Environment and Climate Change Canada
Environnement et Changement climatique Canada
Canada

LAKE WINNIPEG BASIN INITIATIVE

PHASE II FINAL REPORT

2012/2013 TO 2016/2017

Cat. N°.: En4-137/3-2019E-PDF
ISBN: 978-0-660-29341-7

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EXECUTIVE SUMMARY

This report has been compiled to highlight the activities conducted during Phase II (2012-2017) of the Lake Winnipeg Basin Initiative (LWBI) of Environment and Climate Change Canada (ECCC). It contains an overview of the accomplishments achieved under each pillar of the LWBI: Science, Stewardship and Transboundary Partnerships. The Science section outlines the projects undertaken by ECCC scientists including a project overview, results and plans for future research. A full list of scientific publications can be found in Appendix B. The Stewardship section describes the LWBI's grants & contributions program, including funding priorities, eligibility requirements and the application process. This report also describes the results achieved by these projects, with descriptions of each project highlighted in Appendix A. Finally, the Transboundary Partnerships section outlines the interjurisdictional and policy work carried out by ECCC in collaboration with a multitude of partners. Problems and solutions to the challenges facing Lake Winnipeg are interprovincial and international in scope. Any solutions for improving the health of the lake will take time and require the coordinated efforts of multiple stakeholders in the Lake Winnipeg Basin.

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1.0 ACKNOWLEDGEMENTS

Environment and Climate Change Canada (ECCC) would like to thank the other federal departments, provincial governments, Indigenous governments, non-government organizations, academic institutions and individuals that have worked collaboratively with ECCC on advancing our understanding of water quality issues facing Lake Winnipeg and its Basin through scientific research.

ECCC is appreciative of the contributions made by many organizations, boards, working groups and committees working on improving water quality in Lake Winnipeg and its Basin.

ECCC would also like to thank the following members of the LWBSF Public Advisory Committee:

Allan Kristofferson, Managing Director of the Lake Winnipeg Research Consortium;

Kim Poppel, Executive Director, Brandon Seniors for Seniors Co-op Inc.;

Richard C. Rounds, Richard Rounds & Associates, retired Professor and Chair, Department of Rural Development, Brandon University;

Sherry Helwer, Vice President, Shur-Gro & Munro Farm Services Ltd.;

Glen Cummings, retired grain and livestock farmer, former Deputy Premier of Manitoba, Minister of Municipal Affairs and Minister responsible for Public Insurance; and

Tammy Axelsson, Executive Director, New Iceland Heritage Museum and Lake Winnipeg Visitor Centre.

ECCC would also like to recognize and thank all LWBSF recipients for the important work that has been accomplished through their projects. Please see Appendix A for a complete list of projects funded under Phase II.

Photo: Ute Holweger

2.0 LAKE WINNIPEG BASIN INITIATIVE OVERVIEW

The Lake Winnipeg Basin Initiative (LWBI) addressed water quality issues in Lake Winnipeg and its basin by collaborating with citizens, scientists and domestic and international partners on actions aimed at restoring the ecological health of Lake Winnipeg. Phase I of the LWBI (2008-2012) began with an investment of $17.7 million in funding. This report focuses on the activities carried out in Phase II (2012-2017) which invested $18 million over 5 years (2012-17) across the following three pillars: Science, Stewardship and Transboundary Partnerships.

2.1 SCIENCE

In Phase II, greater emphasis was placed on watershed-based research to help identify and measure which actions on the land will best improve water quality in the lake. In-lake research was also conducted to further understand the ecology of the lake and to help set ecologically relevant nutrient objectives. The key science objectives of LWBI Phase II were to:

- Address knowledge gaps related to the impacts of human activity, particularly land use, on the fate, effect and delivery of nutrients in Lake Winnipeg tributaries;
- Develop predictive tools/models to support nutrient management in the Lake Winnipeg Basin;
- Undertake water quality and biotic monitoring to track spatial and temporal flux of nutrients transported from the watershed to the lake and to support the development of modelling scenarios; and
- Address critical knowledge gaps in lake nutrient dynamics relative to changes in nutrient loads to Lake Winnipeg.

Under the Science pillar, research was conducted to ensure decision makers had access to relevant scientific information and tools to guide and evaluate water quality management and protection in the Lake Winnipeg Basin. The science activities were intended to compliment stakeholder actions throughout the basin.

2.2 STEWARDSHIP

The Stewardship pillar provided financial support through the Lake Winnipeg Basin Stewardship Fund (LWBSF) to high-impact, stakeholder-driven projects aimed at reducing nutrient loading in the Lake Winnipeg Basin. Eligible projects had to address at least one of the following priorities:

- Reducing nutrient inputs from rural and urban sources;
- Controlling point and non-point sources of pollution;
- Rehabilitating priority aquatic ecosystems that support nutrient reduction and sequestration; and
- Enhancing research and monitoring capacity to support decision-making.

During Phase II, there were three rounds of funding totaling approximately $5.4 million. A total of 46 application based projects were funded, ranging from $4,000 to over $900,000, with an average project value of $112,000. For every dollar of LWBSF funding contributed to stakeholder projects, almost three dollars of stakeholder funding was leveraged.

The LWBSF also provided directed financial support for two projects:

- The Lake Winnipeg Research Consortium for managing and operating the science platform used to conduct research and monitoring on the lake;
- The University of Manitoba's Lake Winnipeg Basin Information Network, a single-window web-based information network aimed at promoting and enabling data sharing and analysis with partners to support research on the lake and in the basin.

2.3 TRANSBOUNDARY PARTNERSHIPS

The Transboundary Partnerships pillar of the LWBI included collaborative work with other governments (provincial, state, federal) and organizations within the Lake Winnipeg transboundary watershed. This included working with the Province of Manitoba to continue implementation of the 2010 Canada–Manitoba Memorandum of Understanding Respecting Lake Winnipeg and the Lake Winnipeg Basin (CA-MB MOU). The CA-MB MOU provided a forum for communication to support a long-term collaborative and coordinated approach between the two governments in the areas of science and governance to support the sustainability and health of the Lake Winnipeg Basin. Transboundary partnership activities also emphasized collaborative work with other governments and jurisdictions to ensure sources of nutrients outside of Manitoba were being managed to reduce nutrient loading to watercourses in the basin. Domestic and international water management boards played a critical role in managing nutrients in the Lake Winnipeg Basin and therefore were key partners in this initiative.

3.0 BACKGROUND

Lake Winnipeg is Canada's sixth largest lake and its basin covers over one million km² and spans across four provinces and four states. Lake Winnipeg has the largest land drainage to surface area ratio of any of the great lakes of the world; 40 km² of watershed for every 1 km² of surface area.

3.1 NUTRIENT LOADING AND EUTROPHICATION

3.1.1 NUTRIENT SOURCES

Lake Winnipeg's poor water quality is due to excess nutrient loading, notably phosphorus and nitrogen, from multiple local and transboundary sources including agriculture, municipal wastewater, industry and urban runoff. More than 50% of the nutrient loading originates from beyond Manitoba's borders, with the Red River being the largest source. The increased frequency of high precipitation events in the Red River Basin has resulted in higher spring runoff and floods, which has resulted in increased nutrient loading to the lake. The most recent Canadian Environmental Sustainability Indicator for Lake Winnipeg indicated that in 2013, phosphorus concentrations in the lake exceeded the water quality guidelines for the protection of aquatic life most of the time (>50% of samples), while nitrogen concentrations generally met the guidelines.

3.1.2 INTERNAL NUTRIENT CYCLING

During Phase II, ECCC conducted the first direct assessment of the role of sediments in internal nutrient loading in Lake Winnipeg. The results indicated that the loading of total phosphorus and biologically available phosphorus by the resuspension of sediments from the lake bottom is substantial. Internal nutrient loading adds approximately as much phosphorus to the water column as is delivered from watershed-based tributary sources. The top 7 cm of sediments in Lake Winnipeg will remain a significant and active source of internal nutrient loading for several decades, a process which may delay the response of the lake to nutrient management actions in the watershed.

3.1.3 ALGAL BLOOMS

Lake Winnipeg's deteriorating health is evident in satellite images taken over the past decade, which indicate an increasing trend in the frequency and size of algal blooms. Excess nutrients are a food source for algae, enabling large-scale blooms. Algal blooms clog fishing nets, foul beaches and under certain conditions, some algae and blue-green algae can produce harmful toxins that pose a significant risk to wildlife, pets and human health.

Eutrophication

"Eutrophication is the process by which a body of water becomes enriched in dissolved nutrients (such as phosphates) that stimulate the growth of aquatic plant life, usually resulting in the depletion of dissolved oxygen."

3.1.4 EUTROPHICATION

The increasing frequency and size of algal blooms on Lake Winnipeg are evidence that the lake is experiencing an advanced state of eutrophication. Eutrophication refers to the over enrichment of a body of water, resulting in excessive aquatic plant life. A eutrophic lake is characterized by the development of mats of algal scum, including toxic blue-green algae, changes in the abundance and composition of aquatic animals in the lake, declines in oxygen in the lake, and taste and odor problems associated with lake water.

3.2 OTHER ENVIRONMENTAL THREATS

3.2.1 AQUATIC INVASIVE SPECIES

Lake Winnipeg is also facing threats from several other environmental issues. Several invasive fish and other aquatic species have colonized the lake in recent years, with the most notable being zebra mussels (Dreissena polymorpha). Zebra mussels were first discovered in five harbours of the lake in 2013 and have since spread in increasingly larger numbers throughout the south basin and narrows of the lake. They have also been found throughout the United States and Canadian portions of the Red River. The presence of zebra mussels in Lake Winnipeg has potentially severe negative implications for its ecosystem and economic health. They affect how energy and nutrients move through the food web, they aggressively compete with native species for food, and as filter feeders can increase the clarity of the water column in the lake which may result in the creation of more toxic algal blooms. Zebra mussels attach to hard surfaces in the lake and can reach very high densities. This means that infrastructure in the lake such as docks, water intakes, boats, motors, etc. provide a favourable environment for mussel colonization. It is not known how quickly or extensively zebra mussels will colonize the lake. The absence of key information about the lake bottom makes it very challenging to predict the rate and extent of colonization.

3.2.2 CLIMATE CHANGE

Climate change implications for Lake Winnipeg are not widely understood, but could include warmer water, longer ice-free seasons, increased nutrient availability associated with more frequent spring flooding and winter melts, and more intense summer rain events. Future climate scenarios that determine the amount of precipitation and runoff in the Red River Basin will have important implications for nutrient loading and the remediation of Lake Winnipeg.

Photo: Dana Hay
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4.0 SCIENTIFIC RESEARCH AND MONITORING

The Lake Winnipeg Basin Initiative (LWBI) allocated $8.47 million to the Science pillar to conduct freshwater science and water quality research, monitoring and modelling activities to understand the complexity of issues facing Lake Winnipeg and its vast basin. Research and monitoring undertaken by ECCC provided stakeholders across the watershed with sound scientific data to aid in the implementation of water quality and nutrient management activities. A science plan was developed to guide this work aimed at bridging current knowledge gaps related to the lake's ecology and nutrient cycling, and track the sources and movement of nutrients (phosphorus and nitrogen) throughout the lake and its basin. ECCC science activities provided the information and tools that assist in developing nutrient objectives for the lake, as well as developing performance indicators to assess the health of the lake and its response to nutrient management actions. These science activities complemented the work being implemented by the Province of Manitoba and other federal, provincial and state agencies. ECCC also worked collaboratively with binational agencies, academic institutions, and regional and local partners to address data and knowledge gaps.

KEY DELIVERABLES ACHIEVED THROUGH THE SCIENCE PLAN:

Science Deliverable #1

Knowledge gaps related to the impacts of human activity, particularly land use, on the fate, effect and delivery of nutrients in Lake Winnipeg tributaries were addressed;

Science Deliverable #2

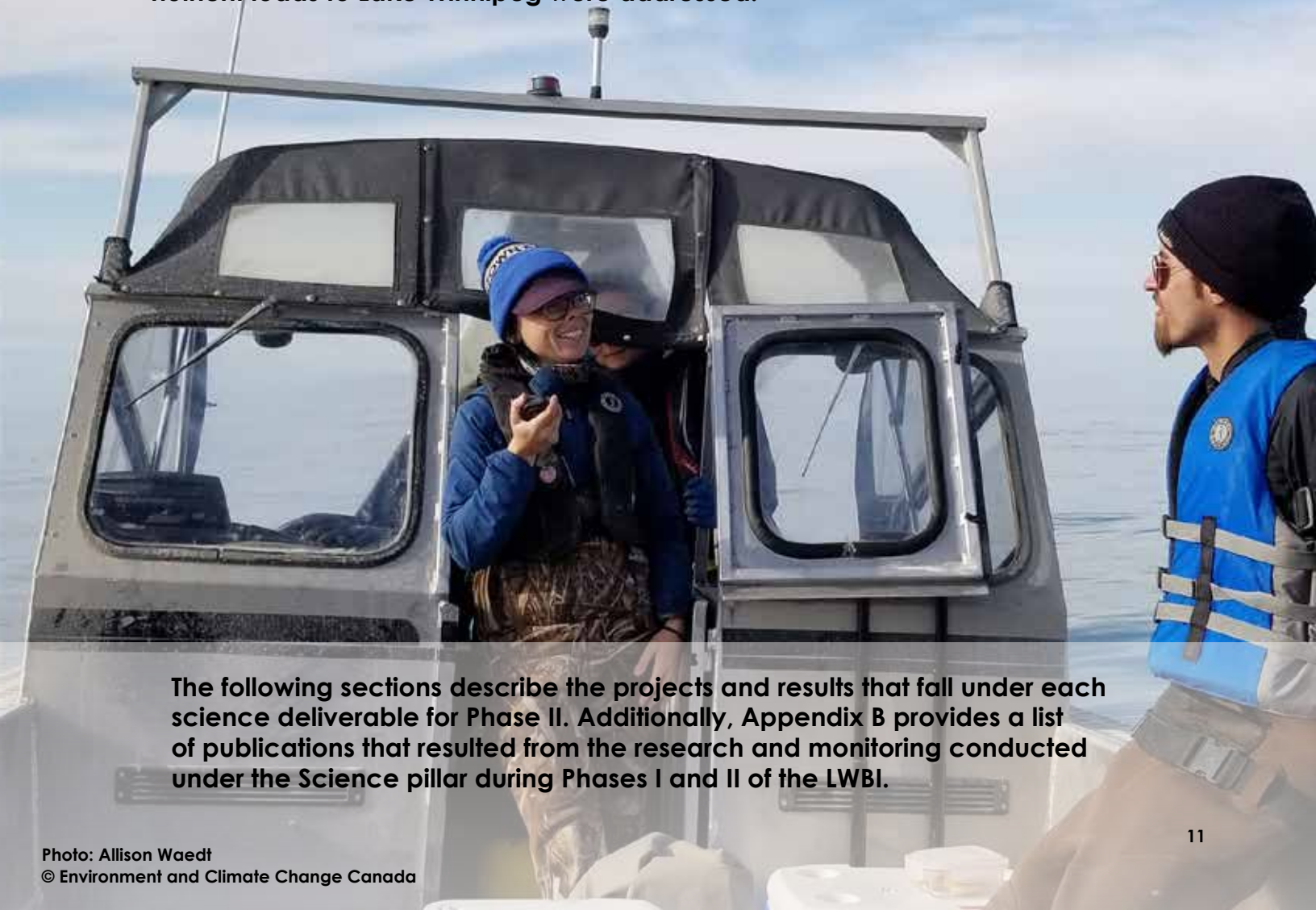
Predictive tools/models to support nutrient management in the Lake Winnipeg Basin were developed;

Science Deliverable #3

Water quality and biotic monitoring was undertaken to track spatial and temporal flux of nutrients transported from the watershed to the lake and to support the development of modelling scenarios; and

Science Deliverable #4

Critical knowledge gaps in lake nutrient dynamics relative to changes in nutrient loads to Lake Winnipeg were addressed.



The following sections describe the projects and results that fall under each science deliverable for Phase II. Additionally, Appendix B provides a list of publications that resulted from the research and monitoring conducted under the Science pillar during Phases I and II of the LWBI.

Photo: Allison Waedt

4.1 SCIENCE DELIVERABLE #1

Knowledge gaps related to the impacts of human activity, particularly land use, on the fate, effect and delivery of nutrients in Lake Winnipeg tributaries were addressed.

4.1.1 INVESTIGATING NUTRIENT SOURCES AND TRANSPORT IN RUNOFF FROM AGRICULTURAL FIELDS

Project Overview

In collaboration with Agriculture and Agri-Food Canada (AAFC) and the University of Manitoba, ECCC continued to build on Phase I research in assessing nutrient sources and transport in run-off from agricultural fields. Monitoring stations were established to collect detailed discharge and nutrient data for snowmelt and rainfall runoff events at four edge-of-field sites, including two sites where hog manure was applied, and at two stream sites in the LaSalle watershed. Data from these sites, along with 14 others in the headwater areas furthered ECCC's ability to develop appropriate management practices to minimize nutrient loss from agricultural lands in the Lake Winnipeg basin. Edge-of-field and stream sites have been monitored for four and eight years respectively, with data being used to identify hydrological drivers and trends in discharge and nutrient transport.

Effects of Hydrological Factors

This research confirms that weather is the dominant factor controlling nutrient transport. Fall soil moisture and snowfall are important drivers of snowmelt runoff, which is the most significant source of water and nutrients to watersheds in southern Manitoba. On average, 75% of discharge from agricultural fields occurs during snowmelt, with 70% of phosphorus (P) and nitrogen (N) being transported. There are indications that events such as mid-winter melts, ice lens formation, and rain on snow are becoming more frequent due to climate variability and as a result, also influence discharge. Runoff producing summer storms have also increased in frequency in southern Manitoba since 2010, when compared to data from the previous 15 years. However despite these changes, snowmelt events still transport the majority of nutrients to surface water.

Effects of Land Management Practices

When hydrological factors were controlled, impacts of management practices on nutrient transport were observed. In field experiments, the conversion of annual cropland to forage plant material for grazing livestock resulted in increased transport of dissolved P during snowmelt. In addition, conservation tillage, a method of soil cultivation that leaves the previous year's crop residue on fields before and after planting the next crop, showed an increased transport of dissolved P during snowmelt. Findings from laboratory experiments studying forages and tillage practices supported the findings in field experiments. Shallow surface soils in conservation tillage fields were nutrient rich and were found to have the potential to contribute more nutrients to runoff during snowmelt than soils in tilled fields. A wide range of forage stands of different compositions, ages and fertilizer regimes were tested in simulated snowmelt conditions in the laboratory. All of the forage stands tested contributed significantly more P in simulated snowmelt runoff than the cereal stubble, even when soil was introduced to buffer nutrient release.

Results

The dominance of snowmelt as a driver for nutrient transport in the Lake Winnipeg Basin has important implications for agricultural land management practices. Beneficial Management Practices (BMPs) that reduce nutrient transport by reducing erosion or trapping sediment will be less successful under prairie conditions. Practices that reduce or delay runoff (hydrologic controls) are likely to be more successful. Although conservation tillage and conversion of annual cropland to forage have not been found to be ideal with respect to P transport, these disadvantages need to be weighed relative to erosion prevention in vulnerable areas, habitat retention and other aspects of environmental stewardship where the practices are beneficial. Reduction in nutrient transport from agricultural land will not come from a single change in practice but from implementation of a suite of practices that address both nutrient sources and transport.

Beneficial Management Practice

"A Beneficial Management Practice (BMP) is defined as any management practice that reduces or eliminates an environmental risk."

Publications

For more information on this project, refer to Appendix B, publication numbers: 12, 21, 35, 36, 37 & 38.

Future Research

Continued monitoring will produce high quality long-term water quality and quantity data that is not currently available for the Red River flood plain sites. This data is valuable to ECCC modeling efforts and will contribute to an AAFC initiative to develop a farm-scale predictive water quality tool that can be used to demonstrate outcomes of different management options on farms throughout the prairie region. The extension of data collection will also be valuable in the development of modules to study the influence of mid-winter melts, ice lens formation and rain-on-snow on water quality and quantity in snowmelt runoff models. The modules will aid in the impact assessment of changing climate on water resources on the prairies.

Extending data collection will also allow completion of the assessment of the influence of livestock currently underway. Data collection at sites receiving hog manure is underway, but more time is required to obtain conclusive results. Assessment of in-field beef cattle overwintering has recently been completed but the impacts of other aspects of beef production require investigation.

Laboratory experiments have confirmed that a wide range of forage types can act as nutrient sources during snowmelt but further research is required to determine whether the hydrologic regime under long-term forage stands can mitigate some of those impacts. The effect of back-flooding of floodplain soils on water quality has also been identified as a data gap requiring investigation at a field scale.

Photo: Dana Hay

4.1.2 QUANTIFYING THE FATE AND EFFECTS OF NUTRIENTS FROM AGRICULTURALLY DOMINANT WATERSHEDS THROUGH TRIBUTARIES OF THE RED AND ASSINIBOINE RIVERS

Land use activity is a major contributor of total phosphorus (TP) and total nitrogen (TN) to small watersheds in the Canadian prairies, and these nutrients affect the ecological condition of prairie streams. To study these impacts further, this project consisted of two components:

- To quantify seasonal patterns in nutrient concentrations in relation to human activity for streams in the Red River Valley; and
- To identify a suite of biological indicators suitable for monitoring the impacts of human activities on the ecological condition of stream ecosystems within the Red River Valley.

4.1.2.1 QUANTIFICATION OF SEASONAL PATTERNS IN NUTRIENT CONCENTRATIONS IN RELATION TO HUMAN ACTIVITY FOR STREAMS IN THE RED RIVER VALLEY

Project Overview

Intensive field sampling was completed during 2010, 2013 and 2014. Results showed that the highest concentrations of TP and TN in the Red River Valley streams occur during snowmelt. The only exceptions were streams which received wastewater discharge from municipal wastewater lagoons during summer.

Effects of Hydrological Factors

The streamflow in small watersheds in the Red River Valley are sensitive to climate variability. A change in precipitation delivery (i.e. from snow to rain) may affect nutrient loss from agricultural landscapes, as observed when comparing P and N concentrations in 2013 and 2014. In 2013, amounts of dissolved N and P in snowmelt were 28-47% greater than in 2014. This result suggests that the historical hydrological regime (typified by 2013) is associated with a greater loss of particulate nutrients than would be observed under future climate scenarios (typified by 2014).

Effects of Land Management Practices

Statistical analysis of the data collected indicated that land use activities such as fertilizer application, livestock density and municipal wastewater discharges were critical factors that influenced TP and TN concentrations. In contrast, physical aspects such as water temperature and discharge were the primary determinants of TP and TN loads.

Publications

For more information on this project, refer to Appendix B, publication numbers: 14, 15, 16, 26, 55, 72, 73, 74, 75 & 76.

Future Research

Further research is required to answer questions related to the effectiveness of BMPs in reducing N and P loading at the watershed scale:

- Percent of watershed area where BMPs have been implemented, types of BMPs, distance from stream channel, length of time since implementation;
- How will a changing climate affect tributary nutrient loads and concentrations, and the effectiveness of BMPs;
- What is the contribution of nutrients from municipal wastewater treatment plants and lagoons to tributary nutrient loads, and;
- What proportion of municipal wastewater nutrient loads is transported to Lake Winnipeg?

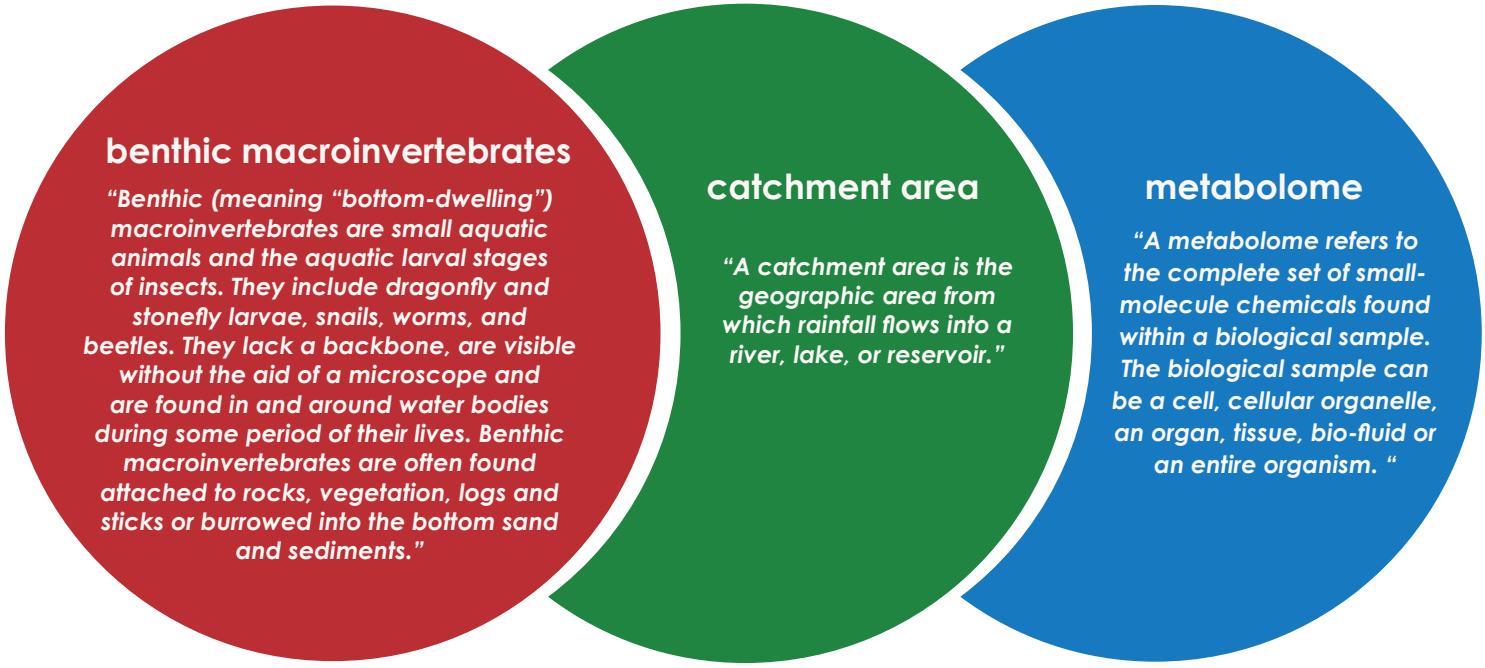
4.1.2.2 IDENTIFICATION OF A SUITE OF BIOLOGICAL INDICATORS SUITABLE FOR MONITORING THE IMPACTS OF HUMAN ACTIVITIES ON THE ECOLOGICAL CONDITION OF STREAM ECOSYSTEMS WITHIN THE RED RIVER VALLEY

Project Overview

In collaboration with partners from the Tobacco Creek Model Watershed Project, biological and biochemical indicators were developed to assess the ecological health of watersheds in Southern Manitoba in relation to nutrient-producing human activities (e.g. agricultural activities, municipal wastewater discharge). The benthic macroinvertebrates Ephemeroptera, Plecoptera & Trichoptera (commonly known as mayflies, stoneflies and caddisflies) were used. Crayfish metabolome were also studied to determine the interaction between the crayfish genome and its environment.

Effects of Land Management Practices

Research showed that the selected indicators were sensitive to the types of disturbance or stress occurring in the Lake Winnipeg basin in southern Manitoba. Landscape scale agricultural activities (e.g. types of land cover) and the intensity of wastewater treatment were important drivers of the ecological condition in the watershed. Ecological health declined when agricultural activity increased, especially if more than 50% of the catchment area was used for agriculture. Ecological health was also negatively impacted by discharges from larger sized municipal wastewater lagoons.



Crayfish metabolome were used to distinguish between the multiple stressors of agriculture and the addition of municipal wastewater effluent through altered metabolic activity. Ecological indicators were more sensitive to specific human activities (municipal wastewater treatment, crop cultivation or livestock production) than to broad land-use categories (percentage of urban or agricultural activity).

Results

The results suggest that the ecological health of Lake Winnipeg Basin tributaries is influenced by the amount and intensity of agricultural and municipal wastewater treatment activities. As nutrient producing activities are intensified, ecological conditions deteriorate, suggesting that those activities cumulatively impact the ecological conditions in streams within the Red River Valley.

Publications

For more information on this project, refer to Appendix B, publication numbers: 1, 11, 14, 26, 42, 72, 73, 74 & 76.

Future Research

Further research is required to assess the ecological effects of BMPs implemented in tributary catchments of the Lake Winnipeg Basin; the capacity of ecological processes to assimilate nutrients in tributaries of the Red River, and the intra- and inter-annual variability in ecological indicators associated with annual hydrologic and nutrient variability.

4.1.3 ASSESSMENT OF THE ROLE OF HUMAN ACTIVITY ON THE HYDROLOGY OF KEY AREAS IN THE LAKE WINNIPEG WATERSHED

Project Overview

This project built on hydrologic studies from Phase I of the Lake Winnipeg Basin Initiatiave, and included an assessment of the impact of land use changes, wetland drainage and climate variability on flooding and nutrient export to Lake Winnipeg. Streamflow generation in the Lake Winnipeg Basin is highly influenced by the capacity of the landscape to store water in natural low areas and wetlands. In order to represent those processes in hydrological models, research was performed at the St. Denis National Wildlife Area near Saskatoon, SK in partnership with the University of Saskatchewan. The work included water budget studies to better understand the importance of groundwater on maintaining streamflow and hydrological process studies to improve the understanding of the relationship between contributing areas and streamflow. Those studies are being used to improve hydrological models that will be used to assess the relative roles of climate and land management on streamflow and nutrient loads to Lake Winnipeg.

Results

Water budget studies demonstrated that groundwater flux can be important for maintaining water levels in ponds with storage capacities that are important in controlling the transmission of water downstream towards Lake Winnipeg. A new ECCC land surface model scheme was developed and tested successfully. The model scheme can account for the effect of storage capacity distribution on streamflow, resulting in better streamflow simulations. It can also properly simulate the fraction of the watershed contributing surface water downstream. When tested on a Lake Winnipeg tributary, this model scheme proved capable of estimating the frequency distribution of areas contributing to streamflow.

Publications

For more information on this project, refer to Appendix B, publication numbers: 10, 43, 44 & 60.

Future Research

Further testing and development of the model is required to ensure it can be more widely applied. Further research is required to determine how the drainage of wetlands and wetland restoration should best be managed in order to maximize benefits for nutrient reduction to Lake Winnipeg.

Photo: Ute Holweger

4.2 SCIENCE DELIVERABLE #2

Predictive tools/models to support nutrient management in the Lake Winnipeg Basin were developed.

4.2.1 MODELLING EFFECTS OF LAND USE CHANGES, WETLAND DRAINAGE AND CLIMATE VARIABILITY ON FLOODING AND NUTRIENT EXPORT TO LAKE WINNIPEG

Project Overview

This project used an integrated modelling framework to evaluate a range of nutrient management scenarios, and to assist in making informed decisions on nutrient management options to improve the ecosystem health of the Lake Winnipeg watershed. This modelling framework was used to link watershed and lake models. The two modelling systems used were:

1) Lake Winnipeg Water Quality Analysis Simulation Program (LW-WASP)
LW-WASP was used to simulate nutrient concentrations (N and P) and phytoplankton dynamics (non-cyanobacteria, N-fixing cyanobacteria, non N-fixing cyanobacteria) using nutrient loadings for the South and North basins of Lake Winnipeg.

2) Canadian Soil and Water Assessment Tool (CanSWAT)
CanSWAT was used for watershed modelling, including the simulation of water quality (P, N and sediment) and quantity (flow) in the watershed and predictioning the impact of land use and land management practices.

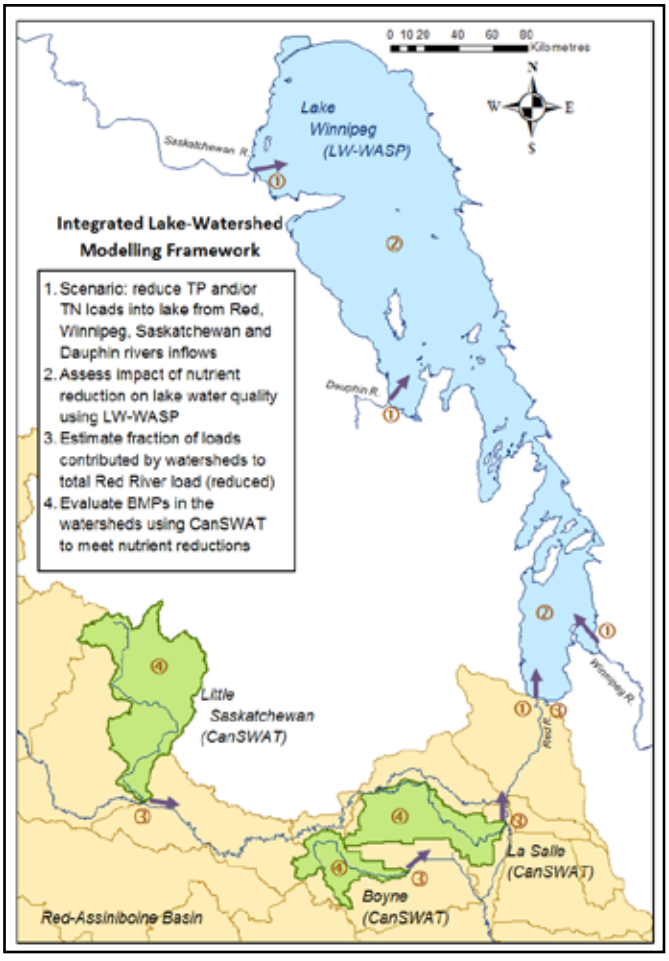


Figure 1: Schematic of Integrated lake-watershed modelling framework
Map: Isaac Wong, E. Agnes Richards-Blukacz, and Phil Fong, Mar 2017. LWBI-2 Integrated Lake-Watershed Modelling Final Report. Environment and Climate Change Canada

The La Salle, Boyne and Little Saskatchewan watersheds were used to run these scenarios.

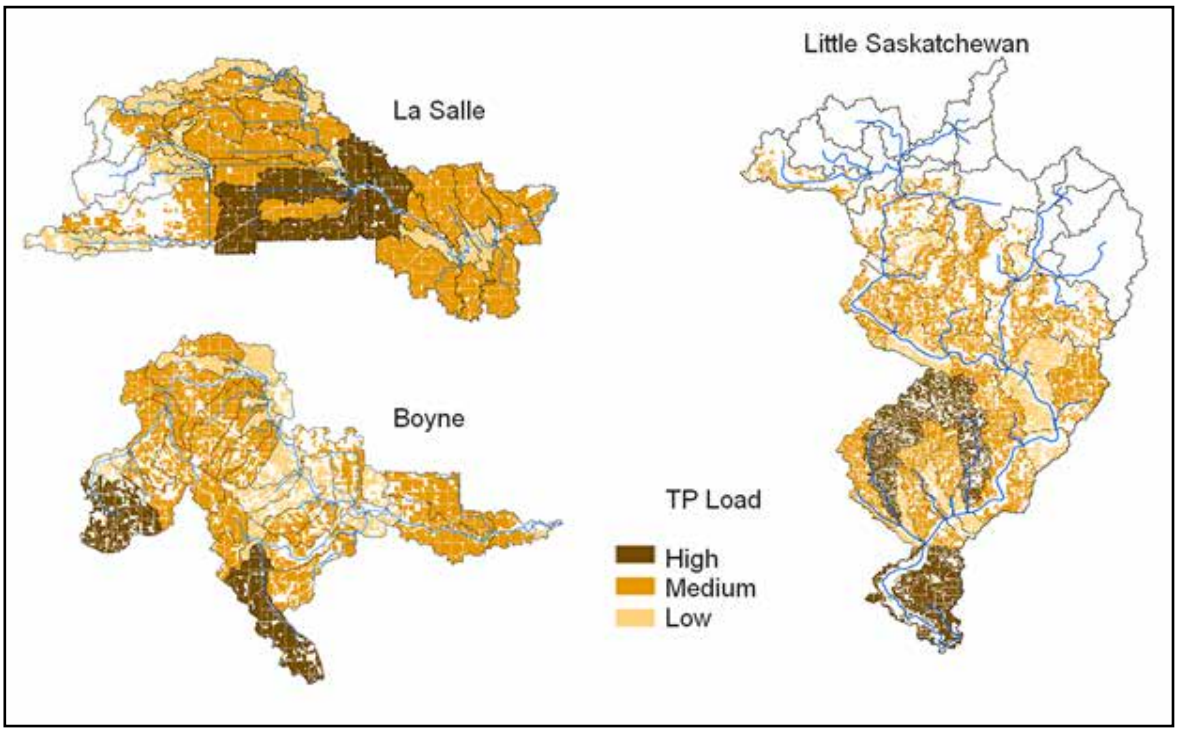


Figure 2: Maps identifying sources of TP loads (SWAT source tracing) in the La Salle, Boyne and Little Saskatchewan watersheds. Darker colours represent sub-basins with higher TP loads. White areas are non-agricultural lands.
Map: Isaac Wong, E. Agnes Richards-Blukacz, and Phil Fong, Mar 2017. LWBI-2 Integrated Lake-Watershed Modelling Final Report. Environment and Climate Change Canada

Calibrating LW-WASP and CanSWAT Models

Both LW-WASP and CanSWAT models were updated and calibrated with current data available from several sources, including ECCC and the Province of Manitoba to simulate the time period from 2002 to 2013. Manitoba Sustainable Development is using this model for establishing nutrient management options in Lake Winnipeg.

Environmental data (temperature, currents, waves, meteorological parameters) were collected to fill knowledge gaps in the understanding of the physical, chemical and biological aspects of the lake. This information was incorporated into ECCC's Lake Winnipeg modelling research to improve the knowledge on the effect of water movements and temperature on water quality in the lake.

ECCC continued to work with Manitoba Sustainable Development to acquire updated and improved chemical and biological data to update the lake's tributary loading inputs, water balance and temperature simulations for Lake Model calibration. The LW-WASP model combined available external/internal information, including physical features (e.g. water movements and water temperature), to simulate lake water quality.

Modelling of Nutrient Reduction Scenarios using LW-WASP

Several scenarios were developed using LW-WASP to assess the impacts of various nutrient load reductions on water quality in Lake Winnipeg and the La Salle, Boyne and Little Saskatchewan watersheds. Scenarios were based on proposed nutrient objectives to produce desirable algal communities in the aquatic ecosystem or to lessen the formation of harmful algal blooms.

Model results of TP, TN and total chlorophyll-a (Chl a) concentrations in the lake were reviewed and compared with baseline outputs (representing current conditions) to test and verify the prediction of impacts of nutrient reductions in tributary loads on lake water quality. The updated LW-WASP model can be used by others to evaluate a variety of reduction scenarios to assist in developing nutrient management options and setting lake water quality objectives.

LW-WASP Results

Generally, TP and TN concentrations in the lake decreased proportionally to tributary load reductions of TP and TN respectively. Declines in lake Chl a concentrations required reductions in TN loads, and when both TP and TN loads were reduced, decreases in concentrations were greater. In general, percentage decreases in TP, TN and Chl a concentrations were higher in the South Basin of Lake Winnipeg than the North Basin. LW-WASP showed that large reductions in TP and TN tributary loads were necessary to achieve the most stringent nutrient reduction scenario objectives for ensuring desirable algal communities. However, the LW-WASP model has a simple spatial setup and has limitations in addressing the spatial variability within the lake basins. The acquired environmental data is ready and available for use in future more complex lake models.

Modelling Scenarios based on Land Management Practices using CanSWAT

ECCC worked collaboratively with Agriculture and Agri-Foods Canada to improve, implement and evaluate beneficial management practices that were selected as the most suitable approaches for reducing nutrient loading within the Lake Winnipeg Basin. Nutrient reduction scenarios for beneficial management practices (BMPs) were developed using CanSWAT.

The selected BMPs included wetland restoration, cropland to forage conversion, nutrient management and vegetative filter strips which were chosen based on their suitability for northern prairie watersheds and the feasibility of modelling in CanSWAT. The source tracing method was used to identify areas of high nutrient loads (“hotspots”) to target BMPs.

CanSWAT Results

Individual BMPs produced small to modest reductions in TP and TN loads at watershed outlets. When two or more BMPs were combined, the reductions were higher. Reductions in TP and TN loads were doubled or more when all BMPs were applied compared to a single BMP. Also, reductions from combined BMPs were slightly less than the sum of reductions from individual BMPs, which may be due to complex interactions of nutrient processes among the combined BMPs. Furthermore, reduction efficacies of BMPs varied among the study watersheds and may be attributed to variable land uses across the watersheds. The BMPs were most effective in reducing nutrients in the Boyne Watershed, followed by La Salle and then Little Saskatchewan. However, all the combined BMPs that were evaluated were unable to meet the pre-determined nutrient reduction targets in any of the watersheds.

Publications

For more information on this project, refer to Appendix B, publication numbers: 9, 69, 70, 71, 77, 78 & 79.

LW-WASP Future Research

The LW-WASP model will need to be revised in the future to increase the spatial resolution. Ongoing monitoring of the physical parameters of the lake would assist in gaining insight and further improving the water balance and hydrodynamics in the lake model. An analysis approach should be developed and applied in the integrated lake and watershed models to account for different sources of variability, to produce uncertainty measures at the outflows and to quantify nutrient dynamics under a range of conditions and scenarios.

CanSWAT Future Research

The development of a single watershed model covering the whole Red-Assiniboine Basin (Red-Assiniboine CanSWAT) is planned to provide a more comprehensive assessment of the impact of nutrient reduction scenarios for the entire watershed and allow for the evaluation of BMPs on a basin-scale. This watershed model will also be capable of accounting for annual and seasonal variability in nutrient loads due to variations in climate and hydrology over time. A source tracing method will be used to target BMPs to "hotspot" areas in future studies. A high resolution three dimensional numerical model will be updated for Lake Winnipeg to study the lake-wide hydrodynamics and water quality. Without accurate models that are able to incorporate new dynamics (invasive mussels), predicting the water quality conditions across the lake will not be possible.

4.3 SCIENCE DELIVERABLE #3

Water quality and biotic monitoring was undertaken to track spatial and temporal flux of nutrients and algae transported from the watershed to Lake Winnipeg and to support development of modelling scenarios.

4.3.1 LONG-TERM WATER QUAILTY MONITORING

Monitoring Overview

Measuring nutrient concentrations is part of the ongoing ECCC monitoring activities implemented on rivers crossing boundaries between Canada and the United States, such as the Red, Pembina and Souris Rivers. Interprovincial rivers such as the Assiniboine, Qu'Appelle and Saskatchewan Rivers (SK–MB), Winnipeg River (MB–ON), and the North and South Saskatchewan Rivers (AB-SK) are also monitored. These activities were enhanced in the Red River and the Rainy River–Lake of the Woods basins in order to support the development of nutrient-based objectives between jurisdictions and nutrient-control performance measurements. Local-scale research in sub-watersheds closer to Lake Winnipeg complemented the nutrient-monitoring activities that ECCC and the Province of Manitoba conducted.

Observations

General observations indicated an increase of total phosphorus loading in the Red and Winnipeg Rivers, while total nitrogen loading remained stable or slightly declined. For the Rainy River, analysis of a time-limited dataset suggested that nitrate/nitrite concentrations increased while phosphorus concentration decreased.

Publications

For more information on this project, refer to Appendix B, publication numbers: 4, 8, 22, 23, 51, 58, 59 & 68.

Future Monitoring

The monitoring of nutrients will continue to track changes in response to climatic conditions and management actions. Approaches to monitoring will be evaluated and refined as needed to provide better information related to the timing of climatic events and the delivery of nutrients to Lake Winnipeg. Statistical analyses will be conducted to confirm trends in nutrient concentrations and loadings. Further monitoring in the Rainy River is required to confirm the trends of the calculated time limited data set.

4.3.2 ANALYSIS OF WATER QUALITY MONITORING FREQUENCY

Project Overview

ECCC analyzed the impact of changes in frequency of water-quality sampling within the Lake Winnipeg Basin on the ability to detect long-term trends for things such as nutrients, major ions and metals. This analysis was a part of a nationwide, risk-based assessment of ECCC's long-term water quality monitoring network.

Statistical analysis was done to determine if the frequency of monitoring was sufficient and able to detect a 10% change with 80% statistical power. The analysis was parameter and site specific and was strongly affected by the range in concentration variability for a parameter at a given site. As a general rule, a higher frequency of sampling is needed when greater concentration variability is present in order to detect change with certainty.

Results

The overall analysis suggested that at a minimum, monthly sampling is necessary for most parameters. For nutrients measured in rivers with high-suspended sediment loads, the analysis indicated an increase in sampling is needed to meet stated change detection and certainty requirements.

Publications

For more information on this project, refer to Appendix B, publication numbers: 3 & 78.

Future Monitoring

For both the Red and Rainy rivers, current monitoring plans include enhanced sampling during seasonal freshet events, as science has identified those events as major contributors to nutrient loading. Work is continuing to improve both the timing and type of monitoring implemented.

Freshet

"The term freshet is most commonly used to describe a spring thaw resulting from snow and ice melt in rivers located in the northern latitudes of North America. A spring freshet can sometimes last several weeks on large river systems, resulting in significant inundation of flood plains as the snowpack melts in the river's catchment area. "

4.3.3 BENTHIC MACROINVERTEBRATE RESEARCH

Project Overview
A study of the benthic macroinvertebrates in Lake of the Woods provided the results necessary for the development of a reference model based on the national Canadian Aquatic Biomonitoring Network (CABIN) protocol. The reference model helped scientists better understand what a healthy benthic macroinvertebrate community should look like within the lake and its watershed.

Results
Benthic macroinvertebrate samples were analyzed and incorporated into an initial reference model developed for Lake of the Woods. The additional samples were used to expand the model to address community types which were underrepresented during the development of the initial model.

Publications
For more information on this project, refer to Appendix B, publication numbers: 42, 51, 52 & 68.

Future Monitoring
Reference sites established during the study will be revisited on a rotational basis to determine whether lake-wide changes are occurring in the benthic macroinvertebrate community. Sites of suspected impairment will also be sampled in order to compare them to an established reference condition, to determine the level and type of impairment.

4.3.4 ALGAL BLOOM MONITORING BY SATELLITE REMOTE SENSING

Project Overview
Satellite remote sensing was used as a cost-effective tool for lake-wide algal bloom monitoring on Lake Winnipeg. To validate the satellite data, environmental monitoring data from the lake was gathered at the same time. A comparison of information from satellite images and lake sampling was used to develop algal bloom index prediction algorithms. Satellite information and quantitative algal bloom indicators (bloom duration, extent, and severity) were gathered and analyzed for the period of 2002-2011. Bloom statistics were used to produce draft annual bloom reports.

Results
The results identified total phosphorus loads and summer lake temperature as strong predictors of inter-annual variability in bloom severity on the lake. Wind mixing is shown as a primary driver of day-to-day variability in bloom severity as seen from satellite imagery.

Publications
For more information on this project, refer to Appendix B, publication numbers: 4, 5, 6, 7, 8 & 9.

Future Monitoring
Moving forward, continuity is needed in remote sensing products. Transferring methods and data gathered previously to a new series of satellite sensors (OLCI on sentinel-3, sentinel-2, Landsat 8) will require updates. Additional data from new satellites is required in order to extend the time period of analysis to include the introduction of zebra mussels to the lake now occurring.

Water clarity remote sensing equipment has been tested on Lake Winnipeg in anticipation of detecting significant ecosystem shifts (i.e. phytoplankton composition) in response to the establishment of zebra mussels. Further satellite monitoring of algal blooms and water clarity is required in order to determine the long-term effects of invasive species and/or nutrient management practices on the ecosystem health of Lake Winnipeg.

Researchers will continue using remote sensing to estimate bloom composition. A cyanobacteria dominance index has been developed and is being applied to time series imagery on Lake Winnipeg to assess spatial and temporal trends in bloom composition. Methods are also being developed which will enable researchers to use total water column chlorophyll as an indicator of total algal biomass.

4.3.5 STABLE ISOTOPE FINGERPRINTING

Project Overview
Nutrients have a distinct "fingerprint" that helps identify where they originated. The technology and science exists to identify the "fingerprints" of the nutrients in Lake Winnipeg and then identify the path they travelled to reach the lake. The research on stable isotope fingerprinting, to determine the origins and distribution of nutrient loading to Lake Winnipeg, continued with intensive sampling in the Red and Assiniboine River basins.

Results
Nitrate concentrations and isotopic compositions in the Red and Assiniboine Rivers were comparable to those at river inputs to Lake Winnipeg. In general, nitrate inputs into the Assiniboine River were associated with animal manure or municipal wastewater sources. In particular, releases of municipal wastewater treatment lagoons in the late summer could be identified by nitrogen and oxygen stable isotopic compositions of nitrate even though concentrations of nitrates remained relatively stable. By contrast, the Red River nitrate inputs were associated to a larger degree with agricultural sources, especially during runoff in the spring.

Publications

For more information on this project, refer to Appendix B, publication numbers: 11, 25, 27, 40, 58, 59 & 66.

Future Research

The results have the potential to effect environmental policy or land management decisions because the sources of nutrients into the two rivers are different. This may guide different nutrient reduction policies depending on location within the Lake Winnipeg Basin. Continued sampling may increase our understanding of differences in nutrient sources caused by annual meteorological and river condition variability, as well as generate a more integrated picture of sources of nutrients entering Lake Winnipeg.

4.3.6 STATE OF THE LAKE INDICATORS

Project Overview

Under the Canada-Manitoba Memorandum of Understanding Respecting Lake Winnipeg and the Lake Winnipeg Basin (MOU), Canada and Manitoba developed a Science Subsidiary Arrangement that includes a commitment to improve reporting on the status of and trends in water quality and aquatic ecosystem health in the Lake Winnipeg Basin. To achieve this commitment, a set of comprehensive, understandable and scientifically defensible indicators will be developed to provide assessments of the health of Lake Winnipeg and its basin and to track progress and change over time. It is envisioned that a summary fact-sheet for each indicator will be developed to highlight the major status and trends of the indicator in the context of Lake Winnipeg and its basin.

Results

ECCC and Manitoba Sustainable Development completed the initial planning for the indicator project. That included hosting a comprehensive workshop involving approximately 30 research and monitoring experts from universities, research institutes, the Lake Winnipeg Research Consortium, and provincial and municipal governments. The workshop focused on confirming the potential physical-chemical and biological indicators that would be key in reporting on the health of the lake and its watershed. A State of the Lake Steering Committee was also established as a governance body to coordinate, support and guide indicator development, assessment and reporting. Focused working groups consisting of subject matter experts were assembled to develop an initial subset of high priority indicators where data were readily available. It is anticipated that the State of the Lake Report will be released in late 2018.

Photo: Dana Hay
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Future Research

Additional working groups will be established to initiate work on a broader set of indicators that cover environmental, social and economic factors that are of interest to the general public and stakeholders. Factsheets to explain the key State of the Lake indicators are currently in development. Indicator factsheets will be updated regularly and will provide a tool for reporting to the public and decision makers on the health of Lake Winnipeg and its basin.

Indigenous governments, communities, and organizations are important partners in ECCC's efforts in the Lake Winnipeg Basin. ECCC will work with Indigenous peoples to better incorporate Indigenous Traditional Knowledge in the broader understanding of Lake Winnipeg's ecosystem and in identifying approaches to improve the overall ecological health of the lake.

4.4 SCIENCE DELIVERABLE #4

Critical knowledge gaps in lake nutrient dynamics relative to changes in nutrient loads to Lake Winnipeg were addressed.

4.4.1 ALGAL BLOOM TOXICITY

Project Overview

As part of our research on Lake Winnipeg and its major tributaries, ECCC evaluated the composition and amount of nutrients flowing into the lake. Using stable isotopes, genetics and other biological tracers, major sources of nutrients were investigated including how they varied over the season and among years, their bio-availability to algal cells, and how they influenced the risk of harmful algal blooms. Part of the research was conducted aboard the research vessel M.V. Namao, allowing scientists to measure algal growth and toxicity, nutrient uptake, cell storage and nitrogen fixation.

Results

ECCC research demonstrated that the most abundant algae blooms were non-toxic nitrogen-fixing cyanobacteria of the genus Aphanizomenon. Those dense algae blooms are very tolerant of turbid water. The presence of more toxic species of the genus Microcystis were also detected, but in lower abundance. Low concentrations of liver toxins called microcystins were found to be present throughout the lake, with higher concentrations at beaches. Analysis of the genetic composition of algal species revealed that the genetic potential for microcystin production was present in all blooms on the lake, but more prevalent in summer. The genetic capacity for other cyanotoxin production was also present (i.e. neurotoxins).

Publications

For more information on this project, refer to Appendix B, publication numbers: 5, 6, 7, 8, 27, 30, 39, 55 & 59.

Future Research

Future research will target identifying and quantifying the presence of additional algae, toxins, and amino acids of interest. Researchers will also continue to investigate non-toxic algae and their effects on the food web, with particular focus on their inhibition of biochemical and ecological processes.

Further work will also target the effects of zebra mussels and other invasive species on Lake Winnipeg ecology. ECCC scientists will monitor whether the introduction of those species will cause a shift in the composition of the algal community due to the changing environment, with a particular focus on toxic algae species. For example, ECCC research may investigate how increased light penetration (due to zebra mussel filtration) affects the abundance of the more toxic algae such as Microcystis. ECCC's efforts will also focus on how the introduction of invasive species affects biochemical processes such as carbon fixation and respiration in the lake. Those changes will be monitored using an Autonomous Phytoplankton Metabolic Monitor.

4.4.2 NUTRIENT RECYCLING

Project Overview

A large proportion of the nutrients entering Lake Winnipeg each year are stored in the sediment on the bottom of the lake and then mixed back into the water during strong wind events. ECCC scientists investigated the importance of that process, called nutrient recycling, in the lake. The large amount of nutrients stored in the sediment in the lake bottom could mean that, even with a reduction in nutrients entering the lake, it may take a long period of time to see improvements in water quality. To better understand the process, scientists measured the amount and mechanisms by which nutrients are released from the lake bottom.

Results

This project demonstrated that strong wind events result in re-suspended sediment being deposited primarily in deeper water. The majority of sediment in suspension in Lake Winnipeg is re-suspended off the bottom of the lake, rather than in new sediment from outside sources; the internal loading of phosphorus by resuspension of sediment is substantial and adds about as much phosphorus to the water column as is delivered by tributaries flowing into the lake. ECCC researchers also demonstrated that in the South Basin, the upper 7 cm of sediment will be re-suspended repeatedly for 20 years or more. This may delay the response of the lake to nutrient reduction efforts in the watershed. In addition, 30% of total phosphorus (TP) in the re-suspended sediment is bioavailable, thus supporting rapid algal growth and reproduction.

Publications

For more information on this project, refer to Appendix B, publication numbers: 5, 6, 7, 8 , 39, 41 & 62.

Future Research

Future research will include work on estimating and modelling internal nutrient cycling and how various factors affect it, including: (i) how P loading changes in low oxygen environments, (ii) changes due to day and night temperature shifts (diurnal flux), and (iii) the influence of invasive zebra mussels. This research will be tied into previous studies and modelling of nutrient recycling and its role in supporting algae blooms.

5.0 STEWARDSHIP

5.1 OVERVIEW

The Lake Winnipeg Basin Initiative (LWBI) Stewardship pillar engaged stakeholders to take action to restore the ecological health of Lake Winnipeg and its basin. This was achieved through an application-based grants and contributions project called the Lake Winnipeg Basin Stewardship Fund (LWBSF), which provided financial support to implement high-impact, stakeholder driven projects aimed at reducing nutrient loadings and improving the ecological sustainability of the lake and its basin.

The LWBSF allocated $5.4 million in financial support of on-the-ground stewardship projects, education/outreach and directed scientific research activities, and leveraged an additional $10.6 million from project partners. With a strong focus on nutrient reduction related activities, the LWBSF addressed ECCC's mandate to "Conserve and protect Canada's water resources", ensuring that Canada's natural environment is conserved and restored for present and future generations. Nutrient reduction projects were supported throughout the Lake Winnipeg Basin in northwestern Ontario, Manitoba, Saskatchewan and Alberta.

There was high interest in the program with 138 project proposals requesting $22.7 million in funding being received. That resulted in the fund being oversubscribed by 420% and requests for funding $17.3 million above the $5.4 million available.

Photo: Dana Hay

5.2 FUNDING PRIORITIES

The projects that received financial support were required to address at least one of the following priorities:

- Reducing nutrient inputs from rural and urban sources;
- Controlling point and non-point sources of nutrients;
- Rehabilitating priority aquatic ecosystems that support nutrient reduction and sequestration; and
- Enhancing research and monitoring capacity to assist in decision making.

Furthermore, the LWBSF supported projects that addressed the following key considerations:

- Reducing nutrient loads to the lake in a cost-effective, demonstrable manner;
- Focusing on sub-watersheds and/or geographic locations that are significant sources of nutrient loading to Lake Winnipeg;
- Providing for on-going benefits to the lake and watershed;
- Having a high probability of success; and
- Leveraging a high level of support from credible third parties.

5.3 ELIGIBILITY REQUIREMENTS

Eligible recipients included non-profit organizations; Indigenous governments and organizations, associations and governments; research, academic and educational institutions; individuals; for-profit organizations; local organizations; and provincial, territorial, municipal and local governments and their agencies. All projects funded had to be located in the Canadian portion of the Lake Winnipeg Basin.

5.4 APPLICATION PROCESS

The LWBSF utilized a two stage application process. The first stage consisted of a Call for Letters of Intent to solicit proposals and determine eligibility for program funding. If a Letter of Intent was deemed eligible, applicants were invited to submit a detailed proposal in stage two. All proposals were reviewed by a Technical Advisory Committee, comprised of technical experts from ECCC and relevant federal and provincial departments, to ensure each project was technically sound. The Public Advisory Committee (PAC), appointed by the Minister of the Environment, met to review and discuss each project proposal and technical review summary, in order to develop funding recommendations for the Minister's approval, based on the funding allotments each year.

PROPOSALS WERE REVIEWED AND ASSESSED IN RELATION TO THE FOLLOW CRITERIA:

- Amount of leveraged funding;
- Extent of project collaboration;
- Project location is within a priority watershed known to be a significant source of nutrient loading to Lake Winnipeg;
- Project addresses funding priorities;
- Measurable environmental benefits derived from the project (e.g. expected phosphorus reduction);
- Technical feasibility;
- Potential for co-benefits of project implementation;
- Clarity and scope of objectives;
- Beneficial management practices that reduce urban and/or rural non-point sources of nutrients;
- New and innovative technologies, cost-saving control technologies and rehabilitation methods;
- Value for money;
- Opportunities for technology and/or knowledge transfer to other parts of the Lake Winnipeg Basin and other watersheds; and
- Quality and completeness of funding proposal.

5.5 FUNDED PROJECTS

The LWBSF solicited applications for funding through three calls for proposals starting in 2013. Through these proposal calls, funds were allocated to a total of 46 application-based projects over the course of the program in addition to 2 directed projects. There was no proposal call in 2016 as all funds were fully allocated for ongoing projects. Please see Appendix A for a complete list of projects funded under Phase II of the LWBSF.

5.5.1 DIRECTED FUNDING

Lake Winnipeg Scientific Research Activities

The Lake Winnipeg Research Consortium (LWRC) received $917,500 in funding to facilitate and coordinate monitoring and scientific research activities on Lake Winnipeg. This support ensured the continued operation of the M.V. Namao, which is critical for scientific research, monitoring and education related to Lake Winnipeg.

On June 23, 2016, the Governor General of Canada presented the founders of the LWRC, Allan Kristofferson, Alexander Salki and Michael Stainton with a Meritorious Service Medal in recognition of their dedication to restoring Lake Winnipeg to its former health.

Lake Winnipeg Basin Information Network

The University of Manitoba received $180,000 in funding to operate and expand the awareness and use of the Lake Winnipeg Basin Information Network (LWBIN). The LWBIN is a web-based information portal that provides access to relevant scientific data, models, information and tools, and supports long-term information sharing, collaboration and support for water management and decision making in the basin.

5.5.2 APPLICATION-BASED FUNDING

The LWBSF supported 46 application-based projects. Below are selected highlights and achievements from these projects.

Lake Friendly Practices and Actions

The South Basin Mayors and Reeves project to build public awareness and create long term changes in behaviour by showcasing practices and actions that reduce nutrients from entering Lake Winnipeg received the 2015 Manitoba Excellence in Sustainability Award from the Province of Manitoba for "Sustainability in Pollution Prevention and Product Stewardship."

Bioeconomy Projects

The International Institute for Sustainable Development (IISD) received funding for two research projects which supported harvesting cattails as an innovative watershed management strategy to reduce nutrient loading in both rural and urban settings. An additional benefit included the use of harvested plant material for producing solid fuel pellets that can be used as a direct replacement for coal and other fossil fuels.

Pelly's Lake Watershed Management Area

The LaSalle Redboine Conservation District carried out a water retention project designed to slow water during spring runoff and allow nutrients and sediment to settle, decrease erosion in downstream channels, recharge groundwater supplies and act as a late season recharge for downstream reservoirs. The project incorporated the harvesting of cattails to remove nutrients from the watershed and produce pellets for heating systems.

Establishment of Pilot Sites for Innovative Surface Water and Nutrient Management Initiatives on Farms

The Manitoba Conservation Districts Association (MCDA) received funding to research and assess the effectiveness of on-farm innovative surface water and nutrient management initiatives including small dams, irrigation ponds and tile drainage in prairie landscapes.

Niverville Lagoon System: The Investigation of Alternative Approaches for Bio-Remediation

The Town of Niverville received funding for the on-site bioremediation of a decommissioned municipal sewage lagoon in Niverville, Manitoba. This innovative project examined the feasibility of remediating bio-solids in wastewater lagoons, rather than following the practice of spreading bio-solids on fields and risking nutrient loading to watercourses. Through technology transfer, the project has presented alternative options for other municipalities that need to decommission sewage lagoons. The project received the 2014 Manitoba Excellence in Sustainability Award from the Province of Manitoba for "Innovation and Research for Sustainability".

5.6 OTHER ACHIEVEMENTS

5.6.1 LAKE WINNIPEG BASIN STEWARDSHIP FUND SYMPOSIUMS

LWBSF Stakeholder Symposiums were held in 2015 and 2016 to acknowledge the important work, collaboration and contributions made by funding recipients in support of on-the-ground nutrient reduction activities, as well as outreach and research projects that were implemented to improve the health of Lake Winnipeg and its basin. Project presentations from funding recipients highlighted project accomplishments and showcased project information. The symposiums provided an opportunity for stakeholders to share information, successes, lessons learned and network to discuss ideas for future nutrient reduction projects and possible collaboration opportunities.

5.6.2 LITERATURE REVIEW

A Literature Review of "Nutrient Management-Related Best Management Practices Used in the Lake Winnipeg Basin" was prepared in September 2015 as a resource for quantifying reductions in phosphorus and nitrogen that contribute to nutrient pollution in Lake Winnipeg. It is available to access via the Lake Winnipeg Basin Information Network database on the University of Manitoba website.

5.7 MEASUREABLE RESULTS

At the conclusion of Phase II, projects supported by the Lake Winnipeg Basin Stewardship Fund are reducing the annual phosphorus loading to Lake Winnipeg by 29,315 kg/year. This is in exceedance of the goal of 10,800 kg/year for Phase II of the LWBSF. These reductions were achieved through BMPs implemented by physical stewardship projects listed in Appendix A, which include wetland and habitat restoration, water retention projects, alternative livestock watering systems and fencing, and the bioremediation of a municipal sewage lagoon, which yielded a one-time reduction of 21,345 kg of phosphorus. Some of the key BMPs implemented:

- 1,352 hectares of wetlands/aquatic habitat were protected or conserved, and 670 hectares was created or rehabilitated to reduce nutrient loading;
- 11,135 metres of stream/lake bank were protected or stabilized;
- 102,340 native plants, trees and shrubs were planted;
- 50 erosion control structures were installed;
- Surface water run-off from 9,437 hectares was retained;
- 9 alternate watering systems for livestock were installed;
- 15,661 metres of fencing was installed, restricting 3,600 livestock from waterways.

Photo: Dana Hay

6.0 TRANSBOUNDARY PARTNERSHIPS

6.1 Overview

The Lake Winnipeg Basin is a vast watershed that covers parts of two countries (Canada and the United States), four provinces (Alberta, Saskatchewan, Manitoba, Ontario) and four states (North Dakota, South Dakota, Minnesota, Montana). As more than 50% of the nutrient loading to Lake Winnipeg originates outside of the borders of Manitoba, the nutrient pollution problem and solution are both inter-provincial and international in scope and involve multiple jurisdictions. The Province of Manitoba has the primary responsibility for decisions related to the management of water quality in Lake Winnipeg as the lake is situated wholly in that province; however, the water quality in the lake is affected by actions in the broader basin. There is a pressing need for basin-wide collaboration to improve the ecosystem health of the lake and its basin, which presents a significant opportunity for the Government of Canada to use its capacity to foster inter-provincial and bi-national coordination of actions to restore and protect water resources in this important watershed.

The Lake Winnipeg Basin Initiative's Transboundary Partnerships pillar emphasized collaborative work with other governments (provincial, state, federal) and organizations within the Lake Winnipeg basin to reduce nutrient loading to watercourses in the basin. The three areas of focus were:

- Encouraging increased action by upstream jurisdictions to manage nutrient inputs in the basin;
- Promoting the coordination of nutrient management efforts in the watershed; and
- Ensuring policy, science and program development were informed with information relevant to Lake Winnipeg ecosystem health.

6.2 DOMESTIC AND INTERNATIONAL WATER MANAGEMENT BOARDS

Domestic and international water management boards such as the Prairie Provinces Water Board (PPWB) and the International Joint Commission (IJC) play a key role in how nutrients are managed in the Lake Winnipeg Basin.

6.2.1 PRAIRIE PROVINCES WATER BOARD

In 2015, the Prairie Provinces Water Board (PPWB) completed the first comprehensive review and update of its water quality objectives since 1992. As a result, there are now 71 interprovincial water quality objectives for water quality parameters,

including nutrients, for six transboundary rivers that cross the Alberta-Saskatchewan border and for six rivers that cross the Saskatchewan-Manitoba border. The PPWB is also in the process of developing an Agreement on Transboundary Aquifers that will support cooperative management of the groundwater that underlies provincial boundaries.

6.2.2 INTERNATIONAL JOINT COMMISSION

The International Red River Board of the IJC has continued to implement the Red River Nutrient Management Strategy (2011) and has made positive progress towards developing a recommendation for nutrient objectives for the Red River at Emerson, Manitoba.

ECCC was also actively engaged in the IJC's Red River Basin Water Quality Committee of the International Red River Board, which was tasked with implementing a Basin-wide Nutrient Management Strategy for the International Red River Watershed. A consultant was engaged to develop a stressor-response model that identified nutrient targets in the Red River protective of water quality in the Red River itself, as well as in Lake Winnipeg. That committee is currently focusing on developing nutrient load allocations and water quality targets for nutrients for tributaries of the Red River.

6.3 CANADA-MANITOBA MEMORANDUM OF UNDERSTANDING RESPECTING LAKE WINNIPEG AND THE LAKE WINNIPEG BASIN (CA-MB MOU)

6.3.1 IMPLEMENTATION OF THE CA-MB MOU

Overview

ECCC and Manitoba Sustainable Development supported the implementation of the CA-MB MOU along with other key federal and provincial departments, including Agriculture and Agri-Food Canada, Indigenous and Northern Affairs Canada, Department of Fisheries and Oceans Canada, Manitoba Sustainable Development, Manitoba Agriculture and Manitoba Indigenous and Northern Relations. The CA-MB MOU, signed in 2010, formalizes the commitment of both governments to a long-term, collaborative and coordinated approach to support the sustainability and health of the lake and its basin. A Science Subsidiary Agreement was implemented under the CA-MB MOU to better align federal-provincial science and research planning. A review to assess its effectiveness was conducted in 2015. The Province of Manitoba and the Government of Canada agreed to renew the commitment for another five years to September 13, 2020.

Meetings and Presentations

During Phase II of the LWBI, the CA-MB MOU Steering Committee met nine times to share information amongst federal and provincial departments on programs and issues affecting the health of Lake Winnipeg. Presentations made by CA-MB MOU Steering Committee members and invited guests included:

- Zebra mussel updates on Manitoba's eradication and prevention efforts;
- The Lake Friendly Accord and Stewards Alliance;
- The University of Manitoba's Watershed Systems Research Program;
- New wastewater treatment systems in Lake Winnipeg First Nation communities;
- Draft Lake Winnipeg nutrient objectives;
- Nutrient sequestration in lakes and reservoirs in the Lake Winnipeg watershed;
- The University of Manitoba's Lake Winnipeg Basin Information Network; and
- Agriculture and Agri-Foods Canada's Red-Assiniboine modelling project.

6.3.2 Reporting on the Health of Lake Winnipeg

State of the Lake Indicators

In 2015-16, the CA-MB MOU Steering Committee agreed to a joint process for reporting on the health of Lake Winnipeg and its basin through the development of a series of State of the Lake indicators that report on environmental, social and economic factors. These indicators will address the reporting commitments in the CA-MB MOU and the Science Subsidiary Arrangement, as well as serve as a tool for reporting to the public and decision makers on the health of Lake Winnipeg and its basin.

State of the Lake Reports

The second reporting component includes the development of regular State of Lake Winnipeg reports. The development of the first State of Lake Winnipeg (1999 to 2007) Report was led by ECCC and Manitoba Sustainable Development and was published in 2011. The State of Lake Winnipeg reports are technical reports that will be generated every five to ten years and will provide an update on physical, chemical and biological lake and watershed science. These reports will serve as a compendium of monitoring and research undertaken over the period since 1999. As was done in 2011, a summary or highlights document will be prepared on Lake Winnipeg Basin research for the general public. Work is underway by staff of ECCC, Manitoba Sustainable Development and key Lake Winnipeg science stakeholders on the next State of Lake Winnipeg report, which is scheduled for release in 2018.

Photo: Dana Hay
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6.4 STAKEHOLDER ENGAGEMENT

ECCC's efforts on transboundary activities included increased engagement with United States jurisdictions on nutrient issues within the U.S. portion of the Lake Winnipeg Basin. Staff regularly attended the Minnesota Water Resource Conference, the North Dakota Water Quality Monitoring Conference, the International Rainy-Lake of the Woods Watershed Forum, North Dakota's Nutrient Reduction Strategy Stakeholder meetings and Red River Basin Commission annual conferences. Conferences and meetings provided opportunities to learn firsthand of major nutrient reduction initiatives and strategies aimed at improving water quality in parts of the Lake Winnipeg basin.

6.5 LAKE FRIENDLY ACCORD AND STEWARDS ALLIANCE

ECCC also provided support to Manitoba Sustainable Development and the South Basin Mayors and Reeves on the formation and implementation of the provincially led Lake Friendly Accord and Stewards Alliance. The Lake Friendly Accord is a declaration of support by signatories to take action to reduce nutrient loading and improve water quality in the Lake Winnipeg Basin. The federal Minister of the Environment signed the accord on behalf of the Government of Canada on March 21, 2014, and was one of the first signatories. ECCC staff also participated in the Lake Friendly Stewards Alliance Steering Committee, assisting in developing an overall vision for the Alliance, overseeing the implementation of the Accord, and participating in working groups related to Governance issues and Science and Research.

7.0 CONCLUSION

The Government of Canada applied a coordinated approach to respond to water quality issues in Lake Winnipeg and its basin through the delivery of the Lake Winnipeg Basin Initiative (LWBI). The LWBI engaged citizens, scientists, and domestic and international partners in actions to contribute to the restoration of the ecological health of Lake Winnipeg, reduce nutrient pollution, and improve water quality.

While the LWBI was successful in achieving its initial objectives, ongoing nutrient loading from multiple sources, including interprovincial and transboundary sources, continues to stress the health of the lake. Other continuing and emerging threats to Lake Winnipeg include the effects of climate change and the recent infestation by aggressive aquatic invasive species (zebra mussels). These factors, combined with continued high nutrient loading, are expected to further stress the lake ecosystem by causing larger and more frequent algal blooms, compromising the food web and impacting lake-based commercial and recreational industries that are significant contributors to the Manitoba economy.

In 2017, an internal evaluation of the Lake Winnipeg Basin Initiative was completed to meet Treasury Board and Financial Administrative Act (FAA) requirements. The evaluation found there is an ongoing need to improve the ecological health of Lake Winnipeg. The evaluation also determined that the program design of the LWBI, with the three pillars of science, stewardship and transboundary partnerships, is a relevant and logical approach for the Government of Canada to address water quality issues in Lake Winnipeg and its basin.

In the context of program renewal, the evaluation recommended that efforts to engage Indigenous peoples in stewardship and partnerships need to be strengthened; early efforts in developing State of the Lake Indicators in partnership with the Province of Manitoba need to be advanced further; and knowledge gaps need to be bridged by improving the dissemination of information and research findings.

Budget 2017 secured $25.7 million in new funding over five years (2017-2022) to protect and improve the ecosystem health of Lake Winnipeg and its basin. The Lake Winnipeg Basin Program will continue to deliver ECCC research and water quality monitoring, federal transboundary leadership, and grants and contributions funding. Part of this funding will be available through an application-based process for targeted, outcome-oriented projects aimed at improving the long-term ecological health of Lake Winnipeg in the following three key priority areas: nutrient reduction, collaborative governance, and Indigenous engagement.

Photo: Ute Holweger

Appendix A

LAKE WINNIPEG BASIN STEWARDSHIP FUND PROJECTS APPROVED IN 2013

Project Name: Manitoba Wetland Restoration Project
Project Recipient: Manitoba Habitat Heritage Corporation
Environment and Climate Change Canada Contribution: $720,000
Description: This project restored wetlands throughout Manitoba over a four year period. This included infilling agricultural and other drainage ditches with earthen dams or other small structures. These restored wetlands help prevent phosphorus and nitrogen from entering Lake Winnipeg. Mid-term securement and protection of the restored wetlands occurred through landowner contracts and registered conservation easements which provide perpetual protection of the wetland regardless of land ownership.

Project Name: Establishment of Pilot Sites for Innovative Surface Water and Nutrient Management Initiatives on Farms
Project Recipient: Manitoba Conservation Districts Association
Environment and Climate Change Canada Contribution: $421,074
Description: This project investigated potential options for capturing agricultural run-off and storing it for agriculture use and preventing nutrients from being released into downstream water bodies. Many farm-based options were considered based on a range of ecozones, hydrology, habitat and agricultural uses across the Lake Winnipeg Basin. The project addressed a number of priority areas including the management of peak flows, reducing nutrient loads from agriculture and developing on-farm drought resiliency. Project activities included retention ponds, other structures, and management systems in the existing drainage network to store water. The water could then be used for agriculture such as for forage harvesting, bale grazing and irrigation of crops.

Project Name: Wetland Restoration (Two Year Program) in the Assiniboine River Watershed
Project Recipient: Assiniboine Watershed Stewardship Association Inc.
Environment and Climate Change Canada Contribution: $250,000
Description: For this project the project recipient partnered with the Saskatchewan Water Security Agency and Ducks Unlimited Canada to restore wetlands in south-east Saskatchewan. Using a reverse auction approach, interested landowners signed 10-year agreements to restore and maintain wetlands. These wetlands have the potential to reduce downstream flooding, retain phosphorus on the landscape and reduce agricultural nutrient loading into Lake Winnipeg.

Project Name: Niverville Lagoon System: The Investigation of Alternative Approaches for Bio-Remediation
Project Recipient: Town of Niverville
Environment and Climate Change Canada Contribution: $242,628
Description: This project investigated the feasibility of remediating biosolids (sludge) in decommissioned wastewater lagoons through in situ treatment using phyto- and bio-remediation methods, under both aerobic (native grasslands) and anerobic (wetland plants) conditions. The Town of Niverville's decommissioned wastewater lagoon was used as a case study with broader application in decommissioning municipal

wastewater lagoons in Manitoba and Canada. This project resulted in a one-time reduction of 21,345 kg in phosphorus from entering Lake Winnipeg.

Project Name: Lake Friendly Practices and Actions - Do What Matters
Project Recipient: South Basin Mayors and Reeves Inc.
Environment and Climate Change Canada Contribution: $210,000
Description: The goal of this project was to build public awareness and create long term changes in behaviour by showcasing practices and actions that reduce nutrients from entering Lake Winnipeg. Building on the first phase of the Lake Friendly campaign, this project expanded on the initial practices identified and provided resources to monitor and track nutrient reducing actions that were implemented in partnership with municipalities and schools. BMPs were introduced and monitored in the partnering sites. Using the results from these sites, a "Lake Friendly Marking System" was developed to allow various sectors and supply chain components to be recognized as Lake Friendly.

Project Name: Cattail and Novel Biomass: Nutrient Capture and Reclamation Turning a Waste/Pollution Stream into an Input for a Sustainable Manitoba Bio-Economy
Project Recipient: International Institute for Sustainable Development (IISD)
Environment and Climate Change Canada Contribution: $180,000
Description: This project demonstrated and assessed the effectiveness of harvesting wetland (i.e. cattail) biomass from nutrient-rich areas upstream in the Lake Winnipeg watershed to directly reduce nutrient loading to the lake. Areas that store flood water and capture nutrients from point and non-point sources were selected, including storm water ditches, upstream surface water retention areas and marginal agricultural land. A further benefit was the use of the harvested plant material to produce solid fuel pellets to be used as a direct replacement for coal and other fossil fuels.

Project Name: Pelly's Lake Watershed Management Area
Project Recipient: La Salle-Redboine Conservation District
Environment and Climate Change Canada Contribution: $162,600
Description: The La Salle-Redboine Conservation District constructed and operated a water retention structure which are designed to slow water during spring run-off and allow nutrients and sediment to settle, decrease erosion in downstream channels, recharge groundwater supplies and act as a late season recharge for downstream reservoirs. An interpretive park was established that overlooks Pelly's Lake and contains educational information about the project, with recognition of all project partners and donors. The project also incorporated the harvesting of cattails to remove nutrients from the watershed and produce pellets for heating systems.

Project Name: Designing and Managing Riparian Areas to Filter Phosphorus and Sediment
Project Recipient: University of Northern British Columbia
Environment and Climate Change Canada Contribution: $114,222
Description: University of Northern British Columbia researchers investigated the effectiveness of riparian areas in intercepting and managing nutrient runoff from agricultural sources. This off-site study included an assessment of how sediment and phosphorus move from agricultural fields into watercourses, and advancing the knowledge of whether riparian buffers are net sinks or sources of phosphorus. It also included research about how buffer features can be modified to increase their filtering capacity. Buffer design criteria were developed by assessing the bio-physical parameters and socio-economic criteria that control their uptake. Outreach materials for use by farm advisors and land managers were then produced, which summarized the improved protocols for the implementation of riparian buffers.

Project Name: Pipestone Phosphorus Reduction Program: Implementation and Measuring Efficacy of Beneficial Management Practices
Project Recipient: Lower Souris Watershed Committee Inc.
Environment and Climate Change Canada Contribution: $120,720
Description: The Lower Souris Watershed Committee Inc. reduced nutrient loading by restoring wetlands in agricultural landscapes and converted annual cropland to perennial forage. Following implementation, a workshop and field day were hosted to promote the benefits of wetland restoration and forage conversion to agricultural producers. Water quality (nutrients, particulates and volume) and quantity were monitored in runoff from spring snowmelt and summer storm events.

Project Name: Development of a Risk Indicator to Identify Soils Prone to Phosphorus Release under Prolonged Flooding
Project Recipient: University of Winnipeg
Environment and Climate Change Canada Contribution: $109,200
Description: This research study developed and validated a risk indicator to identify soils that are prone to releasing large quantities of phosphorus under waterlogged, low oxygen conditions to surface runoff water. The risk indicator was tested using surface soil and subsoil to provide additional information on the influence of top soil removal on phosphorus release to surface water under flooded conditions. The information generated is useful for making recommendations on drainage management of flooded soils and wetland restoration.

Project Name: Successful Initiation of Wetland Restoration Landowner Incentive Program
Project Recipient: Upper Souris Watershed Association Inc.
Environment and Climate Change Canada Contribution: $80,000
Description: This project demonstrated wetland restoration as a beneficial management practice (BMP). Key project elements included: wetland restoration demonstration sites; re-vegetating buffer zones around each restored wetland to perennial cover; polling agriculture producers who have been exposed to the wetland demonstration sites to learn their motivations for draining wetlands and wetland restoration obstacles; and, undertaking various communication efforts including signage, billboards, field tours, newsletter articles, media releases, and radio ads about interesting wetland and watershed facts.

Project Name: Earthen Dam for Water Storage and Erosion Control
Project Recipient: Swan Lake Watershed Conservation District
Environment and Climate Change Canada Contribution: $66,356
Description: The Swan Lake Conservation District constructed an earthen dam for water retention in the Swan Lake Watershed to mitigate downstream municipal infrastructure damage, sheet erosion and temporary inundation of agricultural land. Surface water testing both upstream at high flow rates and at discharge was carried out to provide a comparison of initial nutrient versus nutrient released with variable storage time to optimize nutrient reduction without compromising agricultural production.

Project Name: Development of a Simulation Tool to Identify Priority Areas for Wetland Conservation and Restoration
Project Recipient: University of Manitoba
Environment and Climate Change Canada Contribution: $53,350
Description: University of Manitoba researchers developed a water quantity and quality simulation tool to explore scenarios of wetland conservation and restoration. Due to landscape heterogeneity and variable hydro-meteorological conditions, not all wetlands function the same way. Wetlands that are considered "critical" are those whose drainage would result in the most significant adverse impacts on watershed connectivity, flooding and water quality. This new tool allowed an examination, in a virtual environment, of which wetlands can be characterized as critical and considered a priority for conserving or restoring at the watershed scale.

Project Name: Management of Sediments in Surface Waterways to Reduce Phosphorus Loading in Lake Winnipeg
Project Recipient: University of Manitoba
Environment and Climate Change Canada Contribution: $58,843
Description: University of Manitoba researchers surveyed sedimentation and sediment management practices in the Tobacco Creek and LaSalle River watersheds of the Red River Basin and in the Catfish Creek and Whitemouth River watersheds of the Winnipeg River Basin. Existing and alternative management practices were evaluated for their potential to reduce phosphorus levels within waterways. A detailed evaluation of existing and alternative sediment removal and disposal practices also took place.

Project Name: Whitemud Watershed Surface Water Storage Program
Project Recipient: Whitemud Watershed Conservation District
Environment and Climate Change Canada Contribution: $39,899
Description: The Whitemud Watershed Conservation District constructed three temporary water storage projects in the headwaters of the Whitemud River. Each project consisted of a backflood area (reservoir), earthen dam with rock and/or geotextile for erosion control, and control structures consisting of an open-top culvert, as well as a release culvert with screw-gate valve. The projects that were implemented are designed to fill up during runoff events to Full Supply Level (FSL) with a spillway to allow for any excess water to runoff until the reservoir returns to FSL. The projects hold a significant amount of water and wetlands in the area were restored.

Project Name: Assiniboine Basin Municipal Point Source Assessment and Reduction Initiative
Project Recipient: Upper Assiniboine River Conservation District
Environment and Climate Change Canada Contribution: $34,798
Description: This project assessed wastewater sites in southwest Manitoba to measure and quantify their nutrient contributions and assessed the feasibility of alternate uses (e.g. land availability, soils, irrigation demand/cost). Following this assessment, the Conservation District established two pilot wastewater irrigation sites where trees and shrubs were grown for harvest and other uses, such as heat energy and wildlife habitat. Solar technology was used to irrigate wastewater at these sites.

Project Name: Lake of the Woods Discovery Centre Model Shoreline
Project Recipient: Lake of the Woods Development Commission
Environment and Climate Change Canada Contribution: $29,636
Description: The Lake of the Woods Development Commission built a model shoreline at the Lake of the Woods Discovery Centre in Kenora, ON. This is an interpretive environmental education project driven by community partners and grassroots support. The project included three shoreline demonstration sites: natural shoreline with native plantings; minimal landscaping and fish/aquatic habitat protection; soft shoreline protection to reduce erosion with considerable native plantings and environmentally friendly dock installation; and, hardened shoreline with extensive landscaping to demonstrate significant impact on the environment. The remainder of the shoreline was left natural, with information explaining the benefits of doing so.

Project Name: Quantification of the Internal Phosphorus Load in Lake Winnipeg to Improve Phosphorus Budgets
Project Recipient: Freshwater Research
Environment and Climate Change Canada Contribution: $28,000
Description: This project performed research to determine whether internal phosphorus loading in Lake Winnipeg can be quantified using three approaches: water column phosphorus concentrations, mass balance calculations, and predicting aerial phosphorus release rates from previously determined fractions in Lake Winnipeg sediments. Internal phosphorus loading estimates will improve the predictive ability of any phosphorus mass balance model currently under development, as well as provide a time frame for lake water quality response to external load control. The knowledge gathered on the internal load will be useful in setting nutrient objectives for Lake Winnipeg.

LAKE WINNIPEG BASIN STEWARDSHIP FUND PROJECTS APPROVED IN 2014

Project Name: Nutrient, Wastewater Contaminant, and Toxicity Reduction Using Sub-Surface Filtration Technology
Project Recipient: University of Winnipeg
Environment and Climate Change Canada Contribution: $135,000
Description: This project studied the effectiveness of sub-surface filter treatment technology and its ability to remove excess nutrients from effluent before its release into waterways. This system was proven successful at removing excess phosphorus and nitrogen from the effluents of a municipal sewage lagoon prior to their release. The overall goal of this project was to understand and optimize the physical, chemical and ecological factors that control removal efficiency of nutrients and contaminants by the sub-surface filter treatment technology.

Project Name: Enhancing a Manitoba Watershed Using ALUS (Alternative Land Use Services)
Project Recipient: Delta Waterfowl Foundation
Environment and Climate Change Canada Contribution: $100,000
Description: Alternative Land Use Services (ALUS) is a community-led, farmer-delivered, incentive-based conservation program delivering ecological goods and services on private lands. The ALUS project restored, enhanced, created and conserved wetlands, fenced riparian areas, installed off-site watering systems, restored buffer strips, converted marginal cropland to grasslands and planted shelterbelts.

Project Name: Bow River Phosphorus Management Plan Implementation: Floating Island Pilot Project
Project Recipient: Alberta Environment and Sustainable Resource Development
Environment and Climate Change Canada Contribution: $100,000
Description: The Bow River Phosphorus Management Plan (BRPMP) reduced phosphorus from mechanical wastewater treatment plants and lagoons. This project also supported the installation and testing of the BioHaven® Floating Treatment Wetland in pilot lagoons in the watershed.

Project Name: Reducing and Utilizing Nutrients in Tobacco Creek Model Watershed
Project Recipient: Deerwood Soil and Water Management Association
Environment and Climate Change Canada Contribution: $90,000
Description: This project constructed and evaluated a consolidated network of water retention structures throughout the Tobacco Creek Model Watershed. The structures created, preserved and conserved several acres of wetlands. They were also designed to retain nutrients and limit spring runoff to reduce downstream flooding. Modified and existing designs of small dams, retention ponds, wetlands and ditches were evaluated for flood control, nutrient remediation and likelihood of adoption by farmers.

Project Name: Riparian Health Improvements through Grazing Management Improvements
Project Recipient: Cows and Fish (Alberta Riparian Habitat Management Society)
Environment and Climate Change Canada Contribution: $78,900
Description: This project improved the grazing management practices applied by cattle producers in the Oldman River and Battle River watersheds. The project included a mix of educational and stewardship activities, designed to increase knowledge and adoption, while developing detailed grazing management plans and implementation strategies. Riparian health assessments were completed to identify issues and determine the solutions required. The installation of exclusion fencing, alternative watering systems and the planting of native trees and shrubs are among the Beneficial Management Practices (BMPs) that were implemented.

Project Name: Manitoba Conservation Auction Initiative
Project Recipient: Manitoba Agriculture, Food and Rural Development
Environment and Climate Change Canada Contribution: $75,000
Description: Conservation Auctions were conducted throughout southern Manitoba to provide opportunities for landowners to conserve, enhance, and restore priority wetlands and ecosystems. The auction was a voluntary process whereby landowners submitted a proposal (or bid) for entering into a Conservation Agreement or adopting a Beneficial Management Practice (BMP) Contract on their lands. BMPs offered were specifically tailored in each auction location to address the local needs. Workshops were conducted to provide additional information on the auction process.

Project Name: Cattails for Clean Community Waterways: Urban Application of the Lake Winnipeg Bio-economy Project
Project Recipient: International Institute for Sustainable Development (IISD)
Environment and Climate Change Canada Contribution: $53,000
Description: In this project, the economic and environmental benefits of removing wetland plants such as cattails and other plant species from drainage ditches in an urban setting (Winnipeg) were examined. The bioenergy and biomaterials potential of the harvested plants were explored. This concept had previously been piloted in a rural setting in the Lake Winnipeg watershed.

Project Name: Washow Peninsula and Fisher Bay Change Over Time Analysis
Project Recipient: Fisher River Cree Nation
Environment and Climate Change Canada Contribution: $47,416
Description: This project combined traditional knowledge with new technology to provide and inform land, water, wetlands and shoreline changes over time for Washow Peninsula, Fisher Bay and the mouth of the Fisher River. The project results identified patterns that have led to nutrient loading in the area. Key elements of the project were land and water use interviews/surveys; cartographic data collection; water extent analysis; shoreline field work; as well as data analysis.

Project Name: South Central Eco Institute Enhancement Project
Project Recipient: Prairie Spirit School Division
Environment and Climate Change Canada Contribution: $30,500
Description: The South Ceantral Eco Institute (SCEI) is a data collection program that provided students with the opportunity to work with Conservation District partners in researching and monitoring a variety of phosphorus reduction and watershed improvement projects. SCEI represents a network of partnerships between the academic community, community development representatives, conservation districts and eco-environmental agencies. Each spring and fall, students and staff were provided with the training and equipment necessary to collect water quality data.

Project Name: Moose Jaw River Integrated Excessive Water Management Plan
Project Recipient: Moose Jaw River Watershed Stewards Inc.
Environment and Climate Change Canada Contribution: $45,000
Description: This project implemented beneficial management practices (BMPs) such as buffer strips, alternative water systems and livestock exclusion fencing. Six projects were showcased through stakeholder meetings and newsletters as examples for local producers. Hydrology reports were developed for approximately five sub watersheds and consultations with stakeholders were conducted in order to develop an Excessive Water Management Plan for the Moose Jaw River Watershed.

Project Name: Turtle Mountain Conservation District Ecological Goods and Services Program – Phase 1
Project Recipient: Turtle Mountain Conservation District
Environment and Climate Change Canada Contribution: $41,000
Description: This project created an inventory of drains, wetlands (Class 2-5), and water storage areas that are present within the Elgin Creek-Whitewater Lake sub-watershed. A series of workshops were held to assist with information gathering and to promote the Ecological Goods and Services Program concept. The information gathered in initial stages was analyzed to determine the feasibility of moving forward with a broader Ecological Goods and Services program in Manitoba.

Project Name: Cattle and Creeks: Local Solutions Toward Basin Results
Project Recipient: Upper Assiniboine River Conservation District
Environment and Climate Change Canada Contribution: $25,000
Description: This project restricted the access of livestock to the tributaries of the Assiniboine River to protect stream banks and improve water quality. Key elements of this project included the installation of riparian fencing and alternate watering systems, as well as the development of pasture management plans. Pre and post assessments of each project site were completed and implementation plans were developed to monitor progress.

Project Name: Aquatic Ecosystem Restoration Mercer Creek and Little Dog Lake Drain
Project Recipient: West Interlake Watershed Conservation District
Environment and Climate Change Canada Contribution: $15,750
Description: This project eliminated cattle access along various reaches of Mercer Creek and Little Dog Lake Drain in order to restore degraded riparian areas, improve water quality through the reduction of bacteria and nutrient inputs in the creek, rehabilitate priority aquatic habitat and create and restore important wildlife habitat. This project is being used as a demonstration and knowledge transfer site for future riparian management projects.

Project Name: Restoration of Netley-Libau Marsh: Evaluating the Feasibility and Benefits of Marsh Habitat Management Options for Nutrient Sequestration Enhancement
Project Recipient: Lake Winnipeg Foundation Inc.
Environment and Climate Change Canada Contribution: $20,000
Description: Specialists and stakeholders were invited to take part in evaluating restoration strategies for the Netley-Libau Marsh. This process included a two day, facilitated workshop to explore potential restoration strategies and formulate science-based consensus on restoration options with the greatest potential of success. Netley-Libau Marsh, one of Canada's largest coastal wetland covering 26,000 hectares, has undergone considerable biophysical changes that are contributing to the nutrient loading challenge facing Lake Winnipeg.

Project Name: Promotion of Buffer Strips and Riparian Area Health Assessments for Agricultural Land within the Carrot River Watershed Area
Project Recipient: Carrot River Valley Watershed Association
Environment and Climate Change Canada Contribution: $4,000
Description: This project delivered riparian area awareness workshops and educational materials to the residents of the Carrot River Watershed. Riparian Health Assessments were utilized to identify areas that are stressed and determine solutions for problem areas within the watershed. Newsletters, brochures and workshops were used to highlight the importance of riparian health, riparian area health assessments and the use of buffer strips.

LAKE WINNIPEG BASIN STEWARDSHIP FUND PROJECTS APPROVED IN 2015

Project Name: Management of sediments in surface waterways to reduce phosphorus loading in Lake Winnipeg: Assessment of management options for sediment and associated vegetation and soil
Project Recipient: University of Manitoba
Environment and Climate Change Canada Contribution: $84,552
Description: This research project examined sediment and vegetation management practices in agricultural drainage areas that are effective in removing nutrient-rich sediment from agricultural soil while allowing for quick growth, harvesting and disposal of vegetation that absorb nutrients such as phosphorus. These practices are intended to be easily adopted by the agencies and individuals responsible for managing the sediments in waterways. Research activities occurred in the Tobacco Creek and LaSalle River watersheds of the Red River Basin and the Catfish Creek and Whitemouth River watersheds of the Winnipeg River Basin.

Project Name: The Evolution of Wetland Restoration - Utilizing a Hybrid of Wetland Restoration with Control Structures and Forage Establishment to Manage Nutrient Runoff in the Assiniboine River Watershed - Saskatchewan
Project Recipient: Assiniboine Watershed Stewardship Association Inc.
Environment and Climate Change Canada Contribution: $75,000
Description: The Assiniboine Watershed Stewardship Association's project restored wetlands in Saskatchewan's Assiniboine River Watershed through the installation of earthen ditch plugs and gated culverts to facilitate the control the amount of water being stored. Strategically placed control culverts were used by landowners to retain water in the area and ensure permanency. Perennial forages were also established to capture and reduce nutrient runoff. Landowners were required to sign a ten-year agreement to ensure the restored wetland and perennial forage will remain intact.

Project Name: Strategic Wetland Restoration and Best Management Practices (BMP) Implementation in the Upper Souris Watershed
Project Recipient: Upper Souris Watershed Association
Environment and Climate Change Canada Contribution: $58,117
Description: This project reduced nutrient loading from non-point rural sources through the restoration of strategically located wetlands in the Upper Souris Watershed located in southeast Saskatchewan. The installation of earthen plugs at project sites restored natural water levels in drained wetland basins, demonstrating that new concepts and technology work on the prairie landscape, influencing additional producers to adopt these practices. Demonstration projects were also used to create awareness among local landowners and producers of Beneficial Management Practices (BMPs) related to wetland restoration and grazing management.

Project Name: Predictive Mapping of Wetland Soils to Estimate Risk of Nutrient Transport
Project Recipient: University of Saskatchewan
Environment and Climate Change Canada Contribution: $55,077
Description: This University of Saskatchewan research project helped inform land management decisions related to wetland conservation in the Saskatchewan River and Assiniboine River watersheds by improving the understanding of the relationship between wetland type and nutrient mobility. This resulted in the identification of certain types of wetlands that result in minimal nutrient loading to local waterways flowing into Lake Winnipeg while maximizing productive land. The project included digital soil mapping, nutrient analysis and the dissemination of results through reports and presentations.

Project Name: Cattle Runoff Wetland/Filter Treatment
Project Recipient: East Interlake Conservation District
Environment and Climate Change Canada Contribution: $53,000
Description: Working with a local landowner, consultants and engineers, the East Interlake Conservation constructed a cattle runoff wetland/filter treatment area to reduce nutrients, contaminants and sediments that run off agricultural properties within the Willow Creek Watershed. The wetland/filter treatment area diverted agricultural spring melt and rainfall water, filtering nutrients away from Lake Winnipeg while creating additional habitat for wildlife.

Project Name: Brokenhead Wetland Monitoring and Restoration Planning
Project Recipient: Centre for Indigenous Environmental Resources
Environment and Climate Change Canada Contribution: $37,250
Description: The Centre for Indigenous Environmental Resources' project enhanced and restored wetlands near the Brokenhead River, which flows into Lake Winnipeg. As part of this project, wetland monitoring and hands-on restoration practices were undertaken to reduce nutrient loading, provide and improve habitat for rare and culturally important species and provide information to assist in the planning and collaboration with other First Nations communities to improve the health of Lake Winnipeg.

Project Name: Vegetated Buffer and Contained Grassed Waterway
Project Recipient: Swan Lake Watershed Conservation District
Environment Canada Contribution: $30,500
Description: The Swan Lake Watershed Conservation District's project re-established natural vegetation along waterways within croplands and permanent forage areas. These grassed waterways increase soil stability and prevent erosion which prevents soil-bound nutrients from entering the waterways from the agricultural fields. The project site was also used to educate landowners on the environmental benefits of grassed waterways.

Project Name: Combining wetland restoration and runoff control structures to reduce phosphorus loading in the Lower Qu-Appelle Watershed
Project Recipient: Lower Qu'Appelle Watershed Stewards Incorporated
Environment and Climate Change Canada Contribution: $20,000
Description: The Lower Qu'Appelle Watershed Stewards project remunerated local agricultural landowners to retain water in previously drained wetland areas within the Lower Qu'Appelle watershed, increasing the potential for capturing and storing agricultural nutrients that might otherwise flow into Lake Winnipeg. The program restored wetlands using earthen plugs and gated structures to incorporate additional runoff control. Producers were required to sign an agreement confirming that they will maintain these wetlands for a minimum duration of ten years.

Project Name: Netley-Libau Marsh Restoration: Next steps towards a long term Remedial Action Plan for Netley-Libau Marsh. Consolidating previous science guidance, developing governance mechanisms, and filling in research gaps.
Project Recipient: Lake Winnipeg Foundation
Environment and Climate Change Canada Contribution: $15,000
Description: This project, led by the Lake Winnipeg Foundation, is the second phase of a long term project to restore Netley-Libau Marsh, one of Canada's largest coastal wetlands covering 26,000 hectares. Building on the success of Phase 1, this phase filled in the gaps by providing data that is required for the development of a remediation plan for the Netley-Libau Marsh. A steering committee was established to guide and oversee Remedial Action Plan activities and an In-Marsh Pilot Study to measure and explain some key marsh interactions governing nutrient and sediment fluxes.

Project Name: Sustainable nutrient removal and recovery from municipal wastewater: Anammox based electrically enhanced membrane process
Project Recipient: University of Manitoba
Environment and Climate Change Canada Contribution: $15,000
Description: This University of Manitoba laboratory- based research project focused on the development of an innovative, sustainable treatment method for municipal wastewater. The main objective of the project was to research and develop a completely autotrophic nitrogen removal process with an electrically assisted membrane bioreactor for municipal wastewater treatment at low temperatures. This technology features lower sludge production and lower aeration and chemical dosing requirements and is a step towards a sustainable wastewater treatment plant designed as a resource recovery facility.

Project Name: Yellow Fish Road - Winnipeg, MB
Project Recipient: Trout Unlimited Canada
Environment and Climate Change Canada Contribution: $10,000
Description: Trout Unlimited Canada's project provided Winnipeg youth with the knowledge and tools to make a positive difference to their local waterways through the reduction of nutrients from urban sources and controlling non-point source or urban storm water pollution. Workshops, projects and public events were aimed at educating participants on how we can protect our waterways through responsible household practices such as responsible use of domestic and garden chemicals, use of natural alternatives to fertilizers, herbicides and pesticides; and proper cleanup and disposal of sediment, litter, pet waste and car fluids.

Project Name: Science Workshop on water quality and ecosystem health of Lake Manitoba
Project Recipient: University of Winnipeg
Environment and Climate Change Canada Contribution: $10,000
Description: The Lake Manitoba basin contributes to nutrient loading in Lake Winnipeg, and impacts the lake's water quality and ecosystem health. This workshop assessed the current state of knowledge of water quality issues in Lake Manitoba and its watershed, identify critical knowledge gaps, and brainstorm ways to move forward on improving water quality and ecosystem health in this region.

Project Name: Sustainable Lake Winnipeg Exhibit - Grand Marais Community Central Building
Project Recipient: Rural Municipality of St. Clements
Environment and Climate Change Canada Contribution: $8,500
Description: The Rural Municipality of St. Clements' Sustainable Lake Winnipeg Exhibit, located in the community of Grand Marais, is an interactive community exhibit that tells the story of the creation of Lake Winnipeg, factors that influence both health and threats to the lake's ecology, and provides practical ideas that individuals can adopt to clean up Lake Winnipeg. The exhibit includes two large aquariums to illustrate fish species and the biology of the lake, a touch screen map to help visitors understand the natural and cultural influences on Lake Winnipeg, and interpretive panels that demonstrate what visitors can do to help the health of Lake Winnipeg. The Grand Marais Community Central Building has been identified as a tourist destination and is visited by over 100,000 people annually.

Appendix B

SCIENCE PUBLICATIONS SUPPORTED BY THE LAKE WINNIPEG BASIN INITIATIVE

1. Anderson, J., Jourdan, S., Shoichet, I., Cuscito, L., Alipio, A., Donaldson, C., et al. (2015). Reducing nutrients, organic micropollutants, antibiotic resistance, and toxicity in rural wastewater effluent with subsurface filtration treatment technology. Ecological Engineering, 84:375-385. https://doi.org/10.1016/j.ecoleng.2015.08.005

2. Bawden, A., Burn, D., & Prowse, T. (2013). An Analysis of Spatial and Temporal Trends and Patterns in Western Canadian Runoff: A CROCWR Component. Proceedings of the 19th International Northern Research Basins Symposium and Workshop.

3. Beveridge, D., St-Hilaire, A., Taha, B., Khalil, B., Wassenaar, L., & Conly, M. (2012). A geostatistical approach to optimize water quality monitoring networks in large lakes: application to Lake Winnipeg. Journal of Great Lakes Research, 38, 174-182. https://doi.org/10.1016/j.jglr.2012.01.004

4. Binding, C. E., Greenberg, T. , McCullough, G., Watson, S., & Paige, E. (2017). Remote sensing indicators for enhanced monitoring of algal bloom conditions on Lake Winnipeg, 2002-2010. Science of the Total Environment.

5. Binding et al. Wind mixing effects on satellite algal bloom detection in a shallow eutrophic lake.

6. Binding et al. Satellite observations of water clarity in Lake Winnipeg in response to the establishment of zebra mussels.

7. Binding, C. E., Greenberg, T., & Bukata, R. (2011). Time series analysis of algal blooms in Lake of the Woods using the MERIS maximum chlorophyll index. Journal of Plankton Research, 33(12), 1847-1852. https://doi.org/10.1093/plankt/fbr079

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12. Chen, G., Elliott, J., Wilson, H., Lobb, D., Flaten, D., & Braul, L. (2017). Changes in runoff chemistry and soil fertility after multiple years of cattle winter bale feeding on annual cropland on the Canadian prairies. Agriculture, Ecosystems and Environment, In Press. https://doi.org/10.1016/j.agee.2017.02.003

13. Chittibabu, P., & Rao, Y. (2011). Numerical Simulation of Storm Surges in Lake Winnipeg. Natural Hazards, 60:181–197. https://doi.org/10.1007/s11069-011-0002-7

14. Corriveau, J., Chambers, P., & Culp, J. (2013). Seasonal variation in nutrient export along streams in the northern Great Plains. Water, Air, & Soil Pollution, 224, 1594-1609. https://doi.org/10.1007/s11270-013-1594-1

15. Corriveau, J., Chambers, P., Yates, A., & Culp, J. (2010). Snowmelt and its role in the hydrologic and nutrient budgets of prairie streams. (E. van Bochove, P. Vanrolleghem, P. Chambers, G. Thériault, B. Novotná, & M. Burkart, Éds.) Issues and Solutions to Diffuse Pollution, 64, pp. 179-188.

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