

South Tobacco Creek/Stepler Watershed

The 206-hectare Stepler Watershed is contained within a single farm operation and is located near Miami, Manitoba, approximately 150 kilometres southwest of Winnipeg. It is a sub-watershed of the South Tobacco Creek Watershed, a site that has been the focus of scientific studies and research projects for more than 20 years, and has had a runoff/water sampling infrastructure since the early 1990s (Figure 1).

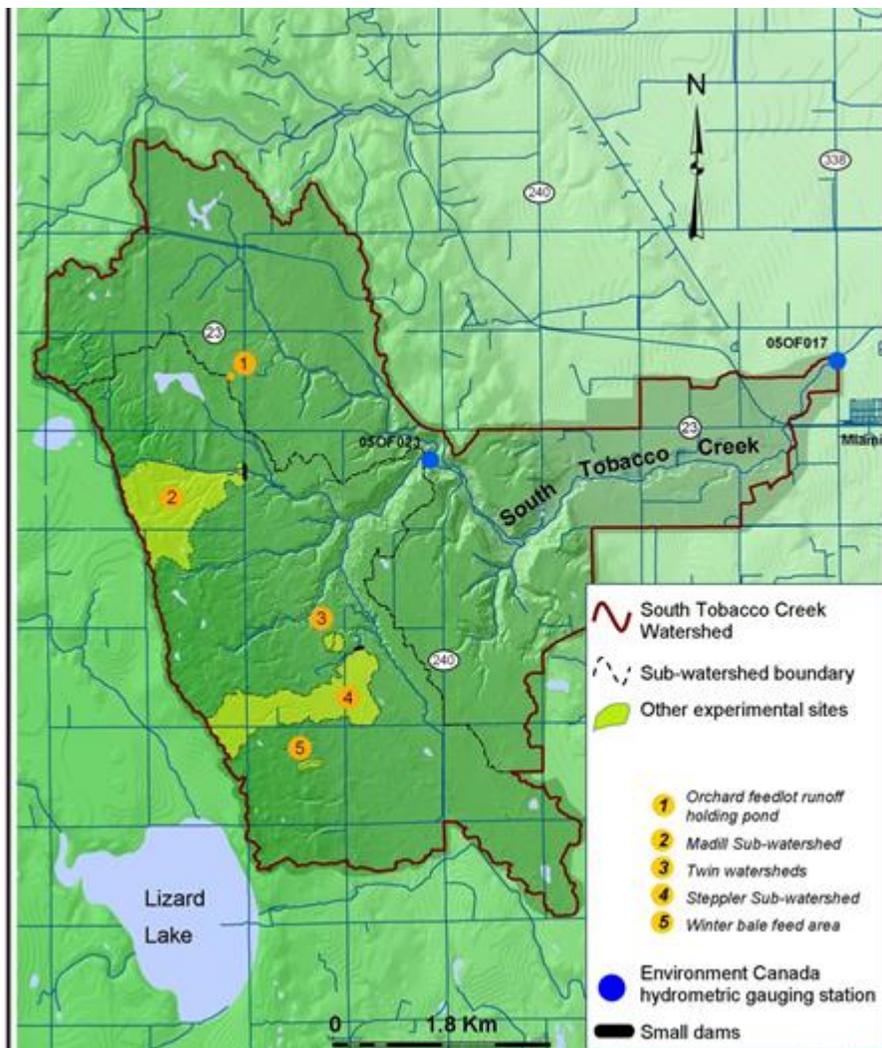


Figure 1. Stepler Watershed within the greater South Tobacco Creek Watershed

The South Tobacco Creek Watershed is situated on the edge of the Manitoba Escarpment such that the elevation drops nearly 60 metres in less than three kilometres. Soils are primarily clay loams formed on moderately to strongly calcareous glacial till which overlays shale bedrock. Land use within the watershed is agricultural, with the majority of the land under annual cropping. Average annual precipitation is about 550 millimetres, of which approximately one-quarter falls as snow.

The Stepler Watershed is in the headwaters of the South Tobacco Creek above the Manitoba Escarpment. The South Tobacco Creek drains into the Morris River, and eventually into the Red River, which then flows north into Lake Winnipeg. Due to water quality concerns, the Government of Manitoba has committed to reducing the amount of nitrogen and phosphorus entering Lake Winnipeg to pre-1970 levels. Much of this reduction must come from non-point sources upstream in the watershed. Effective BMP validation may have a significant impact on where and how efforts to reduce this loading should be focused.

Five BMPs were studied within the South Tobacco Creek Watershed as follows:

- **Winter bale-grazing**
- **Holding pond downstream of a winter cattle containment area**
- **Comparison of conservation and conventional tillage**
- **Small dams and reservoirs**
- **The conversion of annual cropland to perennial forage**



Tillage Trade-offs in a Prairie Watershed



Effect on both environmental and economic performance

Conservation tillage—including zero tillage and minimum tillage—aims to maximize the amount of crop residue remaining on the soil surface and is a beneficial management practice (BMP) widely promoted for its role in reducing soil erosion and the export of soil-bound nutrients into surface water. It can also play an important role in soil carbon sequestration. BMPs are farming practices designed to minimize potential negative impact on the environment. Yet most BMPs, conservation tillage included, have both environmental and economic trade-offs—side effects resulting when actions are taken to address a primary problem.

For example, although conservation tillage significantly reduces soil erosion, a biophysical (environmental) study in the 7,500-ha (18,500-acre) South Tobacco Creek (STC) Watershed in south-central Manitoba (1993-2007) (Figure 1) has shown that conservation tillage can increase dissolved phosphorus (P) export in a cold-climate region, where spring snowmelt is a major portion of annual runoff. A separate economics study in the same watershed (1998-2006) also found that the economic performance of conservation tillage is generally positive for cereals but is negative for canola. In recent years, both studies have been conducted as part of the **Watershed Evaluation of BMPs (WEBs)** program—an Agriculture and Agri-Food Canada (AAFC) national initiative.

Water quality decline caused by excess nutrients in surface water bodies is a growing problem in many agricultural regions across Canada. In Manitoba, there is increasing concern, for example, regarding the health of Lake Winnipeg. The STC Watershed is situated on the edge of the Manitoba Escarpment and is part of the Lake Winnipeg Basin.

What is WEBS?

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 to 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. Conservation tillage study site in south-central Manitoba



What's in a name?

Tillage practices can be divided into three main categories which reflect a decreasing number of tillage passes and associated increase in remaining plant residue:

- **conventional tillage** - at least one tillage pass in the spring and one in the fall
- **minimum tillage** - often only one tillage pass in the spring or fall
- **zero tillage** - no tillage

The term **conservation tillage** can be applied to practices ranging from minimum tillage to zero tillage—as is the case in the STC economic analysis. In the STC biophysical (twin watershed) study, conservation tillage refers to a field treatment that approached zero tillage. It received no heavy duty tillage in the fall, yet soil disturbance sometimes occurred prior to spring seeding when ammonia fertilizer was injected in a separate field operation, or when harrowing was used to break up the straw cover.



Figure 2. Conventionally-tilled field on the left, conservation-tilled field on the right

How was conservation tillage studied in Manitoba?

To study the water quality impacts of conservation tillage, the STC study used a pair of small (5 ha, 12 acre) adjacent agricultural watersheds (Figure 2) to compare the effects of conservation tillage and conventional tillage under a cereal/canola rotation.

To provide a basis for comparing the two watersheds, both were monitored under conventional tillage for the first four years. One watershed was converted to conservation tillage in 1997 and allowed

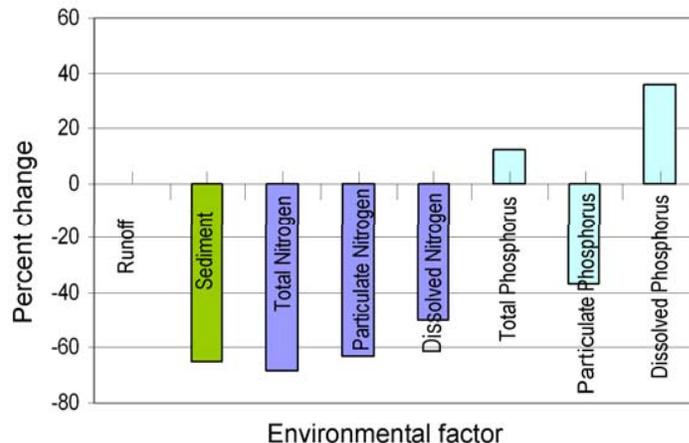


Figure 3. Percent change in sediment and nutrient export after conversion to conservation tillage

to stabilize (equilibrate) for seven years. Data on snowmelt and rainfall runoff and sediment and nutrient transport were then compared for the two tillage systems. This analysis is based on a comparison of pre-conversion data with four years of post-stabilization data.

What effect did conservation tillage have on water quality¹?

Research on clay-loam soils within the STC Watershed has shown no statistically-significant difference in the amount of annual runoff between the conservation-tilled and conventionally-tilled fields (Figure 3). This might be due to the fact that the majority of runoff in this watershed occurs during snowmelt when the ground is still frozen and impermeable. However, on an annual basis, conservation tillage was highly effective in reducing annual sediment and total nitrogen (N) export as compared to conventional tillage.

Sediment and total N export were reduced on average by 65% (23 kg/ha, 21 lb/acre) and 69% (2.3 kg/ha, 2.1 lbs/acre) per year respectively. However, total P export was 12% greater under conservation tillage. This is because while the export of particulate P (the small proportion of P lost that was attached to soil sediment) decreased by 37% under conservation tillage, the portion of dissolved P (the large proportion of P that was water soluble) increased by 36%, resulting in a net increase of 0.06 kg/ha (0.05 lb/acre) in exported total P. The average P loading for conservation tillage was therefore 0.17 kg/ha (0.15 lb/acre).

¹Tiessen, K. H. D., J. A. Elliott, J. Yarotski, D.A. Lobb, D. Flaten, N.E. Glozier. 2010. **Conventional and Conservation Tillage: Influence on Seasonal Runoff, Sediment, and Nutrient Losses in the Canadian Prairies.** Journal of Environmental Quality 39: 964-980.



Even though these nutrient losses may be minor from an agricultural production standpoint, they are ecologically significant since as little as 1 to 2 kg of P/ha/yr (0.9 to 1.8 lb of P/acre/year) is associated with the accelerated eutrophication of lakes. The STC Watershed is one of many that may contribute P to Lake Winnipeg.

These findings suggest that the increase in total P is due to an increase in dissolved P released from crop residues during freeze-thaw events, and/or from soil P that accumulates in surface soils because it has not been mixed during tillage. Results demonstrate that although conservation tillage can effectively reduce sediment and sediment-bound nutrient export from agricultural fields, it can increase the export of dissolved P occurring during snowmelt runoff. In these situations, it may be appropriate to implement additional management practices (such as intermittent tillage) to reduce the accumulation of P at or near the soil surface. These findings could apply to much of the cold, semi-arid landscape of the Canadian Prairies (Figure 4) and may be relevant wherever snowmelt runoff dominates and dissolved P is the major form of P in runoff.



Figure 4: Conservation tillage may not reduce the export of dissolved P in snowmelt runoff.

Don Flaten, a University of Manitoba soil scientist working on the STC WEBs project, emphasizes that conservation tillage has many environmental and agronomic benefits; however, it is not a cure-all in terms of reducing P export from agricultural watersheds in the Lake Winnipeg Basin. “If you take a look at overall environmental health,” he said, “you are better off with conservation tillage than conventional tillage, but we’ve got to be objective and not depend on conservation tillage to solve our P export problems in Lake Winnipeg.”

Jim Yarotski, the AAFC hydrologist leading the STC WEBs project, points out that the research team and participating producer have modified the study to try to reduce dissolved P losses. The conservation tillage field has been converted to intermittent tillage, whereby limited fall tillage will be used to reduce the amount of dissolved P build-up at the soil surface, hopefully without compromising the BMP’s erosion control effectiveness.

Conservation tillage economics in the STC Watershed²

Conventional tillage, not conservation tillage, is the dominant tillage practice in the STC Watershed (for reasons cited below). The economic response to conservation tillage is generally positive for cereals (wheat, barley and oats combined) but is negative for canola (Table 1). This economic analysis is based on nine years (1998-2006) of monitoring the tillage and cropping operations for all 357 fields on some 40 farming operations with at least a portion of their land located within the watershed. Cultivated fields range from 200 ha (500 acres) to only a few hectares, with the average being 18 ha (45 acres).

Table 1. Extent of tillage practices and their estimated net returns to canola/cereal cropping systems within the STC Watershed (1998-2006)

Crop	Area under canola and cereals production				
	Conservation tillage		Conventional tillage		Total
	% of area* (ha)	Net income/ha	% of area* (ha)	Net income/ha	% of area* (ha)
Canola	7.3 (261)	\$88	30.1 (1,074)	\$106	37.4 (1,335)
Cereals	19.7 (703)	\$35	42.9 (1,532)	\$10	62.6 (2,235)
Total	27.0 (964)		73.0 (2,606)		100 (3,570)

* % area represents the portion of the total area (3,570 ha) under canola and cereals production.

² Agriculture and Agri-Food Canada. 2010. **Watershed Evaluation of Beneficial Management Practices (WEBs) Technical Summary #2 – Economics Component Four-Year Review (2004/5 - 2007/8)**. Agriculture and Agri-Food Canada. Ottawa. Ont.

Of the total area farmed within the STC Watershed, 4,200 ha (10,400 acres) are in annual crops, with cereals and canola comprising 85% of this area. Of this cereal/canola portion (3,570 ha, 8,822 acres), conservation tillage occurs on 27% (11% is zero tillage, data not shown) and conventional tillage occurs on the remaining 73% of the land.

Table 1 displays the average net income estimated for canola and cereals for conservation and conventional tillage. For **canola**, the greatest net income of \$106/ha (\$43/acre) is generated by conventional tillage—perhaps reflecting the yield response of such a small-seed crop to more uniform seedbed conditions. Accordingly, most canola in this watershed is cropped under conventional tillage. About one fifth of the canola is under conservation tillage, where a decrease in tillage frequency results in a decrease in the net income for canola to \$88/ha (\$36/acre). This decrease may also be due in part to limited experience on the part of some producers when applying zero tillage. However, the sample size for zero tillage in the STC Watershed is too small to draw conclusions about impacts on canola production.

Comparatively, the income for **cereals** is highest under conservation tillage at \$35/ha (\$14/acre). However, with conservation tillage, the income for specific tillage practices can vary considerably (data not shown), being as high as \$47/ha (\$19/acre) for minimum tillage (likely a reflection of lower fuel and depreciation costs) to as low as \$15/ha (\$6/acre) for zero tillage due to its increased equipment costs and possible yield loss. Yet even then, the income from zero tillage (\$15/ha) is higher than for conventional tillage at \$10/ha (\$4/acre).

These net income figures reinforce why most producers in the STC Watershed prefer conventional tillage for canola, and why some might prefer conservation tillage (minimum or zero) for cereals. Yet most cereals are still being cropped under conventional tillage. This may be because producers who want to include canola in their ongoing rotations could find it risky to invest in conservation tillage equipment. Producers are likely to focus on the tillage method that is the most profitable, with canola generally being a higher-income crop than cereals.

If conservation tillage under canola or increased conservation tillage under cereals is to be promoted in this watershed, incentives will likely be required to encourage its further adoption. This merits further study from social sciences and agronomic standpoints.

Modelling in the STC Watershed

Hydrologic modelling is being conducted to extrapolate edge-of-field information to the 7,500-ha (18,500-acre) STC Watershed level. These data, obtained from experiments on a number of BMPs, are also being used to evaluate the water quality impacts of various tillage options at the watershed scale.

The STC Watershed is one of two WEBs project sites conducting integrated hydrologic-economic modelling pilot studies³. The integrated modelling approach combines information from hydrologic, on-farm economics, and farm behaviour models. By generating various BMP scenarios—combinations of BMPs and adoption incentives—and determining their environmental and economic impacts, the integrated model can ultimately be used for long-term watershed research and planning.

AAFC leads the national WEBs program and provides funding under its Growing Forward initiative. Ducks Unlimited Canada has been a key contributing partner. Other partners at the South Tobacco Creek project include: Deerwood Soil and Water Management Association; Environment Canada; Fisheries and Oceans Canada; Manitoba Agriculture, Food and Rural Initiatives; Manitoba Water Stewardship; University of Manitoba; University of Guelph; and University of Alberta.

For more information on WEBs please visit www.agr.gc.ca/webs or contact WEBs at webs@agr.gc.ca.

³ Yang, W., A. Rousseau and P.C. Boxall. 2007. **An integrated economic-hydrologic modeling framework for the watershed evaluation of beneficial management practices**, *Journal of Soil and Water Conservation*, 62(6): 423-432.



Positive Effects of Small Dams and Reservoirs



Water quality and quantity findings from a Prairie watershed

Summary: Small on-farm earthen dams can reduce downstream peak flow and associated flooding in agricultural watersheds, and can significantly reduce sediment, nitrogen (N) and phosphorus (P) loadings to streams. Researchers in the South Tobacco Creek Watershed in Manitoba have observed these sediment and nutrient reductions immediately downstream of the dams. Computer modelling is underway to predict whether these same values might be reflected further downstream—at the outlet of the watershed or beyond. If so, the cost of constructing and operating the dams could be offset by the public benefits they can bring in terms of controlling water quantity and improving water quality.

The 7,500-hectare (18,500-acre) South Tobacco Creek Watershed is located in south-central Manitoba and is part of the Lake Winnipeg Basin. Because of its position on the edge of the Manitoba Escarpment (Figure 1), the watershed drops 180 metres (590 feet) from its western to eastern boundary in less than ten kilometres (six miles). Consequently, lower-lying agricultural lands and infrastructure are particularly vulnerable to flooding and soil erosion caused by snowmelt and heavy rains. Past flooding events have caused significant damage to roads, culverts, bridges and crops.

In the spring of 1979, one snowmelt-runoff event in the watershed flooded over 3,000 hectares (7,400 acres) of land and caused over \$1.2 million in damages. In response, a local farmer organization—the Deerwood Soil and Water Management Association—initiated the construction of over 45 small dams along the Escarpment to reduce peak flow.

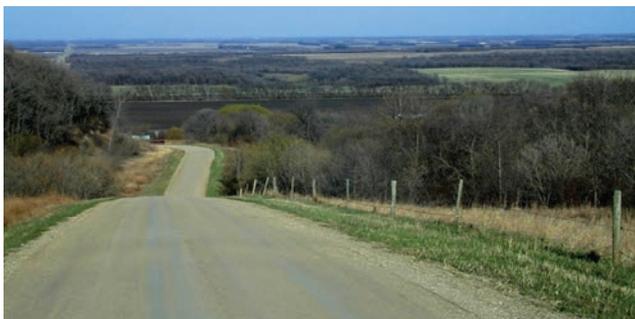


Figure 1: Due to the South Tobacco Creek Watershed's position on the edge of the Manitoba Escarpment, lower-lying agricultural lands are particularly vulnerable to flooding caused by snowmelt and heavy rains.

Three types of earthen dams were constructed with funding provided through an agreement administered by federal and provincial governments:

- **Dry flood-control dams** slowly release flood water in a controlled manner (no storage capacity).
- **Back-flood dams** temporarily store shallow waters over a large area of cropped or pastured land for at least two weeks, before the water is released.
- **Multipurpose dams** are similar to dry dams but retain approximately 10-15% of total storage capacity for summer water use.

Twenty-six of these small on-farm dams are located in the South Tobacco Creek Watershed, such that nearly 30% of the watershed's total drainage area is now managed for flow reduction.

The effects of the dams and their reservoirs on flood risk reduction have been studied since the early 1990s, and their impact on sediments and nutrients has been evaluated since 1999. In 2004, this ongoing study was incorporated into the **Watershed Evaluation of Beneficial Management Practices (WEBs)** program—an Agriculture and Agri-Food Canada (AAFC) national initiative. WEBs researchers have continued to evaluate the effects of these structures on sediment and N and P loadings to downstream waters.

How were the small dams and reservoirs evaluated in Manitoba?

Of the 26 dams constructed within the South Tobacco Creek Watershed, two—the Madill and the Steppler dams—were chosen for evaluation as part of the WEBs study (Figure 2).

The Madill *dry flood-control dam* is located in the north-western part of the watershed. It has a 44,500-cubic-metre (36-acre-foot) capacity reservoir and was constructed in 1988.

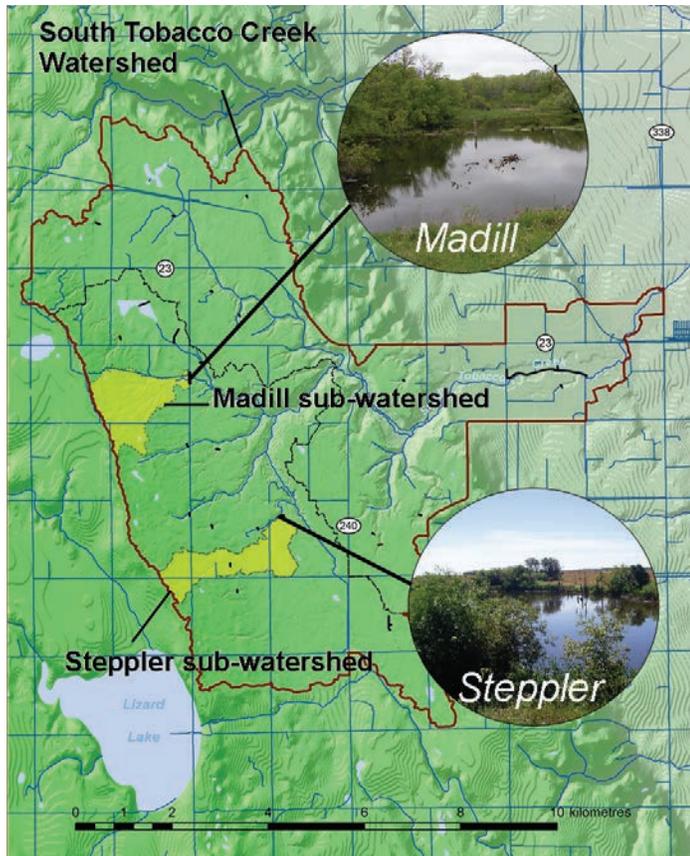


Figure 2: Map of the South Tobacco Creek Watershed, showing the locations of the Madill and Steppler dams.

The Steppler *multi-purpose dam* was constructed in 1986 and has a 50,000-cubic-metre (41-acre-foot) capacity, offering limited year-round water storage (Figures 3 and 4). Located in the south-western part of the watershed, it forms the outlet of the WEBs Steppler sub-watershed.

At the time of construction, the Madill dam cost \$26,000 and the Steppler dam cost \$15,000. Both are estimated to have a fifty-year lifespan.



Figure 3: Steppler reservoir with high flood-retention levels (~ 40,000 m³). The water level meter is virtually submerged (lower right of photo).



Figure 4: Steppler reservoir with low water levels (~ 4,000-5,000 m³). The water level meter is visible in the foreground.

Water quality sampling for sediment and nutrients at the Steppler and Madill dams was performed in conjunction with flow measurements. An auto-sampler collected inflow samples upstream of each reservoir as the water level rose in the stream, and at timed intervals. Reservoir outflow was sampled manually as the water exited each structure (Figure 5).



Figure 5: Manual water quality sampling immediately downstream of the Madill dam.

What is WEBS?

A long-term research program initiated in 2004 by Agriculture and Agri-Food Canada, Watershed Evaluation of Beneficial Management Practices (WEBS) evaluates the economic and environmental performance of beneficial management practices (BMPs) at a 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 small 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.

What effect did the small dams have on peak flow and water quality?

The two dams successfully reduced peak flow as runoff was routed through their reservoirs. As intended, little of the overall runoff volume was retained in the reservoirs. Collectively, it is estimated that the entire network of 26 small dams reduced peak flow due to snowmelt by 9-19% and rainfall runoff by 13-25%. These results are for runoff frequencies ranging from a 1 in 2-year event to a 1 in 100-year event.¹

Figure 6 depicts the average annual percentage reductions in flow, sediment and various forms of N and P for the Steppeler and Madill dams. It shows that, despite differences in construction, both reservoirs significantly reduced not only the export of sediment, as expected, but also the export of total N and total P. This reduction occurred during both snowmelt- and rainfall-generated runoff events.

During rainfall, the reservoirs were occasionally sources of particulate P (average annual increase of 3% for Steppeler and 15% for Madill). However, since dissolved nutrients are the year-round dominant form of N and P in this watershed (> 70% each—data not shown), the two reservoirs were successful in reducing total N and P loads overall.

Ongoing research is investigating why both types of reservoirs are so effective at removing nutrients.

¹ Yarotski, Jim. June 1996. Canada-Manitoba Soil Conservation Agreement, Program 6, South Tobacco Creek Pilot Project: Effects of Headwater Storage on Runoff Peaks, Hydrology Report #142. PFRA/AAFC.

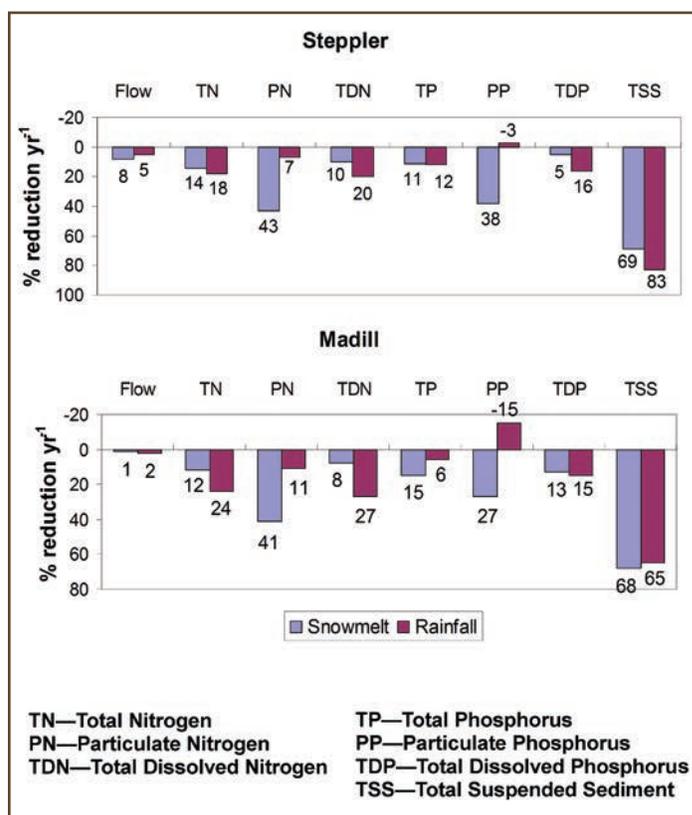


Figure 6: Average annual reduction in downstream (dam outlet) peak flow, sediment and nutrient export during spring snowmelt and summer rainfall events at the Steppeler and Madill dams (1999–2007).

Economic and modelling implications

The small dams in the South Tobacco Creek Watershed have the clear potential to regulate peak flow and thereby directly benefit those landowners who live within the watershed. Additionally, some of the dams may provide back-flood irrigation or have the storage capacity to serve as livestock watering sources.

Although these small dams are largely located on private property, they also provide a public benefit by mitigating downstream flooding and sediment loading. In addition, it is possible that the nutrient reductions that have been measured at the outlet of the dams could be reflected further downstream—at the watershed outlet or beyond. Should this prove to be the case, the construction and operating costs of the dams may be further offset by these public benefits.

Conclusion

In combination with improved flood and erosion control, it is clear that small headwater storage dams are an effective conservation tool that may also reduce downstream nutrient loading into rivers and water bodies. This BMP should merit consideration by watershed managers and policy makers when developing resource protection plans, particularly for agricultural escarpment regions on the Great Plains.

A hydrologic computer model—based on an adapted version of SWAT (Soil and Water Assessment Tool)—has been developed and validated for the South Tobacco Creek Watershed. The model is being used to predict the impacts of the dams at varying landscape scales as well as under a variety of climate and land-use scenarios (such as different farming practices or interactions with other BMPs).

As well, the South Tobacco Creek project is one of two WEBs integrated modelling pilot studies underway whereby hydrologic modelling variables are coupled with economic and social variables. The resulting models will act as decision-support tools towards identifying: optimum BMP location for environmental benefit; likelihood of producer adoption; and cost ranges for construction and maintenance. These WEBs modelling activities are geared towards providing valuable insights into quantifying on-farm and downstream BMP effects.



View from the top of the Manitoba Escarpment, looking downslope to the east.

This fact sheet was created using material from a paper published in the Journal of Soil and Water Conservation:

Tiessen, K.H.D., J.A. Elliott, M. Stainton, J. Yarotski, D.N. Flaten and D.A. Lobb (2011). "The effectiveness of small-scale headwater storage dams and reservoirs on stream water quality and quantity in the Canadian Prairies." Journal of Soil and Water Conservation 66(3) pp. 158-171.

AAFC leads the national WEBs program and provides funding under its Growing Forward initiative. Ducks Unlimited Canada has been a key contributing partner. Other partners at the South Tobacco Creek project include: Deerwood Soil and Water Management Association; Environment Canada; Fisheries and Oceans Canada; Manitoba Agriculture, Food and Rural Initiatives; Manitoba Water Stewardship; University of Manitoba; University of Guelph; and University of Alberta.

For more information on WEBs please visit www.agr.gc.ca/webs or contact WEBs at webs@agr.gc.ca.



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 Stepler 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.

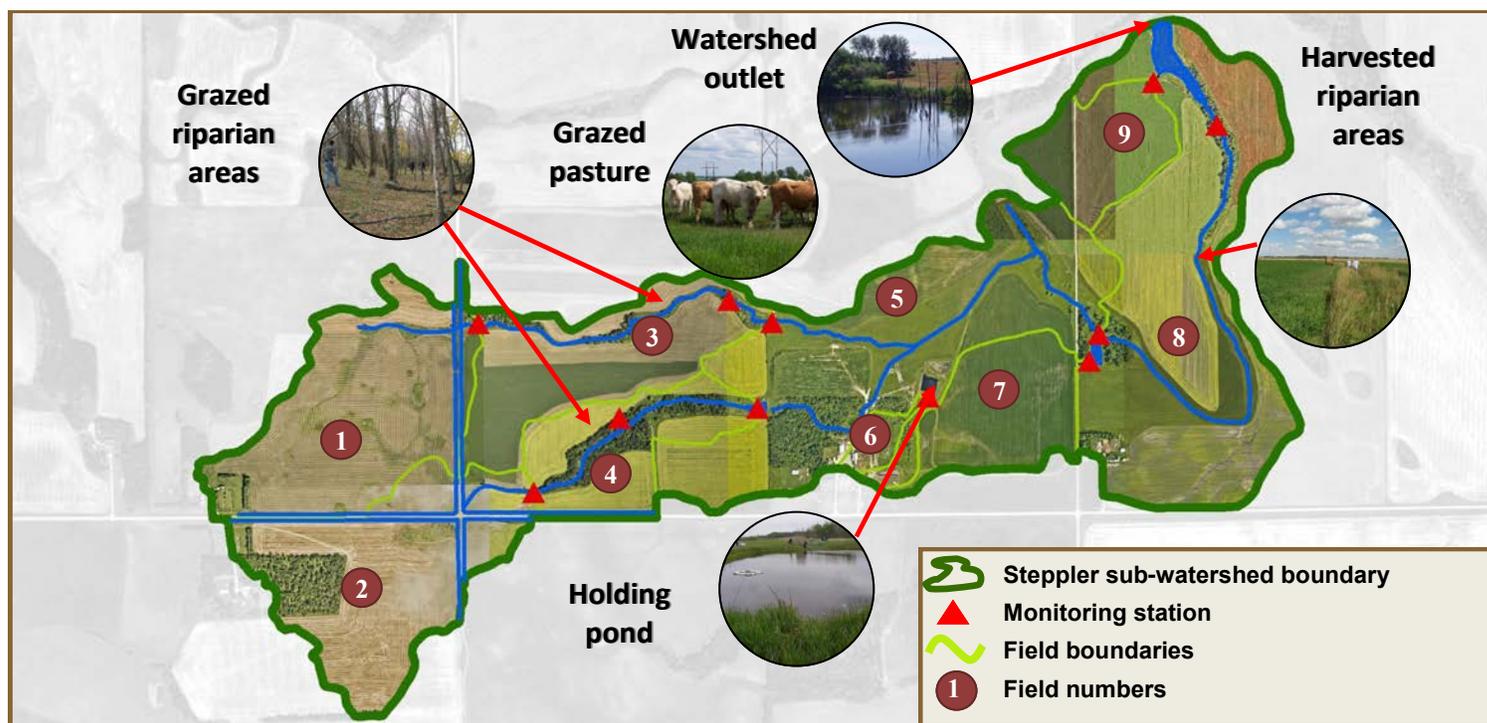


Figure 1: Map illustrating the locations of the nine study fields in the Stepler sub-watershed

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

Field	Drainage area	Treatment	Field	Drainage area	Treatment
1	28.4 ha	<ul style="list-style-type: none"> Annual crop rotation maintained No change to land practice 	6	1.85 ha	<ul style="list-style-type: none"> Feedlot area Runoff captured in holding pond
2	28.0 ha	<ul style="list-style-type: none"> Annual crop rotation maintained No change to land practice 	7	12.7 ha	<ul style="list-style-type: none"> Annual crop rotation maintained Fertilizer application based on soil testing No grazing at any time*
3	20.5 ha	<ul style="list-style-type: none"> 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	<ul style="list-style-type: none"> Annual crop rotation maintained Riparian area within this field widened and buffer mechanically harvested
4	13.5 ha	<ul style="list-style-type: none"> Annual crop rotation maintained Includes rotational grazing in the riparian area Fertilizer application based on soil testing No fall grazing* 	9	10.2 ha	<ul style="list-style-type: none"> Converted annual cropland to forage No fertilizer application when in forage No grazing at any time*
5	42.8 ha	<ul style="list-style-type: none"> 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 Stepler 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 Stepler 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.

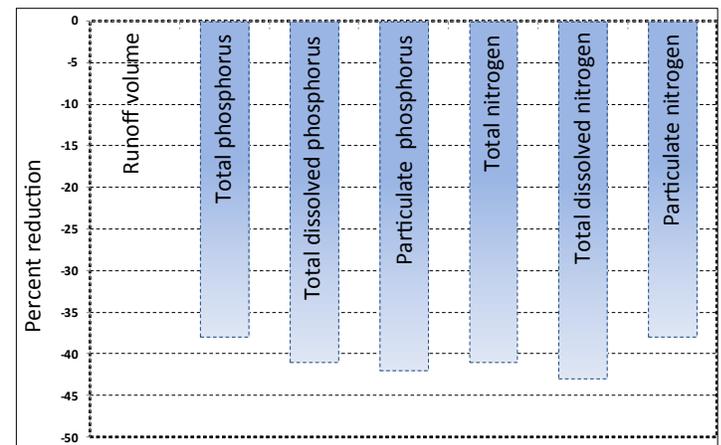


Figure 2: Nutrient exports from the Stepler sub-watershed decreased after BMPs were implemented.

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.

This fact sheet was created using material from a paper by:

Li, S., Elliott, J.A., Tiessen, K.H.D., Yarotski, J., Lobb, D.A. and Flaten, D.N. (2011). *The effects of multiple beneficial management practices on hydrology and nutrient losses in a small watershed in the Canadian Prairies*. Journal of Environmental Quality 40(5):1627-42

AAFC leads the national WEBs program and provides funding under the federal-provincial-territorial Growing Forward Framework. Ducks Unlimited Canada has been a key contributing partner. Other partners at the South Tobacco Creek project include: Deerwood Soil and Water Management Association; Environment Canada; Fisheries and Oceans Canada; Manitoba Agriculture, Food and Rural Initiatives; Manitoba Water Stewardship; University of Manitoba; University of Guelph; and University of Alberta. Special thanks go to the producers on whose land these studies are located.

Please visit www.agr.gc.ca/webs or contact WEBs at webs@agr.gc.ca.