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Effect of Multiple BMPs on Water Quality and Runoff

Substantial nutrient loss reductions achieved in a small Prairie watershed

Summary: Researchers in the South Tobacco Creek (STC) Watershed in south-central Manitoba have discovered that the application of multiple beneficial management practices (BMPs) in agricultural areas can substantially reduce nutrient losses to surface water. BMPs are farming practices designed to minimize potential negative impact on the environment.

Significant nutrient reductions were observed at the outlet of a small (205-hectare, 507-acre) sub-watershed after five BMPs were implemented. The BMPs did not produce any significant change in runoff volumes. Economic assessments of each of these BMPs are in progress, and modelling is underway to scale up the water quality and runoff values over the entire STC Watershed.

The 7,500-hectare (18,500-acre) STC Watershed is located on the edge of the Manitoba Escarpment and is part of the Lake Winnipeg Basin. Deteriorating water quality in Lake Winnipeg has been partly attributed to excessive nutrient loading from agricultural activity. The Lake Winnipeg Stewardship Board (2006) estimates that agricultural activities in Manitoba contribute 5% of the total nitrogen (N) and 15% of the total phosphorus (P) loads to the lake. New provincial agricultural regulations were created to reduce nutrient losses.

Most of the land in the watershed is used to produce cereal crops, oilseeds, perennial forages and livestock. Most of the agricultural land is slightly rolling to hilly with clay loam soil textures. Long-term annual precipitation averages 550 millimetres (22 inches), of which approximately one-quarter falls as snow. The climate consists of large seasonal temperature differences, with warm (sometimes hot) summers and cold (sometimes severely cold) winters.

While BMPs have been developed and promoted for decades, most BMP testing has been done in temperate and humid climates where rainfall runoff and soil erosion predominate. The **Watershed Evaluation of BMPs (WEBs)**, an Agriculture and Agri-Food Canada (AAFC) national initiative, has been studying BMPs in cold-climate regions at the small watershed scale since 2004. Research at this scale captures the complex interactions among the BMPs, the biophysical setting (soils, landscapes and climate) and the land use within the watershed.

How were the multiple BMPs studied in Manitoba?

Treatment and control sub-watersheds

Water quality and quantity at the outlet of a treatment (Steppler) sub-watershed were compared to those at the outlet of a similar sub-watershed (Madill) where BMPs were not applied. Comparisons between the two sub-watersheds were made both before and after BMPs were applied.

The treatment and control sub-watersheds are approximately 205 hectares (507 acres) each and have gently rolling landscapes and similar soils and climate. They are situated in the headwaters of the STC Watershed, approximately 3 kilometres (2 miles) apart. Both sub-watersheds have several small intermittent watercourses traversing farm fields that join and flow into South Tobacco Creek.

No changes were made to the management of the Madill sub-watershed, which served as a control to account for variations in water quality due to differences in climate and hydrology over time.

Five BMPs were implemented in the Steppler sub-watershed (Figure 1) at the beginning of the WEBs project (2006). The objective was to monitor their effect on water quality (in terms of nutrient concentrations and loadings) within the watershed, their effect on flow volumes, and the cumulative effect of multiple BMPs at the watershed outlet.

Two of the BMPs were monitored individually—a holding pond downstream of a confined cattle feedlot, and the conversion of annual cropland to forage. Runoff was monitored and water samples were collected from the feedlot at the inlet of the holding pond and analyzed for nutrients and sediment.

Three of the BMPs—riparian area and grassed waterway management, grazing management and nutrient management were not directly monitored. However, their collective impact was monitored at the watershed outlet.

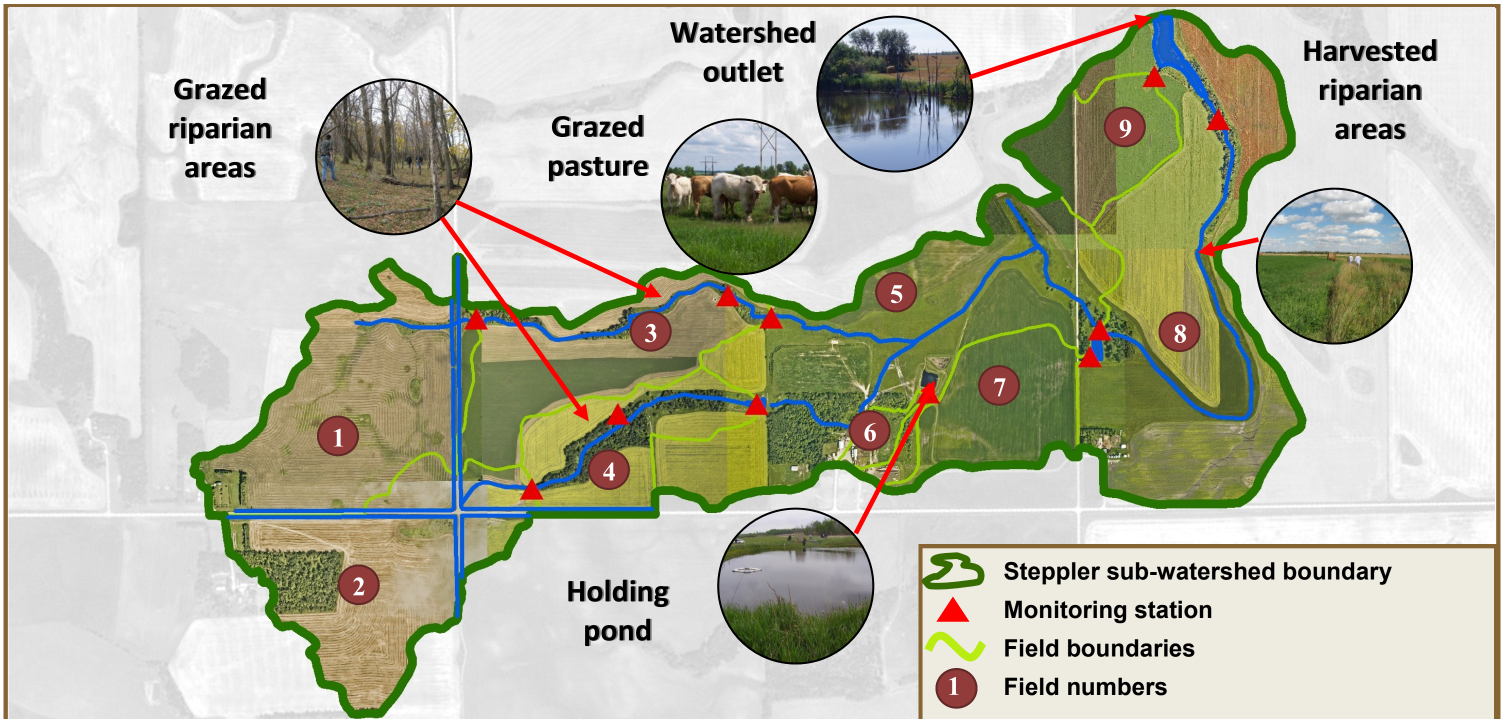

Figure 1: Map illustrating the locations of the nine study fields in the Steppler sub-watershed

Table 1: BMPs and farming practices by field in the Steppler sub-watershed

Field	Drainage area	Treatment	Field	Drainage area	Treatment
1	28.4 ha	• Annual crop rotation maintained • No change to land practice	6	1.85 ha	• Feedlot area • Runoff captured in holding pond
2	28.0 ha	• Annual crop rotation maintained • No change to land practice	7	12.7 ha	• Annual crop rotation maintained • Fertilizer application based on soil testing • No grazing at any time*
3	20.5 ha	• Converted annual cropland to forage • Includes rotational grazing in the riparian area • No fertilizer application when in forage • No fall grazing*	8	42.8 ha	• Annual crop rotation maintained • Riparian area within this field widened and buffer mechanically harvested
4	13.5 ha	• Annual crop rotation maintained • Includes rotational grazing in the riparian area • Fertilizer application based on soil testing • No fall grazing*	9	10.2 ha	• Converted annual cropland to forage • No fertilizer application when in forage • No grazing at any time*
5	42.8 ha	• Pasture and rotational grazing introduced • Cattle kept out of the pasture after mid-August			

* The producer would normally have carried out this practice but was asked to discontinue it for the purposes of the study.

What is the Watershed Evaluation of Beneficial Management Practices?

A long-term research program initiated by Agriculture and Agri-Food Canada in 2004, WEBs evaluates the economic and environmental performance of BMPs at a small watershed scale. To gain a regional perspective, this information is being scaled up to larger watershed areas using hydrologic models.

WEBs findings are helping researchers and agri-environmental policy and programming experts understand how BMPs perform and interact with land and water. This knowledge will also help producers determine which BMPs are best for their operations and regions.

WEBs studies are conducted at nine watershed sites across Canada. These outdoor living laboratories bring together a wide range of experts from various government, academic, watershed and producer groups. Many valuable findings have emerged and research continues at all sites.

Figure 1 shows the nine fields in the Steppler sub-watershed. The associated table (Table 1) identifies the BMP(s) implemented in the fields as well as other agricultural practices conducted to facilitate the BMP assessment.

Water quality and runoff monitoring

Prior to WEBs, water quality and runoff were monitored at the outlets of the Madill and Steppler sub-watersheds from 1999-2004. During WEBs, further monitoring at the outlets continued from 2004-2008. Flows and nutrient exports (the movement of nutrients via surface runoff from the field/sub-watershed/watershed) were compared for the two sub-watershed outlets for seven years before the BMPs were implemented and for another three years after BMPs were implemented. Final analysis included 65 runoff events (19 snowmelt, 46 rainfall) that occurred in both sub-watersheds.

Water quality samples were analyzed for various dissolved and particulate (soil bound) forms of P and N. Nutrient exports were calculated for each runoff event based on the total flow volume. Yearly reductions in nutrient exports and differences in flows were also calculated and compared.

What was the collective impact of the BMPs on water quality and runoff?

Implementation of the five BMPs reduced nutrient export to the stream and resulted in little variation in the flow and volume of surface runoff over the entire sub-watershed (as monitored at the sub-watershed outlet).

As shown in Figure 2, the five BMPs collectively reduced the average annual total P, dissolved P and particulate P export by 38%, 41% and 42%, respectively. The average annual total N, dissolved N and particulate N export was reduced by 41%, 43% and 38%, respectively.

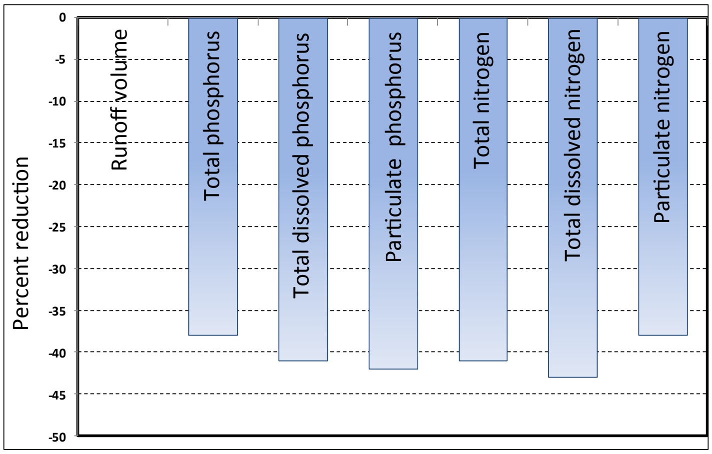

Figure 2: Nutrient exports from the Steppler sub-watershed decreased after BMPs were implemented.

What was the impact of individual BMPs?

Assessment of the effect of multiple BMPs was the primary focus of the study. The nutrient reduction from each individual BMP is difficult to estimate due to varying landscapes, soils, crops and other agricultural practices. However, researchers were able to determine the impact of some specific BMPs on overall nutrient reduction at the sub-watershed outlet.

Of the five BMPs implemented, the holding pond and nutrient management appear to provide the largest proportion of nutrient reduction. Based on measured nutrient inputs, the following estimates apply.

Holding pond

The holding pond captured all of the nutrient-enriched runoff from the cattle feedlot. Before the holding pond was built, the feedlot drained directly into the stream. Not all nutrients from the feedlot would have travelled the distance to the sub-watershed outlet because of opportunities for nutrient capture along the flow path. These may include sedimentation (deposition or accumulation of eroded sediments), infiltration and adsorption to soil or leaching losses, gaseous losses and crop uptake. The extent of this nutrient capture along the flow path is not known. However, if it is assumed that these losses are negligible, the maximum possible nutrient export reduction from the watershed due to the holding pond would be 64% of total P and 57% of total N.

Nutrient management

The nutrient management BMP wasn't monitored directly. However, the practice may have played a role in the reduction of nutrient export from the sub-watershed. Nutrient budget analysis revealed N inputs were reduced by 36% (26 kg ha^{-1} yr^{-1}, 23 lb ac^{-1} yr^{-1}) and P inputs were reduced by 59% (5 kg ha^{-1} yr^{-1}, 4.5 lb ac^{-1} yr^{-1}) in the treatment sub-watershed following implementation of nutrient management strategies.

Integrated Modelling and Economic Analysis

WEBs research and modelling efforts continue to explore the magnitude of individual BMP contributions to nutrient reductions at the sub-watershed outlet and the costs and benefits of the BMPs. These findings will increase our understanding of the processes and agricultural practices that maximize benefits to water quality.

Integration of hydrologic and economic computer models in WEBs will enable analysis of BMP implementation scenarios to identify which combination of BMPs can provide the greatest water quality improvement for the lowest cost. These modelling activities are geared towards quantifying on-farm and downstream BMP effects.

These reductions resulted from lower fertilizer application rates on annual cropland and from minimal fertilizer applications on the land converted to perennial forage. Despite the lower N and P application rates, yields on annually-cropped fields were similar to pre-BMP yields, largely due to crop uptake of nutrients from prior applications. Researchers continue to assess the impact on nutrient budgets of converting annual cropland to forage.

Conclusions and next steps

These watershed studies have clearly demonstrated that a combination of multiple BMPs can be effective at reducing nutrient losses from agricultural lands into water bodies. Overall, the collective nutrient reduction achieved by implementing the five BMPs was substantial (average reductions 41% total N and 38% total P) and provides a public benefit by mitigating downstream nutrient loading. In most cases, however, the relative contribution or non-contribution of individual BMPs has yet to be quantified.

Ongoing studies in the STC Watershed are assessing the effectiveness of these individual BMPs at reducing nutrient loading. Research findings will also lead to the enhancement of current BMPs, as well as the development of new BMPs to further minimize nutrient losses to the environment and maximize efficiency of on-farm nutrient use.

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