Lake Winnipeg Basin Program

Science Highlights 2017-2022

Environment and Climate Change Canada
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Introduction

Budget 2017 provided $25.7 million through the Freshwater Action Plan for the Lake Winnipeg Basin Program being delivered by Environment and Climate Change Canada (ECCC). Of this funding, $8.46 million over 5 years was dedicated to implementing a Lake Winnipeg science plan to conduct freshwater science and water quality research to further understanding the complexity of issues facing Lake Winnipeg and its vast basin. The science plan included four objectives:

- Monitoring to assess status and track changes
- Research on nutrient sources and transport pathways to streams
- Research on lake ecosystem components to achieve a sustainable nutrient balance
- Reporting on progress towards achieving a healthy Lake Winnipeg

Previous ECCC funding for Lake Winnipeg science focused on characterizing the lake to support the development of nutrient targets and initiating watershed-based studies to inform nutrient management planning. Science efforts from 2017-2022 continued to build on the previous work and added a focus on improving knowledge of nutrient export to streams and understanding the impacts of external drivers, for example climate variability and invasive species, on the nutrient balance in the lake. This summary highlights the science advancements and results enabled by the Lake Winnipeg Basin Program funding.

Tributary Monitoring

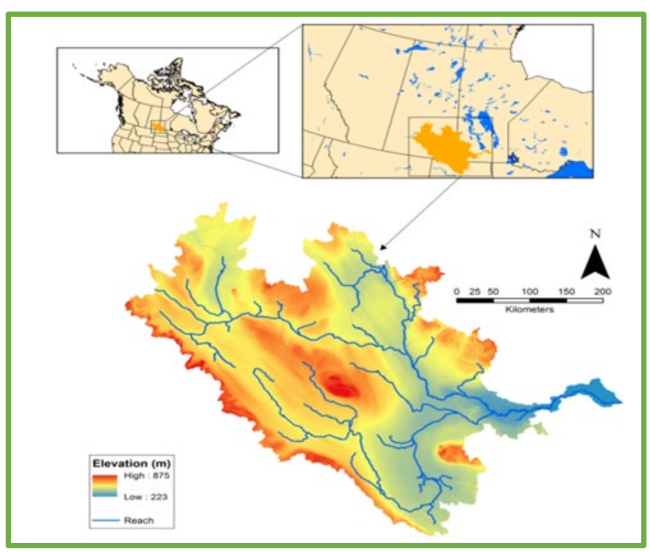
Ongoing long-term ECCC water quality monitoring activities in the Lake Winnipeg Basin include measuring nutrient concentrations (and other parameters) in rivers crossing boundaries between Canada and the United States, in rivers that cross provincial boundaries, and four eastern tributaries to Lake Winnipeg. The data is used by ECCC to establish the water quality status of the rivers and is reported through various mechanisms, including the Canadian Environmental Sustainability Indicator: *Water Quality in Canadian Rivers*. The monitoring data is also used to track status for established water quality objectives, such as those of the Prairie Provinces Water Board and the International Red River Board.

Watershed Modelling

Researchers are developing watershed models to better understand nutrient loading to Lake Winnipeg. Different models are applied depending on the geographic scale of analysis and on the questions being asked. Both statistical and process-based models are being used to further our understanding of where nutrients are coming from, how different management practices can be used to reduce nutrient loss, and how future climate predictions might change the hydrology and nutrient transport in the basin.

Models of the Red and Assiniboine River Basins are a priority because these basins contribute most of the nutrients, particularly phosphorus, to Lake Winnipeg. The Soil and Water Assessment Tool (SWAT) was used to evaluate where nutrients are coming from and how different nutrient management scenarios can be used to reduce nutrient loading under both current and future climate scenarios. Separate models were developed for the Red and the Assiniboine River Basins. The Red River Basin SWAT model performed well at the mainstream stations but poorly at tributary stations. Work is continuing to improve the model by accounting for additional processes, such as reservoirs, lakes, wetlands, point sources, water uses, tile drainage, and grazing and manure management practices. The updated model will assess additional nutrient management scenarios and how nutrient transport may change under future climate scenarios.

Work on the Assiniboine River Basin SWAT model focused on the development of an improved hydrologic component that allowed representation of variable contributing areas, which improved the simulation of streamflow and nutrient dynamics. The model was applied to the present timeframe to validate the hydrologic regime of the Assiniboine River Basin and then applied to quantify the potential impacts of climate change on the hydrology of the basin. These results suggest that



the projected future climate will result in an overall increase in winter and early spring flows as well as annual flow at all the stations. The projections also suggest decreases in late spring and summer flows, particularly in the headwater regions of the basin. Work is ongoing to model nutrient transport under current and future climates with different nutrient management scenarios to assess their impact on load reduction.

A statistically-based assessment of nutrient loading for the combined Red-Assiniboine River Basin was modeled using a Bayesian version of the SPAtially Referenced Regression On Watershed Attributes (SPARROW) model. The model produces estimates of both incremental and delivered phosphorus loads for each catchment area within the larger Red-Assiniboine River Basin. The incremental load represents the amount of phosphorus that is generated within a catchment area, whereas the delivered load represents the amount of phosphorus from that catchment that reaches Lake Winnipeg. Thus, the delivered load accounts for nutrient losses along the way due to storage and assimilation. Future work will apply the modelling framework to nitrogen loads.

Historically, the hydrologic regime of the Lake Winnipeg Basin is classified as snow-dominant, meaning that snow and its subsequent melt has the largest influence on the hydrology of the region. Under future climate predictions of warming and more intense rainfall, the hydrologic regime is expected to change. To understand future impacts to the snow regime of the Assiniboine and Red River Basins, a process-based snow model was developed and used to analyze historical and future snow regime responses to climatic drivers (temperature and precipitation). For the future climate, policy-relevant global mean temperature increases of 1°C to 3°C above the pre-industrial period were simulated. The projections of future snow water equivalent indicate consistent patterns of loss for both the Assiniboine and Red River Basins. During the cold season (October to May) the average and maximum amounts of snow water equivalent are expected to decrease in both basins, and the timing of the maximum snow water equivalent, which is an indicator of snowmelt initiation, is projected to be earlier in the year for both basins. Concurrent with the reduced snow accumulation and earlier melt, total snow cover duration is also projected to decrease. The modeled results also indicate that parts of the Assiniboine and Red River

Basins will shift from a snow-dominant regime to a rain-snow hybrid regime. The shift implies increasing influence of winter and spring rainfall on the runoff generation process.

> ***Did you know?***
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> *Modelling suggests that in the Red River basin, under a climate change scenario of 3°C warming and a 10% increase in precipitation, annual streamflow would increase by an average of 20%?*

To understand potential changes at a broader scale, a basin-classified virtual modeling platform was developed to determine how a warming climate could impact stream flow from different watershed types across the Lake Winnipeg Basin. Watersheds of approximately 100 km^2 within the Canadian Prairie region in the Lake Winnipeg Basin were classified using a clustering approach that incorporated geological, topographical, and land cover data, resulting in 7 classes of watersheds. Virtual basins for each watershed class were then constructed using the median watershed characteristics of each class. The modelling framework was applied to assess the hydrological sensitivity of one basin class (high-elevation grasslands) to changes in climate. This work revealed that high-elevation grassland basins are sensitive to changes in climate, but that the impact varied geographically. For example, one scenario of a 6°C increase in temperature and a 30% increase in precipitation, generated estimates of a 40% decrease in annual runoff from this basin class in climates of the western portion of the Lake Winnipeg Basin, but a 55% increase in runoff from the same class in climates of eastern portions. This modelling framework is now being applied to all basin classes to test a variety of climate and land management (e.g. wetland drainage) scenarios.

Nutrient sources and transport in agricultural landscapes

Over half of the land base in the Lake Winnipeg Basin is used for agricultural production. Runoff from this area contributes significantly to the diffuse nutrient load in the basin. Researchers continue to focus effort on improving our understanding of nutrient loading from agricultural landscapes and studying the effectiveness of beneficial management practices (BMPs) in reducing nutrient loss.

A comprehensive review of BMPs and their applicability in the Northern Great Plains was undertaken. The review considered the effectiveness of a range of BMPs in the context of the largely snowmelt-driven dissolved nutrient runoff that dominates surface water recharge in the Lake Winnipeg Basin. Vegetation based practices such as cover crops and riparian buffers were seen as being less effective in these conditions but practices that held water on the land were seen to have more potential. This will be especially important going forward since the modelling work is projecting increased runoff under a changing climate.

Work on in-field winter bale grazing demonstrated that although soil fertility was improved, nutrient transport in snowmelt runoff increased in the year of feeding and in the case of phosphorus, the increase persisted into subsequent years. This work illustrates that the selection of winter-feeding sites should minimize hydrological connectivity to surface water bodies to minimize nutrient transport. Similarly, manure nutrient export experiments suggest that precision cattle manure application, that reduces rates on hydrologically connected portions of the landscape and avoids areas where water will pond, shows potential for reducing nutrient transport in surface runoff.

Did you know?

Studies show that the BMP known as "Soil Phosphorus Drawdown", which reduces the amount of phosphorus in the soil by reducing fertilizer applications combined with harvest removal, can decrease phosphorus loads without affecting crop yields.

Several projects focused on enhancing knowledge on nitrogen and phosphorus runoff loss. Two snowmelt studies, one on post-harvest crop regrowth and the other on ditch vegetation, illustrated increased nutrient loss from the vegetation in snowmelt runoff. Fine scale temporal dynamics of nutrient release from plant residues during snowmelt was studied to develop a process-based mathematical model to characterize nutrient losses. Other aspects of nutrient release during snowmelt were simulated using the Winter Nutrient Transport (WINTRA) model. Flow concentration relationships for phosphorus were examined and good model fits were found in moderately sloping watersheds with large effective drainage areas. Data from several Manitoba sites were combined to develop a predictive relationship between soil test phosphorus and phosphorus loss in runoff.

Evaluating in-stream processes affecting nutrient transport

Not all nutrients that are released to tributaries in the Lake Winnipeg Basin are transported downstream to Lake Winnipeg. Ecological processes in streams can assimilate and transform nutrients thereby making them unavailable for transport. Researchers conducted three separate studies to better understand some of these processes and the implications for Lake Winnipeg.

In the first study, nitrogen stable isotopes were used to identify the primary sources of nitrogen to food webs in streams of the Red River Valley. This work showed that wastewater sources (either human or livestock) contributed a greater proportion of nitrogen to stream food webs than fertilizer sources, and that waste sources contributed relatively more to food webs in summer than in spring. Despite wastewater lagoons releasing effluent in short-term pulsed discharges, the influence of wastewater on food web nitrogen was observed from the summer release into the following spring. A separate analysis showed a strong correlation between the amount of sewage in a tributary catchment and the concentration of nitrogen in the benthic macroinvertebrate indicators, suggesting that human wastewater sources were the dominant source of nitrogen.

In the second study, the timing and relative contribution of nutrients from fertilizers, human and livestock waste sources to surface water sources were examined in more detail by combining the use of natural isotope analysis with artificial sweetener analysis to distinguish between human and livestock wastewater sources. This work showed that throughout tributaries of the Red River Valley, manure was the major source of nitrogen during snowmelt, whereas during spring and summer both sewage and fertilizer were important sources of nitrogen to streams. These tributaries are a significant source of human and livestock wastewater to the Red River in the summer and fall when effluent is released from storage into these streams.

In the third study, the fate of nutrients from episodic releases of municipal wastewater lagoon effluent was determined by examining nutrient concentrations downstream from one municipal wastewater lagoon. This study illustrated that nutrient processing and retention varied with flow and temperature. Transformation was most efficient for nitrogen during low flow in summer. There was low demand for phosphorus, suggesting that nitrogen was the limiting nutrient in the stream. The study also illustrated that episodic releases of sewage can overwhelm the processing and transformation of wastewater nutrients during effluent releases and that nutrients may end up in the Red River and subsequently Lake Winnipeg. Therefore, instead of pulsed effluent releases, slow continuous discharges may help with nutrient assimilation in the stream.

Lake Ecology

The modelling scenarios used to establish nutrient concentration targets for Lake Winnipeg suggest that significant reductions in nutrient loading must occur to improve the health of Lake Winnipeg. Although the targets are in place and are based on best available science, several knowledge gaps were identified after the modelling work was completed under the previous round of program funding, including questions around the impact of zebra mussels on the lake food web, limited knowledge of sediment phosphorus dynamics, and of the plankton and microbial communities in the lake, and a need for improvements to the lake model to account for missing processes. Work was initiated under the science plan to help address some of these gaps.

A monitoring protocol was developed for the collection of water chemistry, vegetation, phytoplankton, zooplankton, and benthic macroinvertebrates at nine road-accessible sites along both basins of the lake and at sites within the Netley-Libau Marsh. An assessment of the status and trend of emergent vegetation loss in the Netley-Libau Marsh indicated that vegetation change has been variable. Furthermore, periods of low water, as short as one year, result in increased vegetation that can last for more than ten years. Zebra mussel distribution, density, biomass, and population characteristics were also documented within the lake. Data from 2017-2019 indicate that zebra mussels had colonized most of the available hard

Did you know?

The detection frequency of zebra mussels in Lake Winnipeg increased from 8% to 32% between 2017 and 2019, with colonization density of the south basin considered moderate.

substrate in the south basin and Narrows region, but that colonization of the north basin was low. Mean lake-wide densities increased from 2017 to 2019 but remained low overall due to the numerous sites that did not have any mussels present. The distribution appeared to be limited by substrate type and availability, particularly in the deeper areas of the lake, but also due to physical disturbance, likely from wave action and ice scour of suitable substrates in shallow waters. Zebra mussels that were less than one year old were dominant, and larger mussels were rare.

Estimates of sediment phosphorus release and the capacity of the sediments to store phosphorus are needed to improve models of nutrient cycling in the lake. To address this gap, sediment cores were collected to assess phosphorus concentrations, phosphorus binding forms and to estimate diffusive fluxes of phosphorus. Preliminary results indicate that there may be different phosphorus immobilization processes in north basin sediments relative to south basin sediments. In the north basin, the data suggested that sediments may be a net source of phosphorus to the overlying waters, while in the south basin, even with high sediment phosphorus, the sediments of the south basin have a higher capacity to retain phosphorus than those in the north basin.

Work on characterizing the phytoplankton and microbial communities in Lake Winnipeg and investigating factors that influence their distribution to better understand and predict the occurrence of harmful algal blooms in the lake has been initiated. As well, an assessment of sediment microbial metabolism at the sediment-water interface to gain insight on potential periods of anoxia or low oxygen, and on how microbes can influence nutrient cycling in the lake is also underway.

Through previous funding, satellite remote sensing was used to develop a suite of algal bloom indices (bloom duration, extent, intensity, and severity) for Lake Winnipeg. In addition to continued reporting of the bloom indices, the science plan also enabled improvements to the methods used to acquire and process the data, the algorithms used to generate the indices, and the development of new methods to fill in data gaps and new indices of water clarity. A system was developed to fully automate satellite image acquisition and processing using data from the European Space Agency's Sentinel-3 OLCI satellite sensor. Image products and derived bloom indices are now produced operationally on a daily basis, distributed in near-real-time through the EOLakeWatch web portal, and compiled into annual bloom reports for the lake.

> ***Did you know?***
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> *Since 2002, the annual maximum spatial extent of algal blooms has varied from approximately 25% to 88% of the lake area.*

The lake ecosystem model developed under previous program funding was revised using higher resolution data which changed the horizontal spatial resolution from 2km to 500m. The lake bathymetry was updated using recent bathymetric surveys to resolve complex nearshore bathymetry and the Narrows more accurately. The lake model was also used to run scenarios using a combination of buoy-based observations (e.g. flow, temperature) and the outputs from the global model. The lake model can currently simulate year-round hydrodynamics such as inter-basin flow exchanges, ice development/melting, temporal changes in the stratification and circulation patterns, and can be used to assess the year-round lake ecosystem, including ice periods.

Lastly, the second edition of the State of Lake Winnipeg report was published in 2020. This comprehensive report focused on 14 key measures of Lake Winnipeg's ecosystem. The report indicated that no extreme changes were detected in the lake, but that nutrient loading to the lake remained high relative to historical loading rates. The report also highlighted that a significant gap remained in terms of including Indigenous knowledge to inform understanding of current impacts and future risks to the lake. Questions emerged regarding impacts of invasive species, climate change and the effects of microplastics on the aquatic food web were also highlighted.

For more information contact the Lake Winnipeg Basin Program at LW.Info@ec.gc.ca