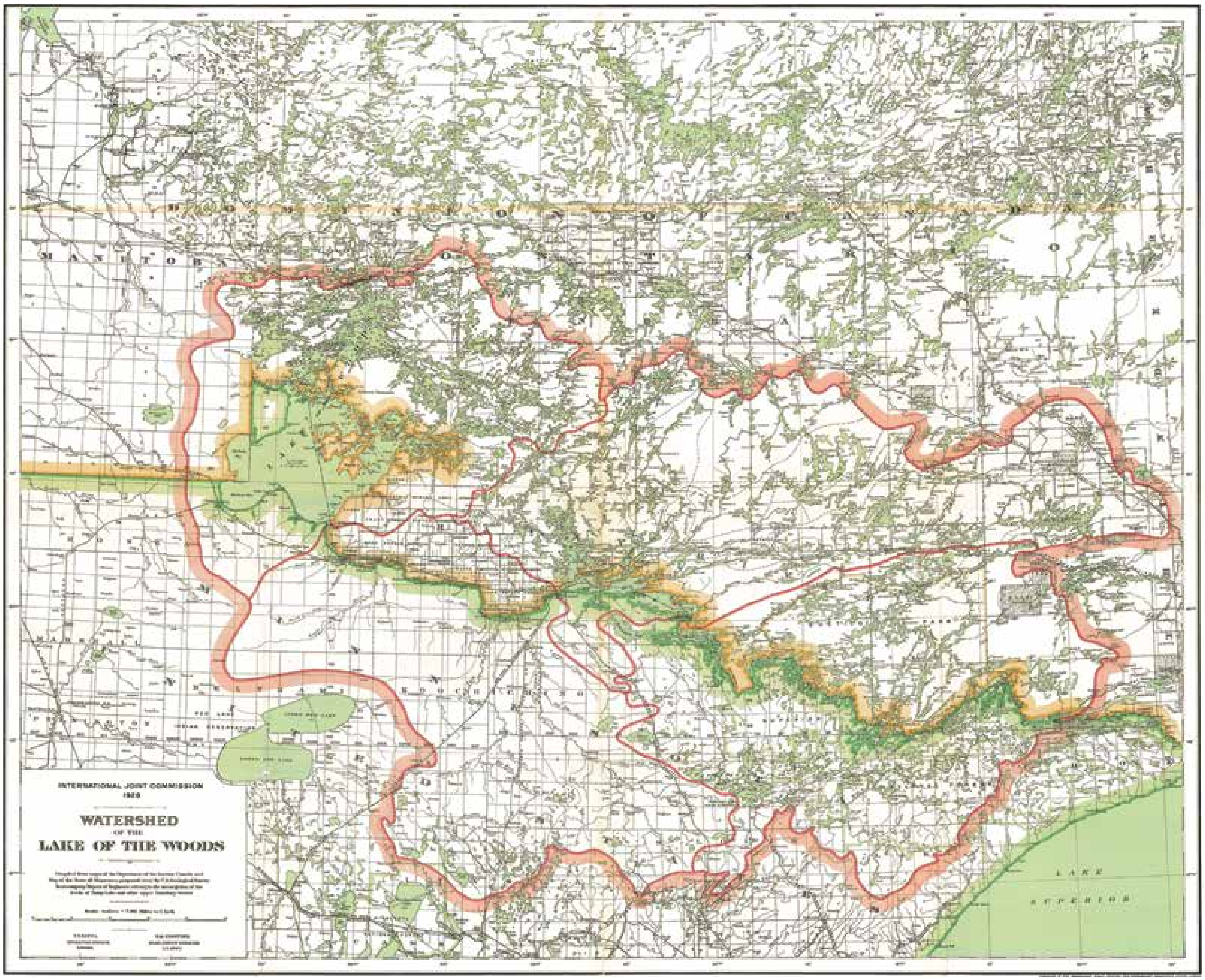
# O V E R V I E W

# RAINY-LAKE OF THE WOODS STATE OF THE BASIN REPORT

2ND EDITION




JULY 2014

*About this Overview Report:*
This Overview report contains information summarized from the full technical version of the Rainy-Lake of the Woods State of the Basin Report, July 1, 2014. This Overview provides summary highlights, in non-technical language, of the detailed technical information and data contained in the full report. We encourage interested readers to explore additional details in the full 228 page version, available from the Foundation's website, www.lowwsf.com/sobr-download.

Published by the Lake of the Woods Water Sustainability Foundation, July 1, 2014

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Funding was provided by the International Joint Commission under IJC contract No. 1042-300765, dated September 30, 2013 and from the Lake of the Woods Water Sustainability Foundation.



**Editors' Note**
Preparation of the Rainy-Lake of the Woods State of the Basin Report was a collaborative effort and its completion would not have been possible without the contributions of numerous researchers, resource managers and agencies in the basin. We extend special thanks to the Editorial Advisory Committee for their contributions and to the International Joint Commission and the Lake of the Woods Water Sustainability Foundation for providing resources for the preparation and publication of this report. We also thank Patty Nelson, of Kenora, for her excellent graphic design and layout of this report.

**Cover:**
*The Watershed of Lake of the Woods International Joint Commission 1928*


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Loon (Bev Clark)


Lake of the Woods (Lee Grim)

# Introduction

Over the past several decades, an impressive amount of research and monitoring has been conducted in the Rainy-Lake of the Woods basin (R-LoW basin). The first State of the Basin Report (SOBR) in 2009 provided details on a wide range of topics, including: drainage basin characteristics, water chemistry and nutrients, biotic communities, emerging threats and an overview of the information gaps and monitoring needs that were identified at that time.

The 2009 SOBR identified 12 important information gaps, some of which were in the process of being addressed at that time. Further information was required concerning:

1. *The relative sources of phosphorus to the Rainy River and Lake of the Woods.*
2. *The sensitivity of different regions to shoreline development and climate change.*
3. *Variation in the frequency and intensity of algal blooms and algal toxins and the causes.*
4. *Meteorological data at different locations on Lake of the Woods and the Rainy River.*
5. *Spatial coverage of water chemistry from atmospheric deposition.*
6. *Bathymetric maps and water-circulation patterns.*
7. *Internal loading and release rates of nutrients, especially phosphorus, from lake sediments.*
8. *Knowledge of the tributary load of nutrients to the Rainy River and Lake of the Woods.*
9. *Contributions of non-point source anthropogenic (human) loads to the nutrient budget.*
10. *Longer-term understanding of the spatial distribution of water quality among monitoring sites.*
11. *Cross-jurisdictional Geographic Information System (GIS) data.*
12. *Long-term variation in algal abundance, composition, and algal toxins.*

Filling these information gaps required a huge effort by researchers and stakeholders. In the five years since these requirements were listed there have been significant advances made **on all twelve of these gaps.**

This new science is the focus of the 2nd Edition of the State of the Basin Report, published July 1, 2014. (www.lowwsf.com/sobr-download).

Even with great progress there are issues and questions that remain and most of these simply reflect the need for a better understanding of ongoing concerns. The general R-LoW basin concerns that are identified by the 2nd Edition of the SOBR include:

- algal blooms and algal toxins
- climate change
- nutrients and internal loading
- surface and ground water contamination
- water levels and erosion
- aquatic invasive species.



The purpose of the IMA is to provide trans-jurisdictional coordination on science and management activities that will enhance or restore water quality in the R-LoW basin.


Water quality monitoring buoy (Environment Canada).

Steps to address these concerns will require the cooperation of multiple agencies. The **International Multi- Agency Arrangement** (IMA) was developed to meet this requirement in May, 2009. The group includes: Environment Canada, U.S. Environmental Protection Agency, Red Lake Band of Chippewa Indians, Lake of the Woods Water Sustainability Foundation, Minnesota Department of Natural Resources, Minnesota Pollution Control Agency, Ontario Ministry of the Environment, Ontario Ministry of Natural Resources, Manitoba Conservation & Water Stewardship and the Koochiching Soil and Water Conservation District.

The purpose of the IMA is to provide trans-jurisdictional coordination and collaboration on science and management activities that will enhance or restore water quality in the R-LoW basin. The IMA has developed a Five Year Study Plan to deal with the specific information gaps that have been identified.

There have also been recent steps forward to improve aspects of governance in the basin since the release of the first State of the Basin Report. In 2013, the **International Rainy-Lake of the Woods Watershed Board** (IRLWWB) was established by the International Joint Commission (IJC) combining the former International Rainy Lake Board of Control and the International Rainy River Water Pollution Board, with an expanded geographic mandate for water quality including Lake of the Woods and upstream boundary waters.

The [Canadian] Lake of the Woods Control Board's role in managing water levels on Lake of the Woods remains unchanged.

The mandate of the IRLWWB is to:

- fulfill the obligations of the Rainy Lake convention to manage water levels on Rainy Lake and Namakan Reservoir
- report to the IJC on existing water quality objectives in boundary waters and recommend new water quality and/or aquatic ecosystem health objectives as required
- establish and report to the IJC on water quality alert levels within the basin.

This board will also support the coordination of research efforts in the basin by developing and implementing the IJC's data harmonization protocols.

An International Watershed Coordinator position was established recently by the Lake of the Woods Water Sustainability Foundation, to assist with coordination and communication between the many groups involved in governance, science, management, and civic engagement in the basin. The IWC reflects the transition from agency and jurisdictional focus to a shared watershed approach and common vision. The IWC is therefore a shared role, jointly funded by the LOWWSF and agencies around the bi-national basin.

The publication of the 2nd Edition of the SOBR provides a launching point for the IJC's development of a Plan of Study for boundary waters in the R-LoW basin. It provides a synthesis of the knowledge developed to date and identifies gaps that need to be addressed.



# Water Quality

## IN THE LAKES

There has been a great deal of monitoring completed in the lakes throughout the R-LoW basin in recent years (Figure 1). In LoW, there has been widespread collection of data by the Ontario Ministries of Environment and Natural Resources (OMOE/OMNR) and by the Minnesota Pollution Control Agency (MPCA). Areas upstream of the Lower Rainy River have been monitored by Voyageurs National Park (VNP) and by MPCA and in many areas by citizen monitoring groups. Much of this data collection has been through routine monitoring whereby samples are collected and analyzed for the same substances in the same locations either annually or on a rotating basis. Other data have been collected in connection with special studies that are limited in scope and these are often directed by universities or through non-governmental organizations to answer specific questions about local ecosystem health. The result is that a great deal of data exists and much of this information is being combined to answer compelling questions that remain about water quality throughout the basin.

Some of the most pressing questions that remain to be answered are surrounding algal blooms, nutrient loads, contaminants, invading species and the effects of water levels and erosion. These topics are covered later in the section on basin concerns.

We know now that there is a great deal of variability in the water chemistry between different locations in the basin and also from season to season in any one place. These differences are linked to both the variations in materials that are exported from watersheds into the lakes through streams and rivers but also by the processes that occur

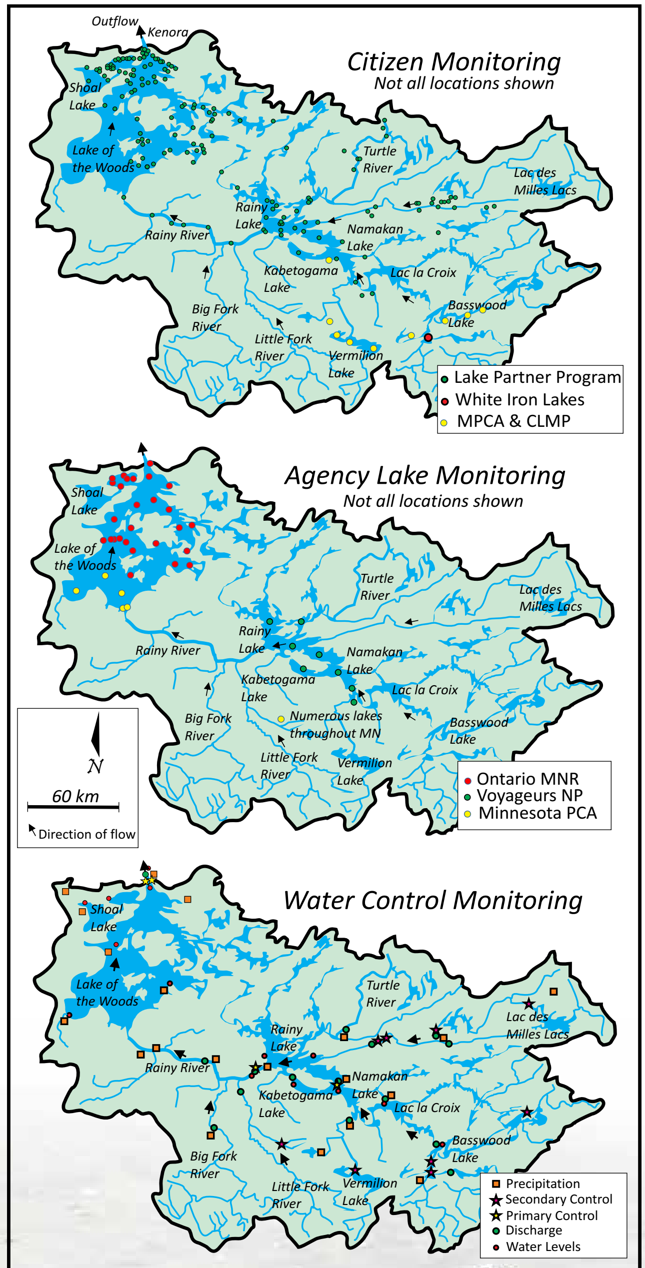



FIGURE 1 - Scope of monitoring in the Rainy-Lake of the Woods basin.



Sediment sampling by Environment Canada (Environment Canada).

within the lake itself throughout the year. The 2nd edition of the SOBR describes many of these processes and outlines the research that is ongoing. Among the important processes that are being studied are:

- factors that influence the timing and severity of algal blooms
- impacts of nutrient loads on the beneficial uses of water
- effects of water level regulation on the ecosystem
- effects of mercury deposition on fish mercury concentrations
- impacts of climate change as a multiple stressor.

These questions are being addressed with more certainty in recent years. For example we can now use satellite images to track the spread and severity of algal blooms between years. We are close to determining the levels of phosphorus loading that would allow managers to correct impaired waters in the southern portions of LoW. There are extensive studies to examine the effects of water level controls on many aspects of ecosystem heath in Voyageurs National Park and we are beginning to assess links between mercury sources and mercury in fish. Finally there is a large body of evidence now that links many in-lake processes to climate change in northwestern Ontario. As an example, the number of ice free days on LoW has increased by 28 days per year since the 1960s (Figure 2).

Since 2009, the listing of the U.S. portion of LoW as an impaired water has required the development of Total Maximum Daily Loads (TMDLs) for total phosphorus (TP) which represent the acceptable TP loads to the lake that will maintain water quality within established criteria. In an attempt to meet these goals there have been many recent advances in the understanding of nutrient inputs and nutrient movements within the basin including:

- refined estimates of relative sources of phosphorus to the R-LoW basin
- improved estimates of sediment and internal nutrient loading



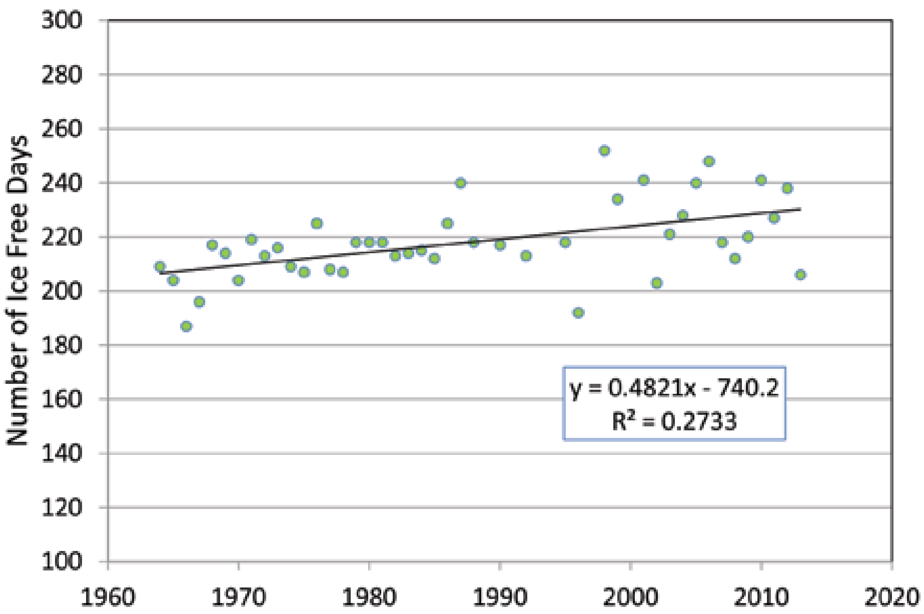



FIGURE 2 - Number of ice free days in Clearwater Bay.

- improved estimates of tributary loads
- advanced modeling efforts to describe seasonal changes in nutrients and their impact on algal biomass within LoW.

## Depth Maps

Lake depth and other physical attributes can influence almost all chemical and biological properties of a lake. Physical attributes including depth and volume are often required as inputs to predictive models to estimate chemical or biological conditions in the lake and to estimate flushing times for different areas of the lake. Depth maps have been available since 1915 but digital depth information has only been recently compiled by Environment Canada which allows the capture of depth information for all areas of the lake (Figure 3).

Detailed bathymetric maps of the littoral zone for selected locations in Rainy Lake and Namakan Reservoir are also being developed to assist research and monitoring studies that are designed to assess the effects of the IJC 2000 Rule Curves on aquatic vegetation, benthos, pike and walleye.

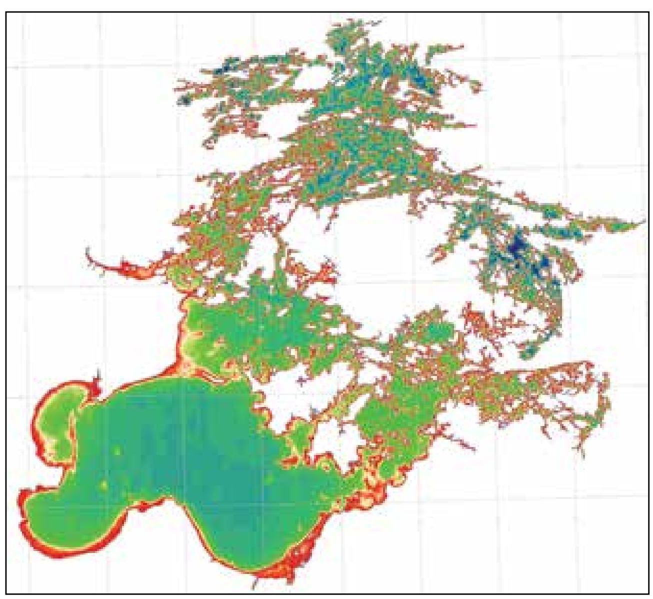


FIGURE 3 - Digital bathymetric map for Lake of the Woods from Environment Canada 2013.

## IN THE RIVERS

Water quality in many of the rivers in the basin has improved substantially in the past several decades. This is especially prevalent in the Rainy River where many substantial improvements have occurred since the 1970s leading to water quality for many substances that is now within the limits prescribed by provincial and state agencies. There is some evidence that the water quality in LoW may be becoming more dilute (less elements and compounds in the water) as a result of improvements in the Rainy River but there is also evidence that we may be paying for our past sins because phosphorus, that has been stored in lake sediments as a result of high inputs from the Rainy River in the past, may still be playing a role by influencing the severity of modern day algal blooms.

There has also been a number of comprehensive studies to examine water quality and those processes that control it in inflows throughout the basin (Figure 4). Excellent summaries of water quality in these rivers are now available on the internet. MPCA's Major Watershed Load Monitoring Program (MWLMP) combines U.S. Geological Survey (USGS) and Minnesota Department of Natural Resources (MDNR) flow data with MPCA, Metropolitan

Council Environmental Services water quality data to calculate loads for 82 streams in Minnesota. MWLMP sites in the Rainy River Basin monitor the Headwaters, Vermilion, Little Fork, Big Fork, Rainy and Rapid rivers. In 2009, the MPCA implemented a loading study for most U.S. tributaries to LoW including Manitou Rapids on the Rainy River which is a MWLMP site.

In 2009 Environment Canada began monitoring water quality at four locations on the Rainy River to estimate nutrient loads (Figure 4). Samples were collected bi-weekly with cooperation of the Rainy River First Nations from transects in the Rainy River. Sampling occurred between May and October and year round at a site at the mouth of the Rainy River. In 2010 mean TP concentrations ranged from 23 µg/L at International Falls to 27.4 µg/L at the mouth of the river. These concentrations are below the Rainy River Alert Level and the Ontario Provincial Water Quality Objective (PWQO) of 30 µg/L.

## Watershed boundary maps

It is difficult to conduct studies at the watershed scale using maps that do not include areas of the watershed that are in an adjacent jurisdiction. Watershed boundaries have been very successfully harmonized so that researchers using Geographic Information System (GIS) based methods can share data across international boundaries in the R-LoW basin. The harmonization effort has been focused on eliminating border artifacts from federal, provincial and state geospatial datasets; creating seamless watershed boundaries and a connected hydrographic framework for the R-LoW Basin (Figure 4). The unified view encompasses 109 subwatersheds for both U.S. and Canada. Agencies can now overlay data onto these harmonized watersheds (e.g., aquatic vegetation, fish populations, temperature, water chemistry, etc.).

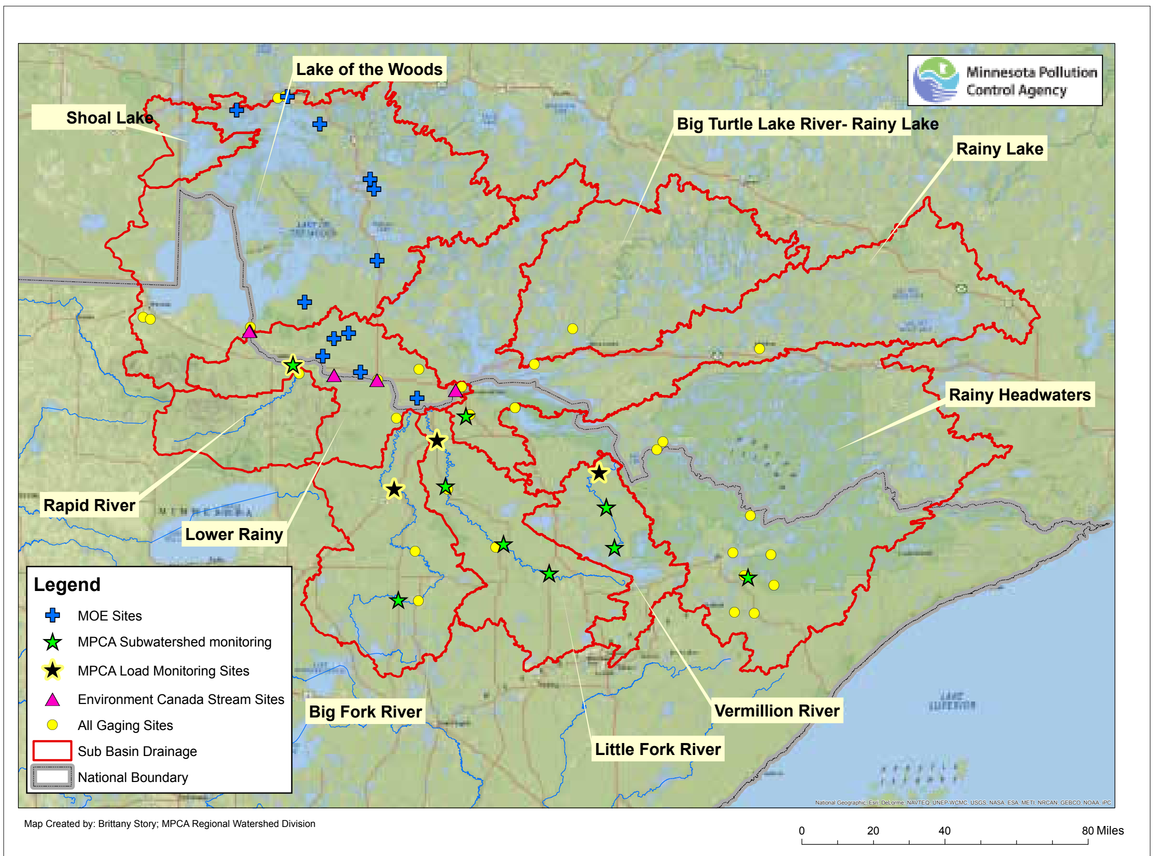



FIGURE 4 - Map showing the stream and river monitoring locations and the major sub-basins of the Rainy-Lake of the Woods Basin (IJC basin harmonization).

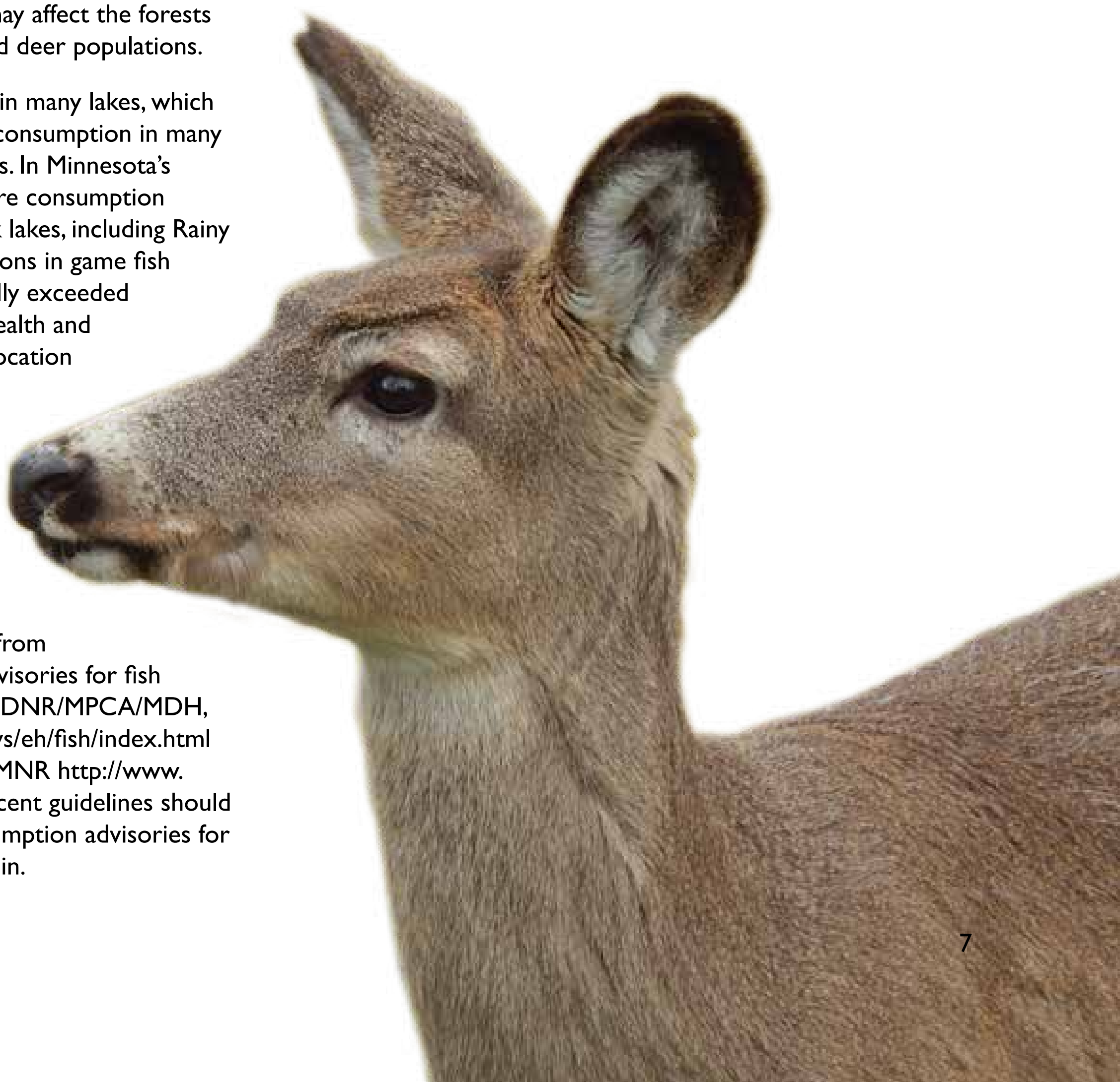


## Fish and Wildlife

Sampling nearshore fish in Voyageurs National Park (U.S. NPS).

Fish and wildlife have been studied throughout the basin with enough detail to allow the assessment of important fish and many waterbirds and mammals. Generally there are many success stories especially in recent years. Fish stocks for walleye, lake trout and sturgeon are recovering following focused efforts to manage their numbers. Bird populations have recovered from the past effects of pesticides in the environment. But there are many things to watch carefully. The list of endangered species for birds such as the piping plover or fish such as the short-jawed cisco are extensive enough to raise concerns. Also, there are indications that climate change may affect the forests and lead to changes in moose and deer populations.

Fish mercury levels are elevated in many lakes, which has led to advisories for human consumption in many lakes including Lake of the Woods. In Minnesota's Voyageurs National Park, there are consumption advisories in the majority of Park lakes, including Rainy Lake. Methylmercury concentrations in game fish in 17 lakes in the Park substantially exceeded Minnesota's criteria for human health and despite the Park's semi-remote location and seemingly pristine condition, northern pike from some lakes contain the highest concentrations of mercury reported in the state. Researchers concluded that mercury in soil and sediments is due to atmospheric deposition and that most mercury in fish is from human sources. Consumption advisories for fish are issued in Minnesota by the MDNR/MPCA/MDH, http://www.health.state.mn.us/divs/eh/fish/index.html and in Ontario by the OMOE/OMNR http://www.ontario.ca/fishguide. The most recent guidelines should be consulted to obtain the consumption advisories for any fish caught in the R-LoW basin.



# Basin Concerns

## ALGAL BLOOMS

Nuisance algal blooms are often caused by phytoplankton called cyanobacteria. These algae are often blue-green in appearance (hence the common name *blue-green algae*), although they can range in colour from green to red. A very high concentration of cyanobacteria is called a *bloom*, and when algal cells rise to the water surface it is called a *surface scum*. Blooms often occur in still or slow-moving water during the warm summer months. Algal blooms occur in many areas of Lake of the Woods and in some areas of the Rainy Lake sub-basin.

The earliest reports of algal blooms in the basin are from over 200 years ago when explorers, fur traders, settlers, and military officials ventured into the area. In recent decades, there have been concerns about perceived increasing frequency and severity of algal blooms especially on LoW. Recent studies have shown that warming trends in the past few decades have led to changes in the algal communities in the lakes in many areas of the basin. These changes in the climate and the environment are known to favour cyanobacteria (blue-green algae). There is also recent evidence that is currently being examined that may show that the perception that blooms are worse in recent years may be correct.

Current algal bloom research is describing a condition whereby blooms are increasing at the same time that nutrient loads have either not increased or have been substantially reduced, as is the case for the Rainy River loading of TP to Lake of the Woods. These seemingly contradictory circumstances are the result of a complex process whereby climate change is influencing bloom intensity and where algae have access to additional nutrients from the lake sediments (internal loads) in some areas.

Algal bloom in nearshore area (Environment Canada).

Satellite imagery has been used in recent years to track the extent and severity of blue-green algal blooms in LoW both seasonally and between years. This has allowed the measurement of algal densities in an extremely large and complex system where concentrations of nuisance algae vary greatly from one place to another. Satellite technologies will allow researchers to help determine which factors contribute to bloom development and to the differences in the severity of the blooms between years. Satellite bloom tracking research by Environment Canada provided some clues as to the factors that may control algal abundance. They showed that bloom intensity was affected by several factors namely:

- more intense blooms were likely to occur earlier rather than later in the season
- January-August cumulative temperatures are related to bloom intensity
- increased spring precipitation has a negative effect on bloom intensity.

This supports the ongoing premise that bloom intensity is increased under warmer and drier conditions.

The Environment Canada results have shown a time-series of intense algal bloom occurrences on LoW over the last decade, with average monthly bloom extent across as much as 80% of the lake's surface. Peak bloom years were coincident with warm, dry summers. This suggests that while bloom intensity and extent appear to be strongly associated with lake temperatures, the shifts in the timing of the bloom each year are caused more by variations in precipitation events and associated nutrient loadings.

The link between bloom intensity and climate may exist more prominently in the R-LoW basin where major changes in physical lake characteristics are linked to climate change (e.g., extended length of the ice free season). Dr. Andrew Paterson presented evidence at the 2011 International Lake of the Woods Water Quality Forum that shows an increase in chlorophyll concentrations (deposited by algae) in lake bottom sediments since the mid-1900s, with larger increases since the early 1980s. This may indicate that blooms have indeed been more severe in recent decades.

### Algal toxins

In addition to algal blooms being aesthetically unpleasant, some species of cyanobacteria naturally produce and store potentially harmful toxins that are released into the water. The levels that accumulate depend on location and severity of the bloom. Toxins produced by certain cyanobacteria can be hepatotoxins (affect the liver) which are prevalent in Canadian fresh waters or neurotoxins (interfere with the transmission of signals in neurons) which are much less common. Microcystins are prevalent hepatotoxins in Canadian water (including the LoW basin) and microcsystin-LR (MCLR) is among the most common of over 70 types of microcystin.

Elevated MCLR concentrations in LoW have been reported during the summer months by many researchers. As a general rule it is advisable to avoid drinking and body contact with water during times when algal blooms are occurring. Water samples cannot be used to assess the safety of the water for drinking since toxins can appear at any time.

## CLIMATE CHANGE

It is important to understand that changes in the climate have the potential to impact every state of the basin that we are attempting to describe. Changes in the duration of ice-cover, for example, which are directly linked to climate will have compounding effects relating to other basin concerns noted here including algal blooms, invasive species and with water levels, waves and erosion.

Colin Beier, a climate–ecologist, noted in 2012 that:
*"Scientific understanding of global climate change has largely outpaced knowledge of climate influences on ecosystems and human communities at the local and regional scales. Local studies of climate change impacts on ecosystem functions and services are needed for informing management, conservation and adaptation efforts, as well as fostering public awareness of the nature of climate change and its consequences for human well-being."*

Recent studies have found that warming temperatures may increase the severity of blue-green (cyanobacteria) blooms in nutrient enriched lakes, because some cyanobacteria may have a competitive advantage at higher water temperatures (e.g., > 25°C). Warming also increases the stability of temperatures in lakes, thus reducing surface water mixing which is good for blue-greens. Algal assemblages in LoW may already be responding to



Satellite photo of Lake of the Woods still covered with ice on April 29, 2014 (MODIS).

recent increases in air temperature. Researchers from Queen's University (ON) examined diatom algal fossils preserved in lake sediment cores from Whitefish Bay (LoW) and found significant changes in species composition since pre-industrial times (pre-1850), with most changes occurring over the past 30 years. The timing of these changes was the same as recent increases in air temperature and increases in the length of the ice-free season. In addition, climate change is expected to have a profound impact on habitat for coldwater fish, such as lake trout and cisco, in North American lakes. Specific effects for coldwater fish in Lake of the Woods will depend on individual sub-basin morphometry and productivity.

Land-based ecosystems are also predicted to change dramatically in response to changes in climate. Researchers have predicted sweeping changes in forest cover from boreal to temperate species together with large changes in the major types of animals on the landscape including shifts from moose to deer. Changes in the types of worms present in the soil will in turn affect the species of vegetation present. These changes will produce novel ecosystems which may be different from anything that we are currently familiar with. It is simply impossible to predict changes to the basin that could have effects that are as consequential as these could be.

## NUTRIENTS

Concerns over nutrient inputs to surface water in the basin are almost always focused on phosphorus which is the nutrient that controls the growth of algae. It is, in fact, responsible for limiting the production of the entire ecosystem. More phosphorus means more fish but it also means more algal blooms. We need phosphorus in the system but excess amounts can be harmful.

When researchers estimate the quantity of phosphorus that is entering the system from each of the many sources, this is called a phosphorus budget. These calculations are necessary so that managers can assess



the potential to reduce the inputs from various sources. To develop a phosphorus (P) budget for the lake, it is necessary to quantify the major sources and losses to and from the lake. The amount of P coming in should equal the amount of P that is lost either to the outflow of the lake or to the lake sediments (both considered losses). When the numbers match then the phosphorus budget is considered to be balanced. This is more complex than it seems since there are many sources that are difficult to measure. Phosphorus can enter surface water from inflows, diffuse and point sources, overland flow, precipitation, and from the sediments of the lake (internal loads). Some of these sources can be controlled and others cannot but a budget is required to assess the degree to which the total loads can be managed.

The development of P load budgets has increased the understanding of the fate of nutrients in the basin. These calculations will help to identify acceptable Total Maximum Daily Loads (TMDLs) which are being developed for impaired areas in the Minnesota (southern) portion of LoW. A TMDL is a calculation of the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards, and an allocation of that load among the various sources of that pollutant.

The Rainy River is the major inflow to LoW. In the past, the pulp and paper companies at International Falls and Fort Frances together with domestic sewage inputs were considered to be the major point sources of nutrients to the Rainy River. In recent decades the implementation of regulations for treatment of industrial and domestic waste effluent has led to significant reductions in nutrient loads to the Rainy River. These reductions occurred most substantially between the 1970s and the 1980s (Figure 5).

Since 2009 there have been attempts to refine nutrient loading information to produce nutrient budgets that can:

1. Identify relative total phosphorus (TP) inputs from all sources including internal loads.
2. Examine the effect of nutrient movements within the lake on algal blooms.
3. Determine acceptable loads (TMDLs) to the lake.

Kathryn Hargan, as part of her Master of Science Degree at Trent University, assembled the first detailed nutrient budget for Lake of the Woods in 2010. The budget was based upon measured flow volumes together with measured P concentrations to calculate loads from the inflows (Figure 6). This budget confirms that the Rainy River is the largest source of P but also shows that more than half of the P that comes into the lake stays in the lake and does not exit at the outflow to the Winnipeg River. This P is lost to the sediments through the settling of particles such as algae and bacteria. The budget also illustrates that the contribution of P from shoreline properties is relatively small on a whole lake scale. However, in more enclosed or isolated bays the same contribution from shoreline properties may represent a relatively larger portion of the P budget. Observing the relative contributions of P from different sources allows managers to evaluate the potential that exists to manage P from various sources.

Another way to help visualize or predict nutrient movements in a lake is by using nutrient models. Joseph Hadash, as part of his Master of Science Degree at St. Cloud State University, used two such models (FLUX and BATHTUB) to examine the fate of P in Big Traverse Bay. He found that the models predicted P loads to Big Traverse Bay that were similar to those measured by Hargan. In addition,

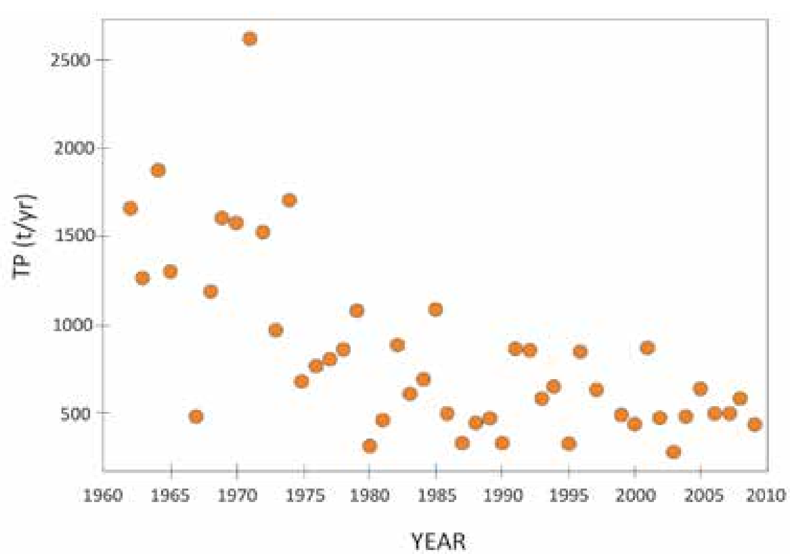



FIGURE 5 - Rainy River total phosphorus loads from Hargan *et al.* (2011).

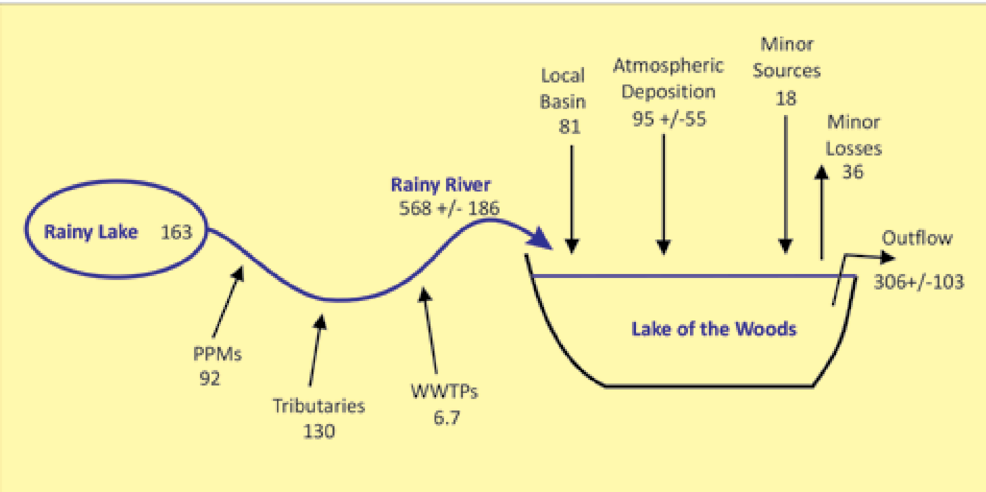



FIGURE 6 - Schematic of summarized annual total phosphorus fluxes to the Rainy River and Lake of the Woods in metric tonnes from Hargan *et al.* (2011). PPM = pulp and paper mill, WWTP= waste-water treatment plants.

the BATHTUB model estimated an internal load from the sediments and the amount of P that leaves Big Traverse Bay to the northern portion of Lake of the Woods.

In the past several years a significant amount of water quality monitoring, modeling, and research has taken place on LoW which has allowed the MPCA to develop more refined models and predictions of water quality for the southern, eastern, and central basins of LoW. The southern portion of LoW was divided into 5 segments based on observed differences in water quality and bathymetry – Fourmile Bay, Big Traverse and Buffalo Bays, Muskeg Bay, Sabaskong Bay and Northeast Big Traverse and Little Traverse Bay/ Northwest Angle.

The model incorporated revised bathymetry data from Environment Canada, measurements of internal phosphorus loading (laboratory aerobic release rates), and revised phosphorus loads from the Rainy River (based on recent event-based sampling). The TP budget was estimated at 1,147 tonnes per year, partitioned into 6 categories- tributary inflow (principally the Rainy River) 42%, internal load 36%, precipitation 13%, shoreline erosion 6%, non-point inflow 2%, and point sources, 1% (Figure 7). The model estimates that 55% of the phosphorus is retained within the lake.

Output from the BATHTUB modeling exercise indicate that we are collectively making progress on completing an accurate P budget. The next step is to assess climate impacts on algal bloom severity, examine the role of dissolved P relative to total P in algal bloom formation and to complete the TMDL.

It is important to note that the budgets discussed above are measured as annual totals. Many processes will have a seasonal impact on the lake including algal blooms. One major consideration is the fact that internal loads are usually at their maximum in the late summer when blue-green algal blooms are developing in the lake. These processes can be examined through the use of more complex dynamic flux models. For example, in 2013, Environment Canada published the results of using a linked hydrodynamic, water quality and algal biomass model on LoW. The model results predicted spatial and seasonal differences in TP and algal densities. This modeling exercise recognized the importance of variations in water quality between different sectors in LoW and the influences of seasonal changes within given sectors. Results were compared to observed measures of TP and chlorophyll. The central and south segments behaved like shallow lakes with strong variability in TP and phytoplankton biomass, whereas two relatively isolated and deeper sectors in the north were characterized by less variability in TP and lower algal biomass. Algal biomass and cyanobacterial dominance were best predicted in the more eutrophic

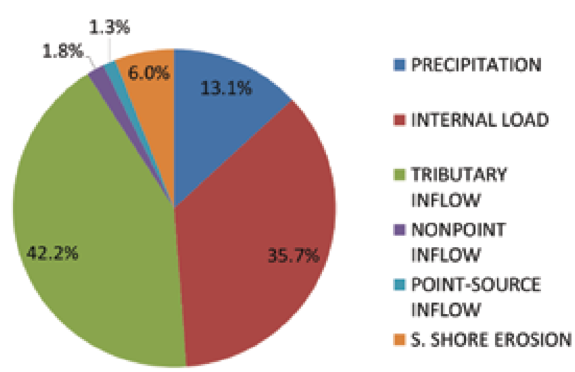



FIGURE 7 - Relative sources of phosphorus to Lake of the Woods (MPCA)..



southern sectors. The results of this dynamic phosphorus modeling exercise reinforces the need to apply multi-segmental models to LoW which cannot be effectively assessed using a single box approach due to differences in water quality from place to place.

These various phosphorus budgets and flux modeling exercises have derived P loads that are in relatively close agreement (Table 1).

One of the important evaluations of these types of models is the degree to which they can duplicate consistent patterns in measured datasets as illustrated for the north end of LoW in Figure 8. Lake Partner Program (OMOE) data show distinct seasonal patterns in P concentrations in many areas throughout the R-LoW basin. These patterns are no doubt responsible for the way that algal blooms behave. Predictions by future models should be able to match these measured concentrations and a comparison of model output to these measured patterns should be a next step in model output evaluation.

## The Effects of Historical Nutrient Loading

A partnership of researchers at the Minnesota Pollution Control Agency, Ontario Ministry of Environment, Minnesota St. Croix River Watershed Research Station and the University of Minnesota at Duluth are undertaking a study of historical nutrient loading from the Rainy River and its effects on current water quality on LoW. This research will determine the effect of decades of uncontrolled pollution from the Rainy River that has previously built up in the sediments of the Big Traverse basin of Lake of the Woods and explore potential remedial measures. Researchers have presented ongoing efforts to construct this historical phosphorus budget for Lake of the Woods at the International Rainy-Lake of the Woods Watershed Forums in 2012, 2013 and 2014 (known as the International Lake of the Woods Water Quality Forum prior to 2014).

TABLE 1 - Comparison of nutrient load estimates from different sources. Due to differences in methods used to derive loads the values shown may not be exactly comparable in some cases. Hargan's total load does not include in internal load.

| TP *(tonnes)* | Hargan *et al.* *Whole Lake* | Hadash *Bathtub* *Whole lake* | MPCA *South, Eastern & Central Basins* | Zhang *et al.* *2009 Sector 1* |
|---|---|---|---|---|
| Internal Load (IL) | | 568 | 410 | 226 |
| Precipitation | 95 | 75 | 150 | |
| Tributary Load | 469 | 453 | 485 | |
| Non-Point Source Inflow | 99 | | 20.7 | 469 |
| Point-Source Inflow | 98.7 | | 15 | |
| South Shore Erosion | | | 69 | |
| P retained in Lake | 60% | 57% | 55% | 63% |
| Total Load | 762 | 1113 | 1150 | 725 |

Shallow and nutrient enriched lakes with no oxygen in the sediments will be subject to additional loading of phosphorus from bottom sediments into the water especially in late summer when algal blooms occur. This is referred to as an *internal load*. The extent and consequences of internal loading in LoW has been examined more carefully in recent years. It may

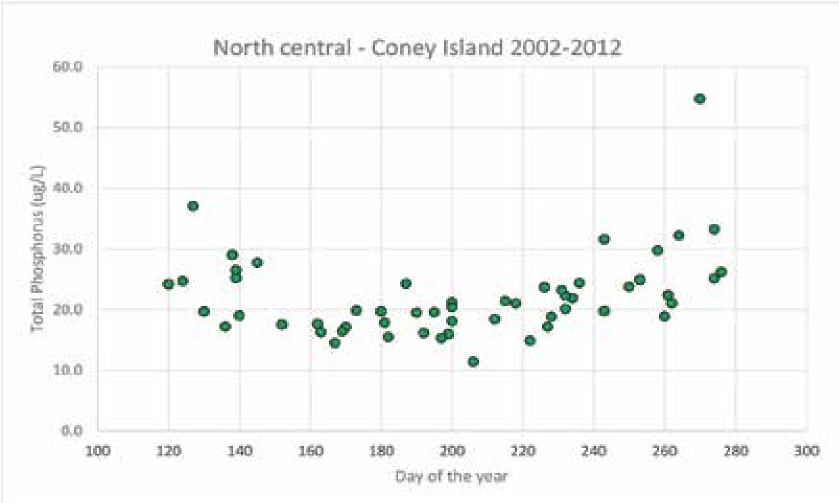



FIGURE 8 - TP seasonal patterns observed for a north central station near Coney Island in Lake of the Woods between 2002 and 2012 (OMOE Lake Partner Program).



be that the nutrients that have been stored in the sediments through years of inputs from the Rainy River can migrate upward in the sediments so that they remain in a location near to the sediment water boundary where they are available at certain times of the year for algal production. This may be an example of how we must pay for past sins for some time to come. This study is ongoing.

## CONTAMINANTS

There are generally less contaminants entering the basin than there would be in other areas of North America, such as in the Great Lakes basin. In addition, the impacts of contaminants have been greatly reduced through reductions of pollutant inputs into the Rainy River. However, there are areas in the basin that:

- are listed as Federal Contaminated Sites (in Canada)
- may have legacy contamination from historic mining activity
- demonstrate atmospheric contamination of lakes and fish by mercury
- receive point-source discharges from industry and municipalities
- are affected by emerging potential for mining activities to increase once again in the basin.

The level of threat varies between individual contaminants and their sources but monitoring to asses threats from contaminants is necessary.

Contaminants may enter surface water (and ground water) from many sources including point sources such as industrial outfalls, wastewater treatment plants, stormwater drains, etc. and diffuse sources such as from agriculture, private septic systems, precipitation, etc. Generally the point sources are controlled through regulation that stipulates the concentrations of contaminants that are allowed in the discharge. Diffuse sources tend to be poorly quantified and are either not controllable directly (e.g., contaminants in precipitation) or must be controlled by more widespread efforts and best management practices such as those required to reduce agricultural inputs or inputs from sources such as road salt.

The 2nd Edition SOBR noted that an effort should be made to complete an inventory of diffuse sources of contaminants in the basin to establish the level of concern that should be attributed to these sources, i.e., whether or not management initiatives are required.

### Mining

There is some evidence of effects on the environment as a result of historic mining. For example, the former Steep Rock Mine, an iron ore mine which operated from 1944 to 1979 near Atikokan, ON, was responsible for the release of dredged and stored suspended sediments to the Seine River during the spring freshet of 1951. The Steep Rock Mine was one of the largest undertakings of its kind with many water diversions and perturbations to the aquatic ecosystem to achieve war time extraction of iron ore. Water management of the former site continues today. Historically on Lake of the Woods there were many gold mining sites and processing operations. Environment Canada (2013) noted that several of its sediment monitoring sites (where sediment concentrations of arsenic and barium were higher than expected) were adjacent to historic gold mines.

In Minnesota, there are effects from leaching metals from sulfide waste rock stockpiles at the historic Dunka taconite mine near Babbitt.

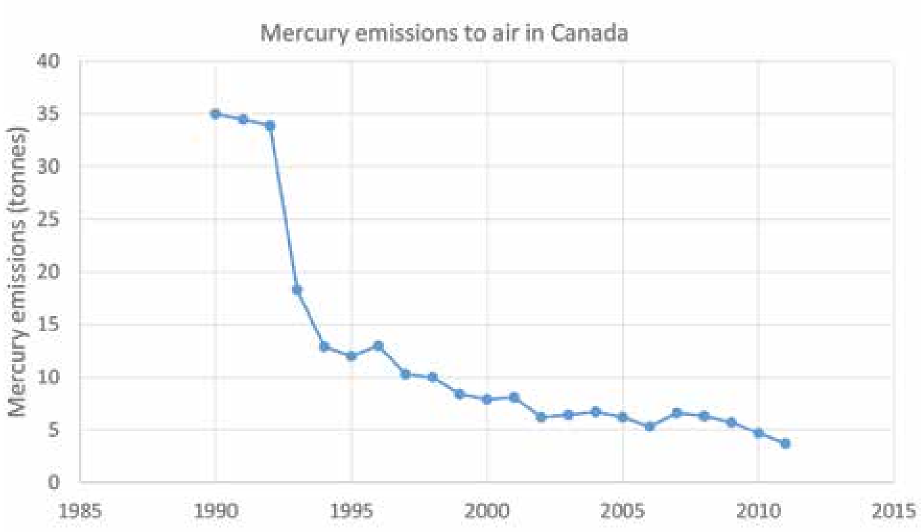



FIGURE 9 - Mercury emissions to air from Canadian sources (Environment Canada).



Contaminants enter Birch Lake which is near to the Boundary Waters Canoe Area Wilderness.

The potential for future mining activity in the basin has been examined in the 2nd Edition of the SOBR and the potential effects of mining will be examined as projects move from exploration phases to actual mine operation.

### Mercury

Mercury is a contaminant of concern in the R-LoW basin. Mercury is a naturally occurring element that is present in rocks and soil, but the contribution of mercury to lakes from these sources is negligible compared to atmospheric sources with origins relating to human activity. Mercury in the aquatic environment will bioaccumulate in biota and biomagnify in aquatic food webs. Larger fish, and especially older fish, have higher concentrations of mercury due to their higher position in the food web and a longer time spent accumulating mercury. Mercury concentrations in fish have resulted in fish consumption restrictions in both Ontario and Minnesota.

In Canada, the major contribution of atmospheric mercury until the 1980s was the chloralkali industry but all chloralkali plants are now closed in Ontario. The resulting decline in emissions combined with reductions from mining and smelting industries throughout the 1990s has resulted in an overall decline in the amount of mercury emitted to the atmosphere from human sources (Figure 9). In 2011, Canada emitted under 3.7 tonnes of mercury, 27% of which was attributed to electricity generation and 26% to incineration. Ontario was responsible for 27% of the total Canadian emissions. U.S. mercury emissions are also declining (from approximately 250 tons/yr in 1990 to 100 tons/yr in 2005).

Despite these reductions in North American emissions the deposition of mercury may continue to increase due to increases in global emissions which may delay recovery in mercury contamination in the biota. Studies in Minnesota and elsewhere in the Great Lakes basin have shown decreasing trends in mercury in fish between the 1980s and the mid-1990s after which the trend of mercury in fish tissue begins to rise once again. One explanation for this is that although regional emissions of mercury have declined considerably over the past 30 years, these have been offset by recent increases in the global emissions of mercury.

### Other Contaminants

Although contamination of food webs by persistent pollutants, such as PCBs, do not pose immediate threats to biota in the R-LoW basin, it is important to note that contaminants that include industrial chemicals are released as by-products of many industrial and domestic processes.

Painted Turtle
(Bev Clark)

Pesticides, particularly those which are suspected endocrine disruptors, were identified as a possible health risk factor in LoW by the IJC Health Task Force. Environment Canada sampled herbicides and pesticides at several of its LoW monitoring stations in 2009 and 2010 and the maximum concentrations detected were below Canadian Water Quality Guideline concentrations for the protection of aquatic life by several orders of magnitude suggesting that the concentrations present in LoW do not pose a threat to biota.

There does not seem to be any indication that the basin is impacted by contaminants other than mercury but **very little is known about the prevalence of emerging contaminants of concern (such as those associated with pharmaceuticals in waste water) within the basin.**



# Water Levels and Erosion

The effects of water level control are currently being studied in the Rainy Lake and Namakan Reservoir system to assess whether the 2000 Rule Curves should be modified. Projects are being completed following a Plan of Study designed to fill data gaps that remain after agency monitoring and research. Upon completion of these studies in 2015-2016, the IJC will initiate the evaluation of the Rule Curve effects.

There have also been studies to assess the effects of erosion in the southern areas of LoW where the shoreline is experiencing significant erosion. Analysis of aerial photos from 1940 to 2003 showed rapid erosion of several undeveloped wetland areas of the shoreline and relatively slow erosion of developed areas along Sandy Shores and Birch Beach. Analysis of Pine and Sable Islands showed a combination of erosion, rebuilding, and shifting. This erosion threatens habitat that provides refuge for a number of federally threatened and endangered species.

These eroding sediments are a source of nutrients to the lake. Results show an estimated average total phosphorus load of 82 tons/yr but it is unclear what the net load to the water itself would be, after particulate phosphorus settles out.

On Lake of the Woods, there were many potential ecological effects that followed the installation of outlet control structures at Kenora in the 1890s. These structures raised the water level in LoW by approximately 1 meter (3.3 ft) and this has had many effects on ecological function some of which have been noted in research studies that have examined long-term changes in LoW algal communities.

The equalization of the water levels in LoW and Shoal Lake make it possible for water to flow in both directions between the two lakes and potential effects of this are an ongoing concern.



# Invasive Species

The basin has been invaded by many non-native species which have disrupted the biological communities. Invasions have occurred in all trophic levels of the aquatic ecosystem from algae up to fish. The hybrid cattail, spiny water flea, rusty crayfish, papershell crayfish, clearwater crayfish and rainbow smelt are confirmed invaders in parts of the R-LoW basin. Zebra mussels have been reported by MDNR in headwater lakes of the Big Fork River near Bemidji, MN (May 2013). There is potential for further invasions which will require ambitious focused effort to avoid/slow the spread of these species and to better understand their impacts to natural systems.

Rusty Crayfish (Laureen Parsons, OMNR)



# SOBR 2nd Edition Recommendations

The following recommendations and suggested steps forward were provided in the 2nd Edition of the SOBR. Some of these, such as the need for continued communication or the necessity for secure funding for critical programs go almost without saying. Others involve the continued collection of information to answer those clear and compelling scientific questions or objectives that remain. Recommendations are listed under *Governance* and *Research*.

## GOVERNANCE

1. Continued support for the IJC Rainy-LoW Watershed Board governance model including inputs from community and industry advisory groups.
2. Ensure continued communication, including continued support for the International Rainy-Lake of the Woods Watershed Forum, the International Multi-Agency Arrangement (IMA), and increased involvement of First Nations, Métis, and Tribes.
3. Secure funding for monitoring and research.

## RESEARCH

1. Fill information gaps for each of the listed basin concerns. This should be prioritized and aligned with the objectives of the IMA and will provide a basis for the IJC Lake of the Woods Basin Water Quality Plan of Study.
2. Assess adequacy of current monitoring programs.
3. Assess the need for International Water Quality Objectives.

**About this Overview Report:**

This Overview report contains information summarized from the full technical version of the Rainy-Lake of the Woods State of the Basin Report, July 1, 2014. This Overview provides summary highlights, in non-technical language, of the detailed technical information and data contained in the full report. We encourage interested readers to explore additional details in the full 228 page version, available from the Foundation's website, www.lowwsf.com/sobr-download.



# Summary

Major improvements in governance and in the understanding of watershed processes have been realized in the five years since the first State of the Basin Report was published in 2009.

There have been milestone achievements including the formation of the International Multi-Agency Arrangement to oversee technical aspects of basin management, and the establishment of the IJC International Rainy-Lake of the Woods Watershed Board to provide a binational watershed governance framework.

From the beginning the Lake of the Woods Water Sustainability Foundation continues to coordinate a wide variety of basin activities with benefits to multiple stakeholders. There is at this point no apparent need for the development of any further groups to facilitate science and governance in the basin. This can be considered as a major accomplishment.

With respect to the understanding and management of drainage basin processes, the first 2009 State of the Basin Report recommended the following:

- enhance meteorological monitoring
- improve spatial coverage for the collection of deposition chemistry
- improve bathymetric maps and water circulation/internal water movement data
- collect further data on internal loading and release rates of nutrients from lake sediments
- quantify tributary nutrient loads to the Rainy River and LoW
- quantify non-point source anthropogenic contributions of nutrients
- improve the spatial distribution of water quality monitoring sites with continued discussion regarding the location and sampling frequency of core monitoring sites
- integrate GIS base layers from U.S. and Canadian watersheds
- improve understanding of algal abundance and composition, and algal toxins in LoW.

Within the last five years many of these recommendations have been fulfilled. All those who have worked on projects to better understand, safeguard or improve ecosystem integrity in the R-LoW basin should be proud of their accomplishments to date. The degree to which our understanding of this basin has improved in only a few years is a rare, if not unique, accomplishment.