REPORT SUMMARY

Positioning Water Retention for Phosphorus Reduction

A spatial targeting strategy for Canadian Prairie watersheds

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May 2025

Key Messages

- Water retention, such as wetlands or small naturalized dams, reduces flood/drought risk and improves water quality, which is **critical for climate change adaptation in the Canadian Prairies**.
- Through spatial targeting, we can **improve the position of water retention projects** to intercept phosphorus, maximizing benefits and return on investment.
- **Spatial targeting is possible today with models such as PTMApp** that leverage publicly available datasets like LiDAR-based digital elevation models.

The Importance of Water Retention

The loss of natural water storage on Canadian Prairie landscapes over time has resulted in reduced water availability during dry years and greater flooding during wet years. With our changing climate, more frequent prolonged dry periods and more extreme rainfall events exacerbate these issues.

Agriculture and Agri-Food Canada

Manitoba Association of Watersheds

Natural infrastructure that provides water retention, like wetlands or small naturalized dams, is widely recognized for providing a multitude of benefits that can help us adapt to our changing climate on the Canadian Prairies (Simoes et al., 2023). These benefits include reducing the risks of both floods and droughts, improving water quality, creating habitats and improving biodiversity, and reducing atmospheric carbon, along with a variety of other economic benefits that make water retention an investment with a strong return (an estimated CAD 2.45 in benefits for every dollar spent [Puzyreva et al., 2022]). However, the wealth of benefits offered by water retention may only be achieved alongside careful site design, maintenance, and operation. Analytical practices that quantify flood mitigation for water retention site designs are common, but benefits like phosphorus reduction are often only qualitatively assessed.

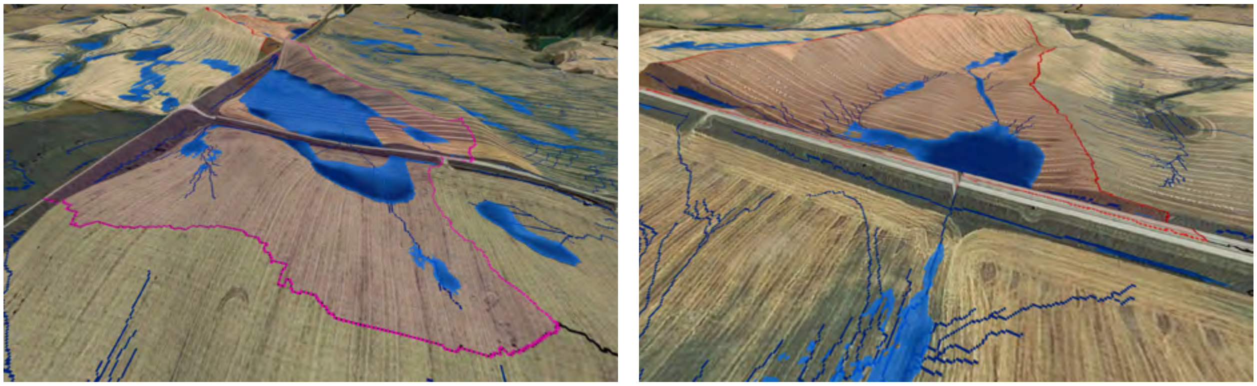
Phosphorus reduction analyses and site selection for new water retention projects need to consider both the spatial variability of water quality across the landscape and the performance of potential sites in treating that water. These considerations allow us to better assess and maximize the water quality benefits at a given cost. Spatial targeting models like the Prioritize, Target, and Measure Application (PTMApp) help us respond to this need, but strategies for developing and using these models that respect the unique characteristics of the Canadian Prairies are required.

A Spatial Targeting Strategy for Canadian Prairie Watersheds

Any successful spatial targeting strategy needs to consider the physical and climatic conditions, as well as any water-related objectives relevant to the local geography for which they are developed. In the Canadian Prairies, the eutrophication of Lake Winnipeg is of particular concern, and spring runoff is simultaneously a high-frequency and high-magnitude phosphorus-loading event that we can use to conservatively evaluate water retention project performance. In fact, we have found that the average yearly spring runoff event is 78% larger by volume than the largest rainfall event that can be estimated to typically occur in a day over the course of 10 years within the Swan Lake study area of the Living Lab Eastern Prairies.

Non-contributing areas also pose difficulties in the development of Canadian Prairie watershed models. Non-contributing areas are the parts of the watershed that do not contribute to downstream runoff under average annual conditions. Naturally, these areas can vary year by year depending on the weather and climate, but it is important to know approximately where they are so that we can deprioritize water retention project development in regions that are already effectively retaining water and excess nutrients like phosphorus (Figure 1).

Figure 1. 3D visualizations of prairie pothole agricultural landscapes and known non-contributing areas (delineated purple and red areas)



Source: Authors' diagram.

Data Needs

With the increasing availability of Light Detection and Ranging (LiDAR)-based digital elevation models (DEMs), culvert inventories, and spatially distributed phosphorus concentration datasets on the Canadian Prairies, more accurate estimates of phosphorus loading from spring runoff events and non-contributing areas have become possible in recent years.

Figure 2. Field-scale flow accumulation analysis using a LiDAR-based DEM (elevation drops primarily from right to left)

Source: Authors' diagram.

LiDAR-based DEM data, which provides high-resolution surface elevation information, is a necessity for detailed field-scale hydrologic analyses. High-resolution DEMs enable the precise mapping of terrain, water flow paths, and landscape features critical for modelling Canadian Prairie runoff and drainage patterns. For example, Figure 2 shows primarily western-directed flow paths over a 1 mi^2 section of farmland and the patterns of drainage through natural undulations of the landscape, made possible using a LiDAR-based DEM. Culvert inventories are another important data set that can be used to further increase the accuracy of runoff and drainage patterns in developed areas. However, to be most useful within modelling, culvert inventories need to include specifications for culvert inlet and outlet coordinates, including surveyed elevation.

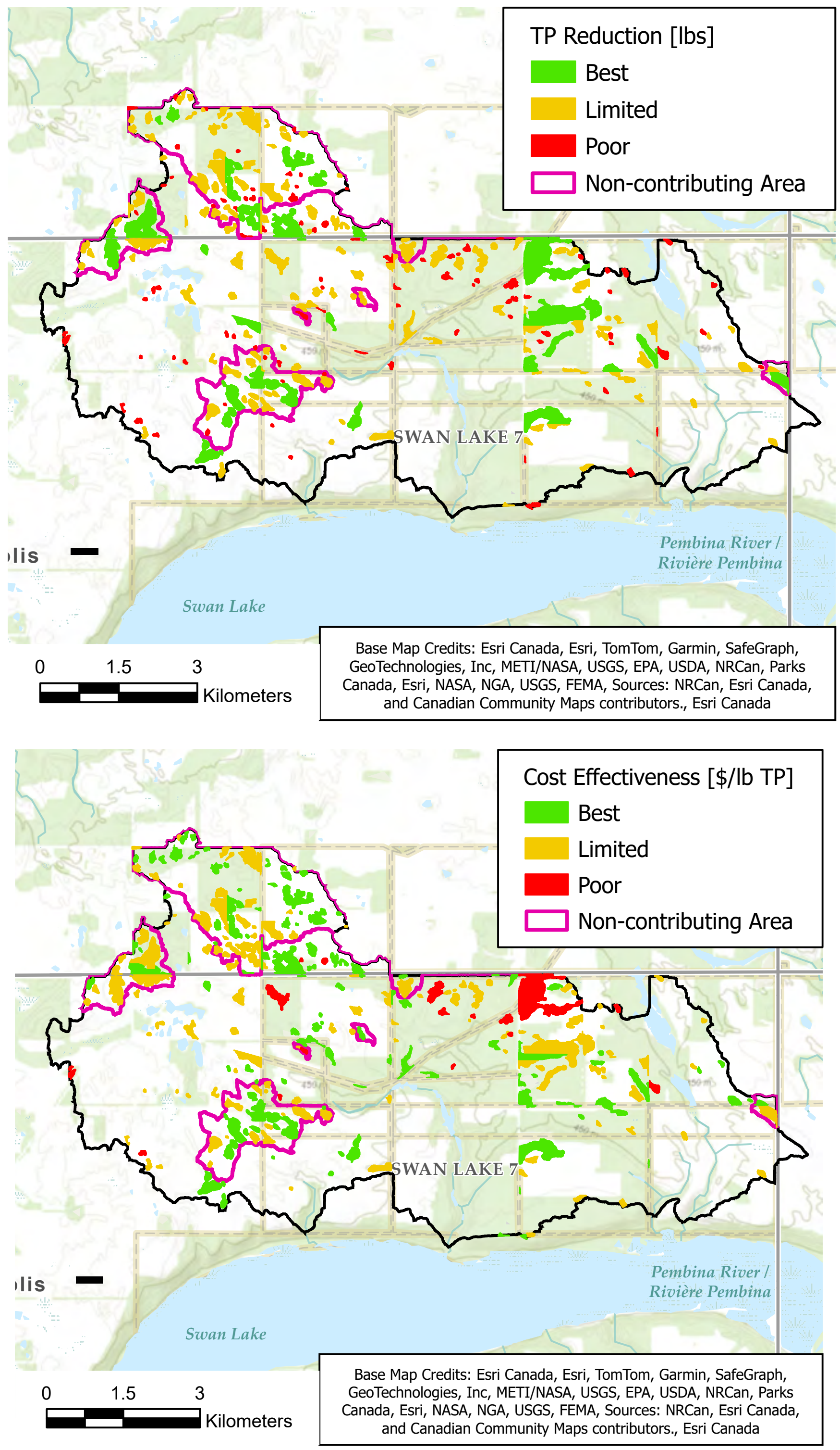
Beyond the standard datasets needed for hydrologic model development, spatial targeting models like PTMApp require export coefficients to estimate phosphorus runoff originating from different land types. By default, PTMApp provides phosphorus export coefficients associated with different land types to determine non-point source nutrient loads, but without calibration, these can be inaccurate for Canadian Prairie watersheds. Using publicly available phosphorus data from rivers and streams (Lake Winnipeg Foundation, 2019; Manitoba Environment and Climate, n.d.), the accuracy of these export coefficients can be improved by grounding them in measured data from hydrologic events like the spring runoff.

Phosphorus data not available in your watershed?
IISD shared calibrated phosphorus export coefficients for 1-in-2- and 1-in-10-year spring runoff events that may be applicable for use within your study area. See page 28, Table 2, in the full report.

Your Next Water Retention Project—But Better

IISD has developed and shared a strategy to perform spatial targeting of water retention projects on the Canadian Prairies. It was also developed for an ungauged basin, which makes the strategy replicable in regions where measured water quality and quantity data may be limited or unavailable. Furthermore, a method for the identification of non-contributing areas was also tested, making the strategy more relevant to the Canadian Prairies. Best of all, with the exception of ArcGIS (Map or Pro), any additional tools and models used in this strategy are all publicly available and free to use.

Figure 3. Total phosphorus reduction (top) and cost-effectiveness (bottom) of water retention and non-contributing areas



Source: Authors' diagram.

While IISD's focus to date with the PTMApp model has been within Manitoba, its use can be expanded across Canada anywhere high-resolution DEM data is available. Our strategy demonstrates how you can map out feasible projects in your watershed, including cost-benefit ratios based on water quality benefits. For funders investing in water retention projects, this information is invaluable for ensuring more strategic use of tax dollars and funding. For Watershed Districts exploring water retention options, this information can support identifying new sites and provide confidence that selected projects will meet their water quality improvement objectives.

To demonstrate, Figure 2 shows the total phosphorus reduction performance and cost-effectiveness of water retention project options resulting from a 1-in-2-year spring runoff event and the average annual non-contributing areas for a subset of the Swan Lake study area. The green shaded areas in the left map provide the greatest phosphorus reduction, and the shaded areas in the right map represent the most cost-effective. Areas bounded by purple in both maps already retain water well during lower-flow years. Access to this information enables funding for future water retention projects to be used more strategically.

Recommendations

To accelerate the adoption and use of spatial targeting models, several recommendations can be made regarding data, training, funding, and support. The availability of data for modelling and creating inventories of beneficial management practices and natural assets (including but not limited to water retention projects) needs to be improved to better track our progress toward specific goals outlined in integrated watershed management plans. Watershed practitioners need training on how to develop spatial targeting models and the best approaches for leveraging model outputs to support management decisions. Funding is also needed to support the timely development of these models by engineers.

Improved Data Collection and Sharing

Across the Canadian Prairies, many groups are working on climate adaptation plans. Within many of these plans, water retention is likely to stand out for reducing flood and drought risk and for improving water quality, among other benefits. With spatial targeting models, plans including water retention can be developed more systematically and less opportunistically, resulting in greater overall impact. To accomplish this, we need **good data**, but it is up to governments, watershed managers, and other stakeholders to fund and facilitate the collection of LiDAR DEMs, culvert inventories, and water quantity and quality data.

Education and Awareness for Prioritizing Watersheds

IISD's strategy for developing spatial targeting models helps **train** watershed practitioners. However, selecting the right watersheds to dedicate resources for future spatial targeting models is another important consideration. Spatially distributed monitoring data like that collected by the Lake Winnipeg Foundation can be used to identify water quality hotspots directly and develop recommendations. Alternatively, publicly available model outputs like the binational SPAtially Referenced Regression On Watershed attributes (SPARROW) model (Robertson et al., 2019) can be used to assess watersheds that are not yet monitored.

Funding Programs and Projects for Development and Implementation

Considering the provision of so many benefits from water retention, there is a strong case for **funding** the development of new projects, even without considering the flood benefits that typically motivate their construction. Producers and watershed districts would benefit from funding, such as through government support, to create programs and support the implementation of better water retention practices. The financial support can incentivize adoption and benefit communities through improving water quality, creating habitats and improving biodiversity, and reducing atmospheric carbon, along with a variety of other economic benefits that make water retention an investment with a strong return.

Support and Awareness for Producers and the Agriculture Industry

Securing funding can help convince producers that their support in integrating water retention as part of agricultural operations benefits everyone. Having programs in place to alleviate the costs of implementation, explain benefits, and motivate potential partnerships for new water retention projects can build support and momentum and increase awareness within the agricultural industry. For the Living Labs Eastern Prairies, this support was facilitated through the process of co-development and is recommended for any similar spatial targeting efforts.

Are you interested in developing spatial targeting models for your watershed? IISD can develop spatial targeting models using PTMApp or provide you with the assistance you need to create your own.

For more information, contact Joey Simoes at jsimoes@iisd.ca.

To learn more, see our full report.

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Published by the International Institute for Sustainable Development

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