Fig. 3.). Ideally the sample should be taken a week or so after ice out to allow the lake to completely mix. Samples should be taken, however, before water temperatures reach ~10°C. It is not acceptable, to include values in the database that are collected outside this window. It should also be noted that a single spring TP sample will not be adequate to describe the conditions that occur in complex systems such as;

- in very large lakes
- where large inflows dominate the nutrient concentrations in the lake
- in eutrophic lakes where there are large nutrient fluxes or a high degree of spacial variation
- in lakes where anthropogenic loads are high such as in lakes that adjoin urban centres.

Figure 3. The 5 m composite sampling method.

For more information, contact
Bev Clark, DESC, 705-766-2150
Email: clarkbe@ene.gov.on.ca

PIBS 7642e

Help your Septic System

- and our lakes!

Contaminants in the wastewater entering your septic system include nitrate, phosphorus, disease-causing bacteria, viruses and parasites. Careful use of your septic will prevent these contaminants from entering the ground water, your well water and local surface water (creeks, rivers and lakes).

Waste water enters the septic tank from the house. Solids settle to the bottom of the tank (where they stay until they are pumped out every few years), and the liquid exits the tank near its top and flows into the drainfield. The sewage trickles through soil for 2 or 3 feet, where aerobic bacteria and minerals in the soil break down the remaining organic material and kill most of the remaining germs. The soil also locks up chemicals such as phosphates.

Don't flood your septic system!

Reduce your water usage. A septic system has a lower capacity to receive water than a city sewage system. Excessive water can flood the drainage field until it is saturated, potentially causing the septic system to back up into the house or causing a sewage smell or forcing the contaminants in the wastewater to leave the drainage field unprocessed by the bacteria in the soil.

Space out the use of your water. Schedule your laundry throughout the week rather than doing it all on one day. Have short showers and if you have lots of company, ask them to turn off the water in the shower as much as possible. 🛇Don't run the dishwasher and the washing-machine simultaneously. Rent a port-a-potty if you have a big crowd. Keep water in the fridge so you don't have to run it until it's cold. Turn off the tap when brushing your teeth. 🛇 Don't drain water softeners, sump pumps, hot tubs or swimming pools into your septic tank. In order to avoid saturation of the drainage bed, divert the rainwater from your eavestroughs.

Don't block your septic system!

Only toilet paper should be flushed into your septic. Anything else may plug the exit pipes or the holes in the drainage pipes. Do not flush or put down a sink or bathtub: 🛇Grease and fats (wipe cooking pans before washing) 🛇food scraps 🛇baking supplies, coffee grounds, tea leaves (flour etc). 🛇 Avoid liquids that will kill bacteria in the drainfield, such as excessive amounts of bleach, heavy cleaners, antibacterial soap, salts, paint and thinner, fluid from washing brushes 🛇excessive amounts of hair conditioner and fabric softener that form a hard gum and stay in the pipes 🛇paper towels 🛇condoms 🛇menstrual pads or tampons 🛇disposable diapers 🛇baby or hygienic disposable wipes, even if they say they are safe for septic systems 🛇medications 🛇 any other objects 🛇Don't use septic tank additives because they may cause harm by adding extra solids to the system that can clog your drainage field and the chemicals they contain can also pollute groundwater and surface water.

Only grass or clover should be planted on top of the drainage field or septic tank. The bacteria in your drainage area requires oxygen to process wastewater contaminants and heavy weight can pack down the soil and break the pipes 🛇Do not park cars, trucks, snowmobiles, boats or trailers etc on your drainage field 🛇 Do not put patios, carports, decks, storage sheds, sports courts, landscaping plastic or allow grazing animals on the drainage area, the drainage reserve area or the septic tank. Remove any trees or bushes that start to grow on the drainage field.

Lake Stewardship and Environmental Committee of McKellar Township, 2023