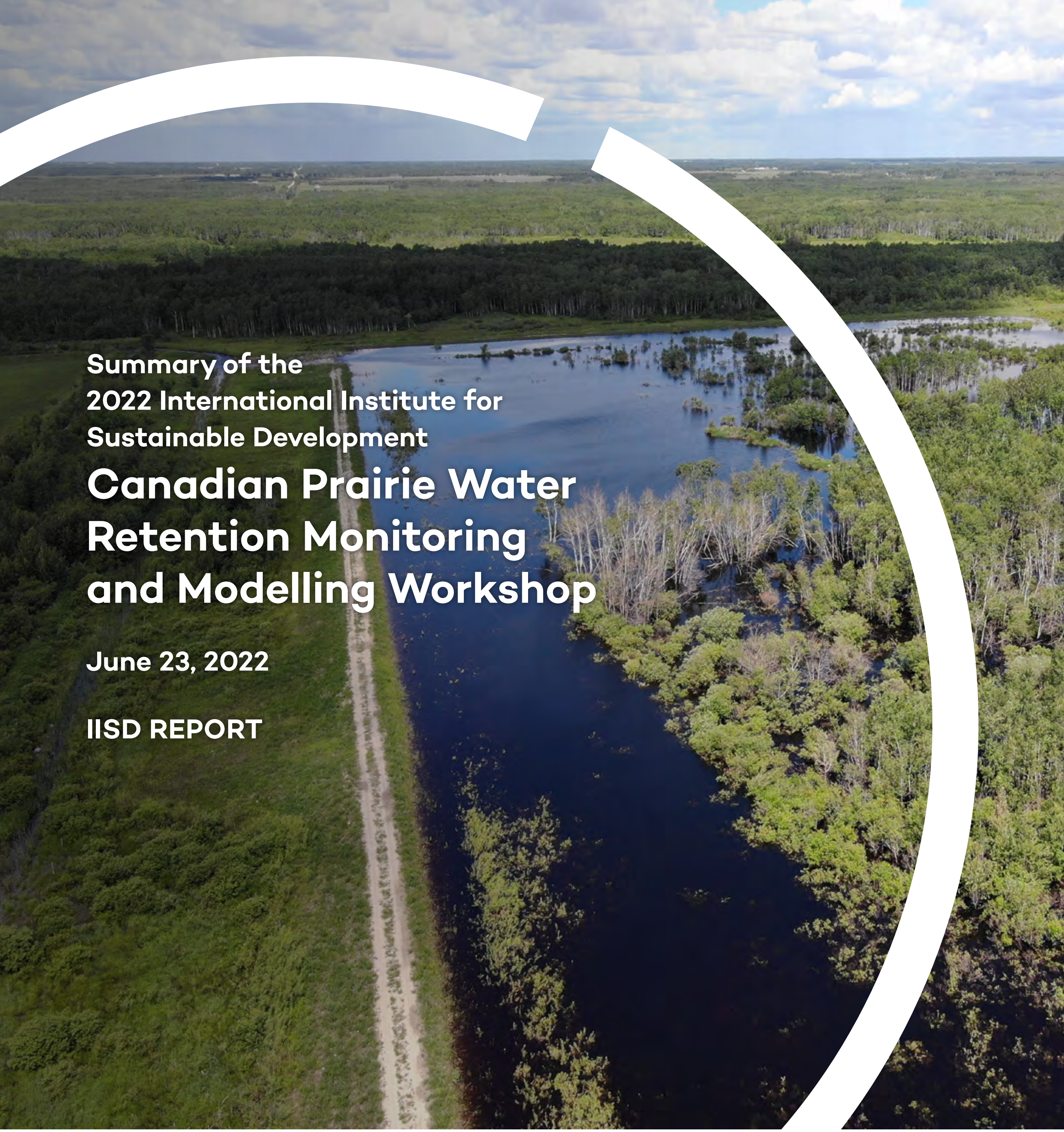

Summary of the
2022 International Institute for Sustainable Development

Canadian Prairie Water Retention Monitoring and Modelling Workshop

June 23, 2022

IISD REPORT

International Institute for Sustainable Development

November 2022

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Cover photo: IISD

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Event Summary

On June 23, 2022, The International Institute for Sustainable Development (IISD) hosted a full-day virtual workshop on monitoring and modelling for water retention projects across the Canadian Prairies. The meeting was designed to be a place to share, receive feedback, and determine collaboration opportunities with respect to existing, ongoing, or proposed water retention projects. Participants from government and non-government organizations, academia, and industry were all invited to participate. In total, the workshop provided nine different presentations for 20 attendees and ended with a discussion session to identify opportunities and next steps in the areas of advancing water retention science and business case development. Presentations ranged from foundational historical research, like for those water retention structures monitored as part of the Watershed Evaluation of Beneficial Management Practices (WEBs) program, to how technologies like spectral sensors are being used to advance the state of the art in water retention monitoring and modelling today. This document summarizes those talks and key takeaways from the workshop's final discussion session.

Participants

Joey Simoes (host, IISD), Jason Vanrobaeys (Agriculture and Agri-Food Canada [AAFC]), Justin Reid (Redboine Watershed District), René Morissette (AAFC), Bryan Page (Ducks Unlimited Canada), Ashley Rawluk (IISD), Shanwei Xu (AAFC), Julie DePauw (University of Waterloo and Lake Winnipeg Foundation [LWF]), Sung Joon Kim (Government of Manitoba), Mark Lee (Government of Manitoba), Richard Grosshans (IISD), Chelsea Lobson (LWF), Jane Elliot (Environment and Climate Change Canada [ECCC]), Alexander Wall (University of Manitoba), Abu Ahmed (Government of Manitoba), Ken Rakhra (Government of Manitoba), Chris Parsons (ECCC), Colin Gluting (Northeast Red Watershed District), Colin Whitfield (University of Saskatchewan), Steven Simpson (Aquatic Life Ltd)

Small Dams in the South Tobacco Creek Watershed: Water quantity and quality

Presented by Jane Elliot (ECCC)

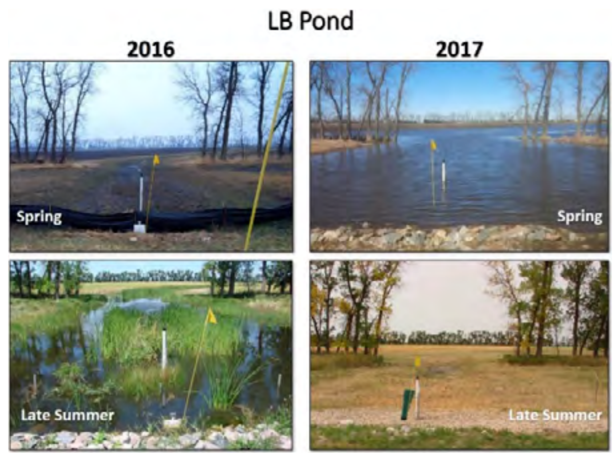
A series of 26 small dams (five dry dams, six back flood dams, and 15 multipurpose dams) was constructed in the South Tobacco Creek Watershed between 1985 and 1995 to provide peak flow reduction, decreasing the risk of flooding across 30% of the watershed. Two dams were monitored for their effectiveness, including the Steppler dam from 1999 to 2014 and the Maddill dam from 1999 to 2007. Results indicated that the small dams were successful at reducing peak flow and extended the flow period. The effectiveness in removing nutrients and sediment was less consistent and was influenced by the depth of the reservoir during the snowmelt or precipitation event, as well as the quantity and timing of the runoff event. Nutrient loads could be further reduced if the reservoir water was used as irrigation for annual cropland and/or if the reservoirs are regularly maintained to avoid becoming a nutrient source (rather than a sink).

Source: Provided by the presenter.

This project has led the way for more water retention projects in the Prairies, although there was, and continues to be, a lack of funding for monitoring their effectiveness, particularly with regard to nutrient retention and sedimentation. The Steppler and Maddill data sets will be publicly available and may be useful for the IISD lead project Nutrient Reduction Modelling Meta-Analysis for Cold Climate Prairie Water Retention (final presentation) and other efforts.

Water and Nutrient Retention Study: Retention Pond Performance Summary 2016–2019

Presented by Jason Vanrobaeys (AAFC)



Source: Provided by the presenter.

Researchers at the Morden Research and Development Centre site identified two locations within their research fields that were often not seeded or had poor yields due to standing water and/or saturated soils. In 2014, they built two dams with water control structures to manage the quantity of water in the newly constructed retention ponds. They have monitored flow and nutrients, including total dissolved phosphorus (TDP), total phosphorus (TP), and total suspended solids (TSS) since 2016, as well as the crop type and yields in the surrounding fields. Hydrological conditions were inconsistent throughout the years, providing insight into a broad range of conditions. For example, the spring of 2016 had little snow melt, and the pond depth remained low, but then heavy precipitation throughout the summer filled the pond. Conversely, heavy snow melt filled the ponds in 2017, which dried up as the summer progressed with little precipitation. Water samples were only collected when there was inflow to, or outflow from, the retention ponds.

Results from 2016 to 2019 for the 0.79 ha "LB" pond built along a natural swale demonstrated its effectiveness. The average % reduction from 2016 to 2019 was ~65% for water quantity, ~80% for TDP, ~78% for TP, and ~82% for TSS. Overall, the retention provided good performance, with a relatively low investment and the removal of some marginal agricultural land from production. Future work will examine the influence of soil and vegetation in the pond and surrounding land on phosphorus levels, as well as the value of harvesting emergent vegetation to further reduce phosphorus concentrations in outflow.

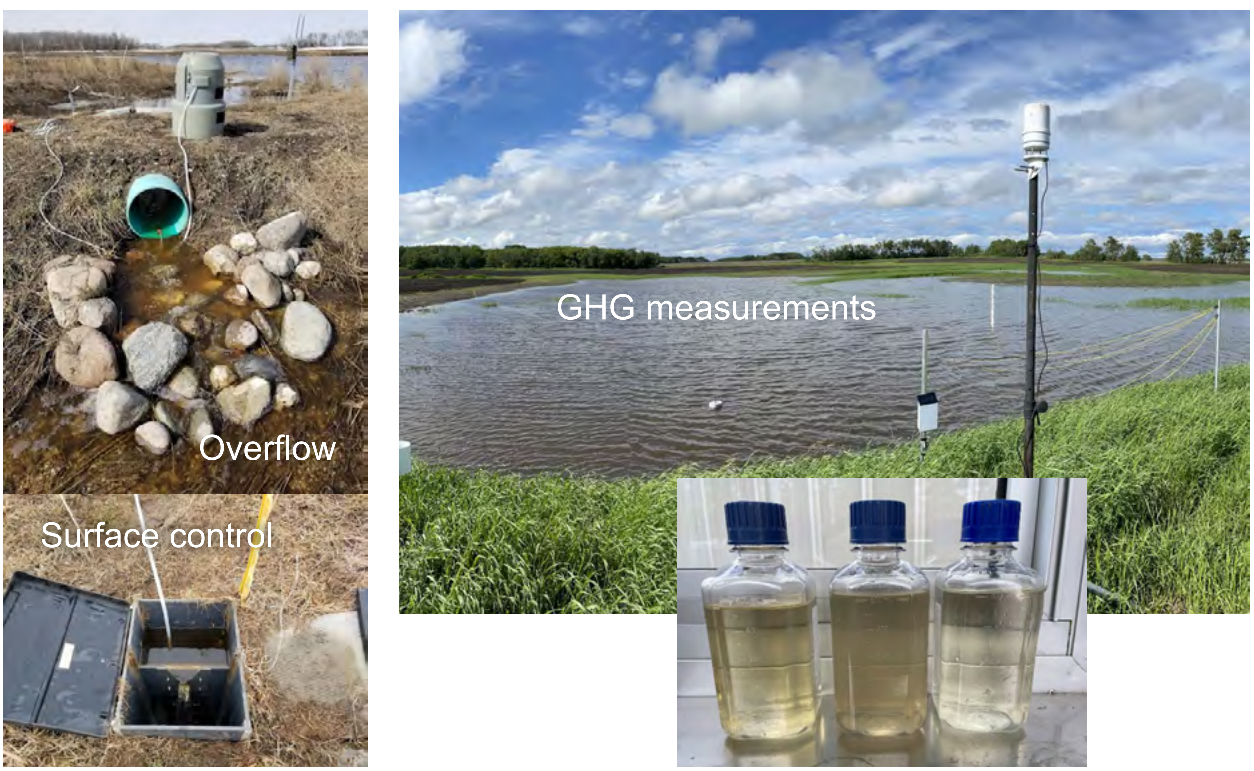
Despite impressive reductions to flow and nutrients, a workshop with local crop producers indicated that interest in converting agricultural land for water retention is low, even on marginal land, as it is difficult to farm around these areas with large, modern equipment and the perception that the presence of standing water will devalue the land. The installation of water control structures, such as gated culverts and stoplog bays, facilitates water level management and can be manipulated to bolster performance (e.g., increased retention time can improve nutrient retention).

Updates for Morden and Kenton Sites

Presented by Shanwei Xu (AAFC)

The Kenton Water Retention and Infiltration Gallery (1-ha) was constructed in 2019, with a 61-ha contributing area that is high in phosphorus, receiving applications of liquid hog manure. A portion of the ponded area has tile drainage installed to facilitate harvest and encourage deeper flow paths and soil water interaction. Initial results showed lower TDP concentrations in the outflow from tile-drained land as compared to surface drainage during snowmelt in 2020, while drought season resulted in no outflow observed in 2021. Hydrological measurement and sample collection work are currently being conducted over snowmelt and rainfall runoff season in 2022.

Future research includes measurements of greenhouse gas emissions (GHG), assessments of other contaminants, including antimicrobials and pesticides, and microbiome characterization of the water and sediment. The environmental benefits will be compared with the financial investment, as well as modelling work to compare and evaluate various sites at the watershed scale.



Source: Provided by the presenter.

Water Quality Implications From Natural, Restored, and Drained Wetlands

Presented by Bryan Page (Ducks Unlimited Canada)

Historical wetland loss across the Prairies is estimated at 483,000 ha, and drainage, unfortunately, continues today. Research near Rapid City, Manitoba (2014/2015) and in the Broughton's Creek Watershed (2008/2009) demonstrates that drained wetlands facilitate the movement of phosphorus off the landscape, often at a rate greater than cropland export rates reported for Manitoba (0.65 kg/ha/year with conservation tillage and 0.39 kg/ha/year with conventional tillage). The 2-year average phosphorus export was 1.7 kg/ha/year from the drained wetlands basins in annual cropland at Broughton's Creek and 0.43 kg/ha/year from the drained wetlands basins within a region of high wetland density near Rapid City. Intact wetland basins near Rapid City demonstrated an average TP retention of 3.28 kg/ha/year over 2 years, which is desirable for improving downstream water quality.

Source: Provided by the presenter.

Further research examined the retention capacities of newly restored wetland basins along the edge of annual cropland in southwestern Ontario over 2 years (2019/2021). The average wetland retention capacity of TP was 11.7 kg/ha/year, with 7.4 kg/ha/year in year 1 and 16.1 kg/ha/year in year 2. Both years demonstrated that as the TP load increased, so did the TP nutrient retention capacity.

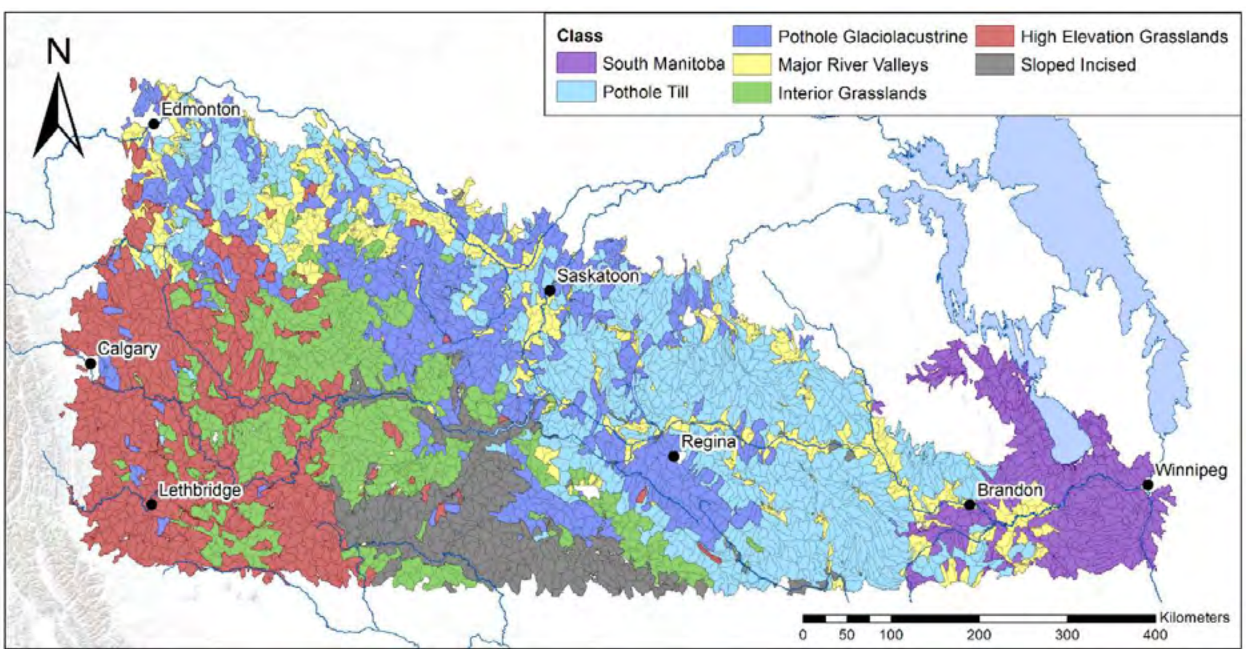
Overall, drained wetlands facilitate the export of TP downstream, while intact and restored wetlands retain TP on the landscape. There is some indication that Manitoba's cold climate may decrease TP retention in comparison to warmer climates, but the most significant influence on TP retention is the TP load into the wetlands. Monitoring other forms of phosphorus, such as Soluble Reactive Phosphorus (SRP), is encouraged whenever possible as SRP is the most bioavailable form of phosphorus for algae. SRP analysis is relatively inexpensive to incorporate into an established water quality monitoring program and provides critical information that can further guide nutrient management in Manitoba.

Nutrient Cycling and Greenhouse Gas Dynamics of Agricultural Reservoirs and Wetland Ponds

Presented by Dr. Colin Whitfield (University of Saskatchewan)

Dr. Whitfield is leading research looking at GHG emissions from retention ponds at South Tobacco Creek and wetlands across the Prairie ecozone, including St. Denis National Wildlife Area. At South Tobacco Creek, the addition of carbon and/or nitrogen increased the production of nitrous oxide (short term) and methane, although methane release varies considerably amongst the reservoirs. Existing pothole wetlands at St. Denis showed that nitrogen is cycled quickly via uptake by microbes in both light and dark conditions, and in the benthic zone, dissimilatory nitrate reduction to ammonia was favoured over denitrification.

Dr. Whitfield is contributing to an updated watershed classification for the Prairies, which is being used to explore how wetland drainage affects streamflow patterns in the pothole till watershed class (teal). The impact of wetland drainage increases hydrologic connectivity and surface water runoff from small watersheds, with phosphorus export expected to double or triple in watersheds where wetland drainage is complete or near complete.



Source: *Watershed classification for the Canadian prairie*, https://hess.copernicus.org/preprints/hess-2018-625/hess-2018-625.pdf

LWF's Agricultural Water Stewardship Program: Initial results summary

Presented by Julie DePauw (LWF and the University of Waterloo)

The LWF's flagship initiative, the Lake Winnipeg Health Plan, is focused on eight evidence-based actions to reduce phosphorus entering Lake Winnipeg. Action 4, Monitoring Our Waterways, includes the Lake Winnipeg Community-Based Monitoring Network (LWCBMN), which coordinates citizen scientists and watershed partners to frequently sample across Manitoba in response to snowmelt and rain events. The LWCBMN findings are displayed in phosphorus hotspots (red zones) maps, which can be used to strategically implement reduction strategies.

Source: Provided by the presenter.

Action 6, Promoting Agricultural Water Stewardship, was a 2-year pilot program monitoring phosphorus concentrations and flow from two water retention ponds (Pelly's Lake and McLean's dam), located in phosphorus hotspots. The preliminary 2021 Pelly's Lake results demonstrated higher TP concentrations at the outlet than inlet; however, with approximately 40% phosphorus sequestration in drought conditions. The medians calculated from the 5-year concentration dataset show that on average, phosphorus concentrations are greater at the outlet than the inlet, though mass loading rates are needed to understand the full extent of change.

Due to variability in snowmelt and rainfall events, as well as site management (e.g., releasing water at Pelly's Lake in 2021 due to downstream water shortages), further analysis of the 2020 dataset and exploration into the impact of flow is needed to better understand the variability in phosphorus concentrations. For example, the low inlet concentrations may accumulate some phosphorus from the vegetation or legacy phosphorus as it moves through the pond. Evaporation may also influence the concentration, particularly during drought.

De Salaberry and Ste. Geneviève Water Retention Monitoring and Modelling

Presented by Joey Simoes (IISD)

IISD has been collecting data and modelling performance at the De Salaberry retention pond since 2019. Models developed for the site include a hydrologic model developed with the Hydrologic Engineering Center's Hydrologic Modeling System (HEC-HMS) for the upstream watershed, a 2D hydraulic model developed in HEC-RAS for the interior of the site, and a water quality treatment model, again for the interior of the site, which relies on outputs from HEC-RAS for retention time and reservoir depth estimates. The monitoring program has been adapted with a continually improving understanding of the system and as access to additional technology has become available. For example, to better plan field trips, cellular trail cams were added in 2022 to provide observations of on-site conditions remotely. An additional automated water quality sampling site was added in 2021 at the centre of the site to allow the study area to be divided into two separate water quality modelling domains.

Results from the monitoring and modelling efforts indicate that the De Salaberry water retention site provides an approximate 40% to 50% reduction in peak discharge for 10 to 100-year 24-hour storm events and retained 237 and 98 kg of phosphorus in 2019 and 2020 respectively. Alternative site management and design modifications to improve retention time at the site were assessed to evaluate impacts on water quality treatment performance. The design modification

Source: Provided by the presenter.

assessments included changing the outlet culvert size and elevation; adding a gate or water control structure; raising spillway elevation; and increasing the reservoir size. Better management of the site to ensure that the inlet is unobstructed was also recommended so that the maximum volume of water enters the retention site during low flow periods, improving overall nutrient removal.

IISD initiated monitoring at the Ste. Geneviève water retention site in 2022 and includes the use of remotely accessible data from UV-Vis spectrometers. These technologies were implemented at this site in collaboration with Aquatic Life and were discussed in more detail in their following presentation. The monitoring program will continue at Ste. Geneviève beyond 2022 but may eventually move from De Salaberry to a new site, depending on 2022 monitoring results. A 2D-hydraulic model is not currently planned for development at Ste. Geneviève, like what has been developed for De Salaberry, as it may not be required to meet specified project objectives. That is, the objective of the Ste. Geneviève monitoring project is to contribute additional data for the Nutrient Reduction Modelling Meta-Analysis for Cold Climate Prairie Water Retention project discussed in the final presentation for the workshop.

Spectral Sensors for Water Retention

Presented by Steven Simpson (Aquatic Life Ltd)

Aquatic Life provides unique water monitoring solutions, including UV-Vis spectrometers, multiparameter sondes, hydrometric instrumentation, and cellular and satellite telemetry. Monitoring is conducted within the Winnipeg River Basin (three sites) and at the Ste. Geneviève retention pond, where a UV-Vis spectrometer is operated in conjunction with an ISCO autosampler, collecting four measurements 120 seconds apart at the top of the hour. This frequency provides a balance between data collection and battery life, particularly where foliage may shade the solar panel. The spectrometer scans the spectral "fingerprint" of water, identifying different substances based on the wavelength at which they absorb visible and ultraviolet light (Beer-Lambert law).

Source: Provided by the presenter.

The data generated at the Ste. Geneviève site is unique, with dissolved organic carbon (DOC) and turbidity relatively stable, but with fluctuation amongst phosphorus, nitrogen, and biological oxygen demand. Phosphorus does not directly respond in UV-Vis, and may be determined using a surrogate relationship with total/dissolved organic carbon, turbidity, and colour. These surrogate parameters, however, are highly dependent on the local watershed and seasonal factors.

Currently, the accuracy of the UV-Vis data is dependent on conditions at the site location, so there is interest in moving beyond colour and turbidity to measure phosphorus. A technique has been developed for the laboratory, but it is large and requires a lot of energy and thus is not yet usable in real-world applications. Another goal is to develop a more general calibration that doesn't require upfront site-specific data collection. To maintain accuracy, the lens is cleaned twice a day via an air compressor to remove debris; a mechanical wipe is most commonly used, although there is a greater risk of scratching the lens. The price of UV equipment depends; base models are around $20,000 and the price increases with additional features like remote data access as opposed to an onboard data logger.

Nutrient Reduction Modelling Meta-Analysis for Cold Climate Prairie Water Retention

Presented by Joey Simoes (IISD)

It is common for analyses of water retention sites to assess the percent reduction in nutrients: this value is sometimes simply transferred between sites with similar characteristics to provide estimated removal rates. Treatment models are beneficial in that they can be used to develop nutrient reduction estimates that consider parameters known to significantly influence reduction rates such as retention time, retention depth, and nutrient gradient through a site. Using a nutrient removal model originally designed for treatment wetlands, a treatment rate coefficient can instead be the parameter that is transferred between water retention sites to estimate removal rates, accounting for differences in unique site characteristics.

Source: Provided by the presenter.

This approach was used in the De Salaberry modelling; however, IISD could not calibrate their own treatment rate coefficient due to the observed internal loading between the site inlet and retention volume prior to the deployment of an additional automated water sampling deployment location at the centre of the site. Thus, an average treatment rate coefficient from an existing meta-analysis of cold climate free water surface wetlands was used instead. Simply applying the percent removal rate from a previous treatment wetland meta-analysis to the South Tobacco Creek Steppler dam and the De Salaberry site creates a gross overestimation of percent TP reduction. By extrapolating the average treatment rate coefficient instead at De Salaberry, the average percent reduction was 6.7% and 7.6% in 2019 and 2020 respectively. These percent reductions are expectedly low due to high flows and spillway usage, resulting in limited hydraulic retention times.

With data requirements for site retention time, retention depth, and incoming and outgoing nutrient loads satisfied, the treatment rate coefficient can be determined for a specific site. An average treatment rate coefficient for cold climate prairie water retention can also be determined by compiling values from sites of similar geography and climate. IISD is collaborating with other organizations that have carried out (or are currently carrying out) water retention monitoring and intends to collect the data required to perform this meta-analysis. An accurate average treatment rate coefficient for cold climate prairie water retention would be useful in designing future retention sites to optimize nutrient removal in addition to flood reduction. This average treatment rate coefficient could also be used to increase the accuracy of assessments for existing water retention site performance needed for cost–benefit analyses and reporting for conservation programs.

Discussion: Opportunities and Next Steps

Following the nine workshop presentations, attendees discussed opportunities and next steps to further water retention research in the Prairies and to enhance collaboration. One of the questions posed to the group was with regards to whether there were known plans to expand the number of water retention sites currently being monitored in the Prairies. At present, no attending organization could confirm additional sites to be monitored in the future. IISD is considering discontinuing monitoring of the De Salaberry water retention site after the 2022 field season but wishes to examine the 2022 data first and identify more useful alternative sites before committing to any action. Although new collaboration opportunities could not be identified for new sites, it should be noted that a high degree of collaboration already exists between attending organizations, including sharing of monitoring equipment, access to laboratory analyses for water quality sampling, and data sharing to reach similar research objectives.

Another question posed was whether the current state of research could support building a better business case for natural infrastructure projects like water retention, enabled through tools that could optimize both their flood and nutrient reduction benefits. Participants noted that it is difficult for provinces and rural municipalities to estimate monetary benefits from nutrient reduction but quite easy to quantify benefits from water volume reduction (e.g., less flooding and fewer washed-out roads). They also stated that straightforward modelling approaches are important, so that nutrient reduction benefits can be increased with only minor adjustments to existing standard practices. That is, many consultants already use simple methods for designing the size of a pond (e.g., the rational method), and they may not be keen on including more complicated parameters, such as those required for nutrient considerations. Furthermore, there is a need for more and longer-term phosphorus hotspot maps to better target those locations on the landscape that would be best served by water retention project development to maximize their benefits. Ultimately, it is well understood that many new water retention projects are being developed in the Prairies, but optimization for nutrient reduction is largely not considered. A small shift in design philosophy for these water retention structures (which primarily focus on flood mitigation and water supply) could prevent additional co-benefits from being left on the table.

Further discussion also occurred regarding performing cost–benefit analyses to support greater adoption of natural infrastructure like water retention in the Prairies. It was noted that an economist at AAFC is looking at the impact of taking marginal land out of agricultural production to build retention ponds, as it is hard to quantify the production losses in economic assessments. Research and development at the University of Saskatchewan is also underway to create a wetland conservation tool for producers to determine the cost and benefits of draining or conserving a wetland for producers in Saskatchewan, where land is still actively drained. This tool may help influence producers to keep from draining wetlands for their own and societal benefits. Finally, funding programs to compensate producers for taking marginal land out of production were also discussed and agreed to provide positive results (e.g., Alternative Land Use Services).

The discussion period for the workshop concluded on the topic of needs within the field of water retention studies. Those prominent needs identified included:

- Higher frequency and quality of water quality monitoring data and more reliable methods of time-series analysis to process them.
- Measurements for other variables of interest beyond states of matter like total, dissolved, and particulate nutrients, such as the reactive forms of nutrients and salinity.

With current needs apparently being focused on data quality, frequency, and variety, there is an agreed-upon need for continued and more comprehensive monitoring efforts for water retention in the Prairies. These monitoring programs, however, are limited based on available funding. Existing research through efforts such as the WEBs program has been foundational to increasing the adoption rate of water retention across the Prairies. However, there are still plenty of opportunities to optimize the ways in which we engineer, manage, and quantify the primary and co-benefits of these systems simultaneously.

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