Evaluation of Beneficial Management Practices (BMPs)

South Tobacco Creek Watershed

Project Partners

Research and field work are conducted in conjunction with a number of partner organizations, including: the Deerwood Soil and Water Management Association (an established farmer-run conservation group); Environment Canada; Fisheries and Oceans Canada; Manitoba Conservation and Water Stewardship; Manitoba Agriculture, Food and Rural Development; the University of Manitoba and the University of Regina. The University of Guelph and the University of Alberta previously conducted modelling and economic studies for the project.

The local landowners, Dale and Caroline Steppler, are supporting the project by incorporating the BMPs and working with the technical experts to assess the BMPs.

Canada

South Tobacco Creek Watershed Project

The South Tobacco Creek (STC) Watershed project is a study of the environmental and economic performance of several agricultural beneficial management practices (BMPs) at a small watershed scale. Water quality degradation caused by excessive sediment and nutrient runoff can impact agricultural watersheds. Evaluating BMPs at the watershed scale enables researchers to combine the effects of soils, topography, local climate and land use, giving a clearer picture of BMP performance. This study is conducted on working farms where operational realities are taken into consideration in designing and conducting BMP experiments.

The STC Watershed project includes ***biophysical evaluations*** to measure the environmental impact of the BMPs, as well as the landscape processes that affect their performance. See the ***Monitoring*** section for biophysical parameters monitored. ***Economic evaluations*** examine the costs and benefits of implementing BMPs. Studies are conducted by eight research scientists from Agriculture and Agri-Food Canada (AAFC), Environment Canada, University of Manitoba and University of Regina.

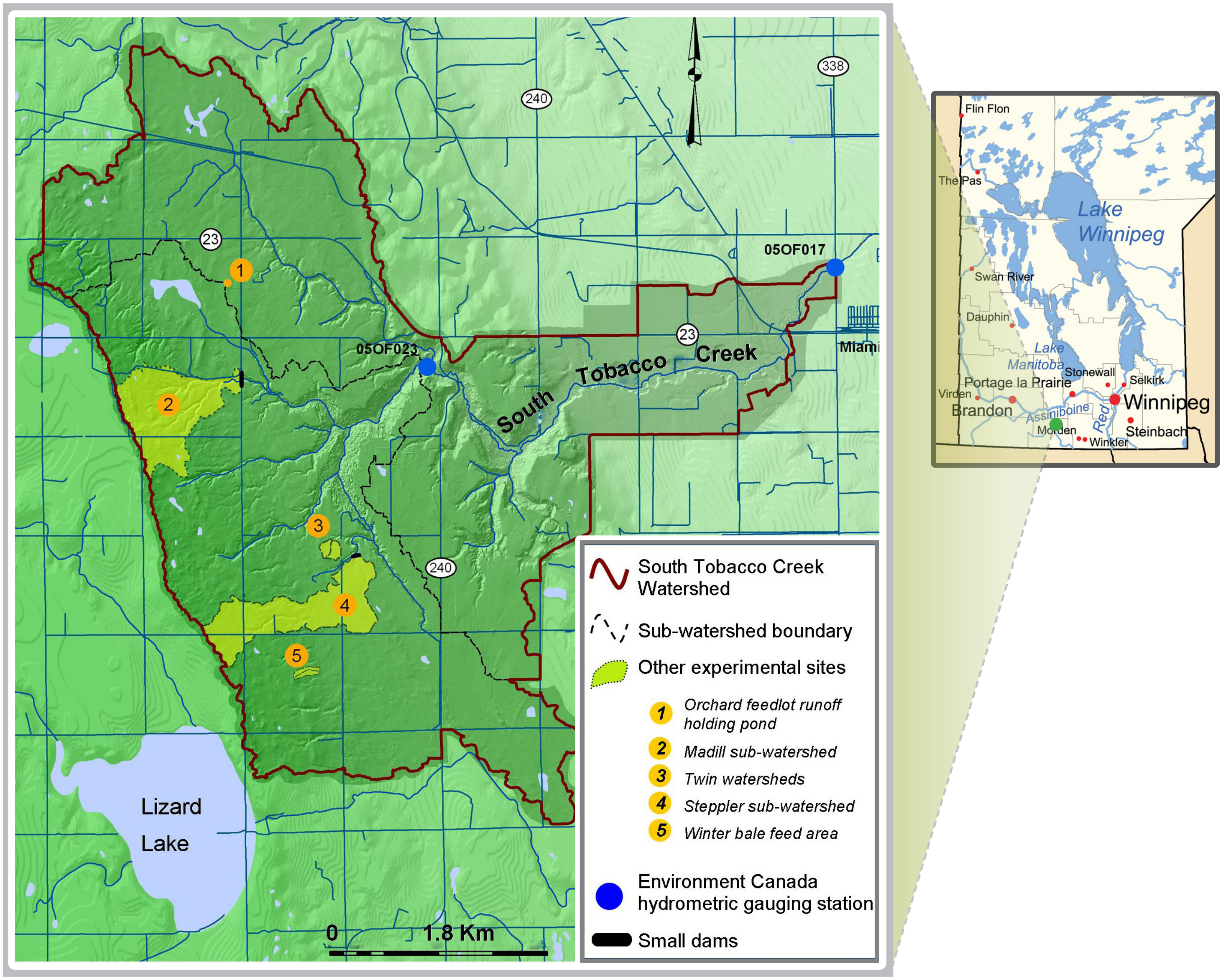
Several agricultural practices are being assessed within the Steppler sub-watershed and surrounding sub-watersheds, as listed in the table below.

Agricultural Practice/BMP Studies	Stage of Evaluation
Small reservoirs/dams	Completed – results published*
Conservation tillage effects on nutrient loss	Completed – results published*
Cumulative effect of multiple BMPs	Completed – results published*
Rotational tillage of conservation tilled field	Completed – results published
Factors affecting nutrient export from annual cropland	Completed – results published
Conversion of annual cropland to forage	Completed – results published
Holding pond downstream of small feedlot	Evaluation ongoing - Initial results available
Winter in-field cattle feeding	Evaluation ongoing
Spreading of feedlot manure on annual cropland	Evaluation initiated in 2013
Sediment fingerprinting	Evaluation ongoing–some results published

**Factsheets available at http://www.agr.gc.ca/eng/?id=1297269073820*

South Tobacco Creek Watershed Project

The 206-hectare Steppler sub-watershed, in which several BMP studies are conducted, 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 7,500-hectare STC Watershed—a site that has been the focus of scientific research for more than 20 years, and has had a runoff/water sampling infrastructure since the early 1990s.



The STC Watershed is situated along the edge of the Manitoba Escarpment such that the elevation drops nearly 180 metres from the western to eastern extremity in less than ten 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 being annually cropped. Average annual precipitation is about 550 millimetres, of which approximately one-quarter falls as snow.

The South Tobacco Creek drains into the Morris River and eventually into the Red River, which then flows north into Lake Winnipeg. In order to provide improved water quality, the Government of Manitoba has committed to reducing the amount of nitrogen (N) and phosphorus (P) entering Lake Winnipeg to pre-1970 levels. Because non-point sources are a major contributor to the nutrient enrichment issues of Lake Winnipeg (Manitoba Conservation and Water Stewardship), efforts focused on understanding and evaluating BMPs targeted to non-point source controls will have a significant impact on the reduction of nutrient loadings to waterways.

Agricultural Beneficial Management Practices (BMPs) within the South Tobacco Creek Watershed

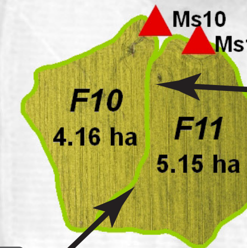
Conversion of annual cropland to forage

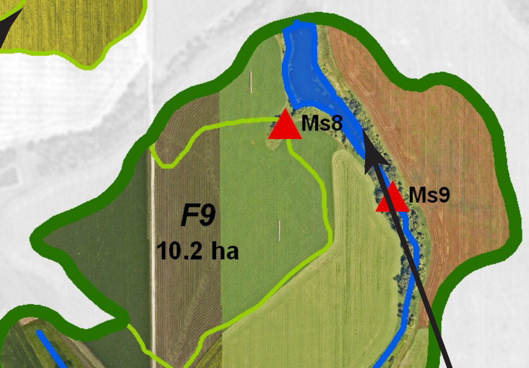
The impact of converting annual cropland to forage production on water quantity and quality (sediment and nutrient export) were assessed using a twin watershed approach for two pairs of sub-watersheds. The research design left two of the fields in annual cultivation (F3 and F9) and two fields were converted to forage (F4 and F7). After an initial three-year period, the forage fields were returned to annual crop and the annual crop fields were seeded to forage and the study continued for another three years.

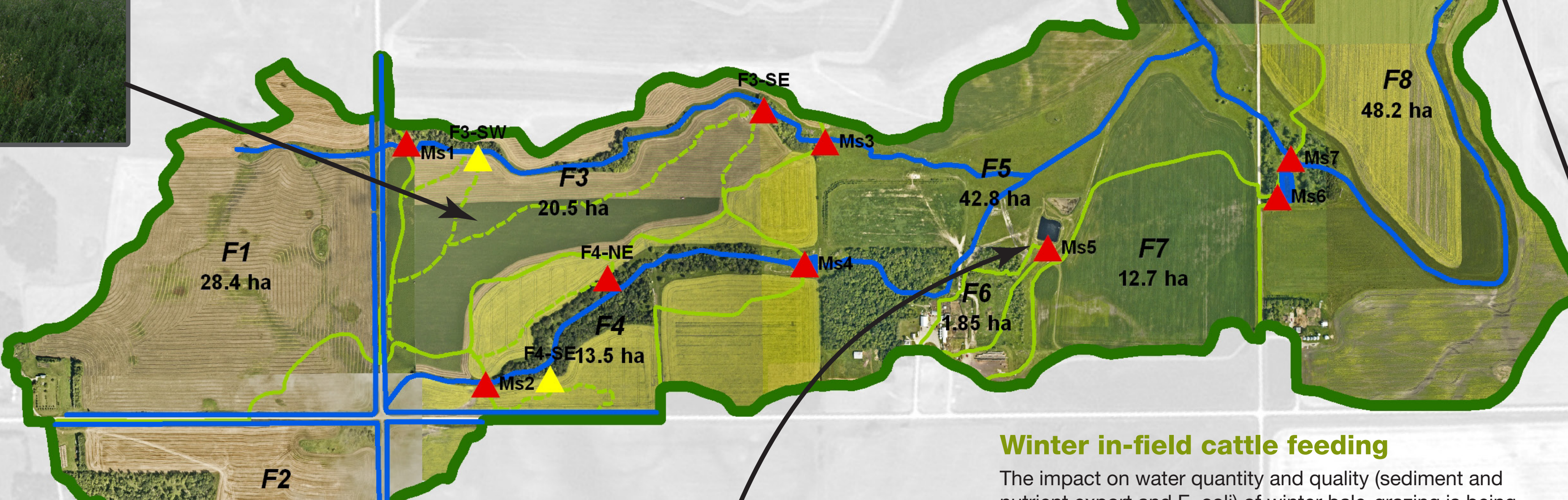
During snowmelt, particulate nutrients and sediments in runoff were the same for the forage and annual crop fields. Concentrations of total N and total dissolved N were higher in runoff from the annual crop fields than the forage fields but there was no difference in N loss (dissolved, total or particulate) between the fields, as runoff was higher from the forage field. Losses and concentrations of total P and total dissolved P in the runoff water were greater from the forage fields than the annual crop fields.

Manure application

The impact of field application of raw cattle manure on downstream water quality (nutrients and pathogens) is being evaluated in conjunction with other aspects of crop and livestock management. Manure is being applied to two fields in the fall, alternating between fields every second year, starting in the fall of 2013. Manure is applied only to the upper and mid slopes of the fields. Manure is applied to a third field (F7) every year.







Steppler sub-watershed boundary
Field boundaries
Ms1 Runoff monitoring/sampling station
F3-SW Edge-of-field manual water sampling site (and approximate location of soil, residue and snow core transects)

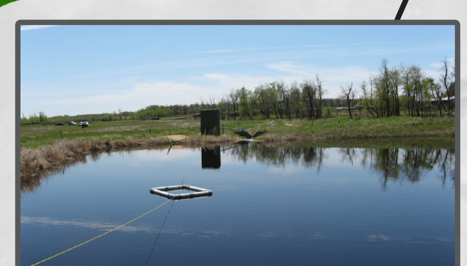
Holding pond

A small holding pond was constructed downstream from a winter cattle feeding/ containment area to intercept the flow and prevent the nutrient rich runoff from entering the stream. The captured runoff is applied to a nearby forage field using a small irrigation system.

A second holding pond was constructed at the Orchard farm in 2008 to provide replication to the experiment.

The holding ponds were highly effective at capturing runoff with high nutrient concentrations and E. coli counts from the cattle feedlot, thus helping prevent these contaminants from draining into the stream. Prior to holding pond construction, natural process caused bacteria levels to decline rapidly as they moved downstream. However, net nutrient and E. coli reductions were significant and E. coli counts were further reduced following the holding pond construction.

In a separate study of the cumulative impact of various BMPs in the Steppler sub-watershed, the holding pond was found to be associated with, at maximum 26% reduction in the total P and, at maximum 22% in the total N.



Conservation tillage

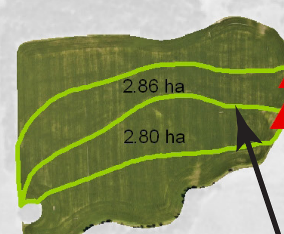
A pair of small adjacent agricultural watersheds was used to compare the runoff and nutrient loading of conservation tillage and conventional tillage under a cereal/canola rotation. The research design compared the two watersheds by monitoring them under conventional tillage for four years. The east field (F11) was then converted to conservation tillage and, following seven years of stabilization, data on sediment and nutrient transport were compared for the two watersheds

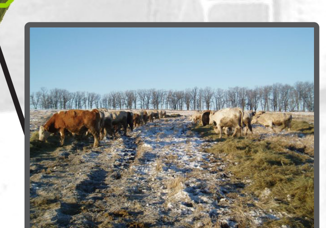
No significant difference was found in the amount of annual runoff between the two fields. However, conservation tillage was highly effective in reducing annual sediment export (average reduction 65%) and total N export (average reduction 69%) as compared to conventional tillage. The export of total P was 12% greater under conservation tillage, largely due to an increase in the export of dissolved P during snowmelt runoff.

To address increased dissolved P losses due to build-up of P in residues and surface soil under conservation tillage, intermittent tillage (tillage in the fall of every second year) was assessed beginning in 2008. Intermittent tillage was successful in reducing the P export but did increase export of N and carbon. Nutrient losses (N and P) from intermittent tillage were not significantly different from those from conventional tillage.

Winter in-field cattle feeding

The impact on water quantity and quality (sediment and nutrient export and E. coli) of winter bale-grazing is being assessed using a paired watershed approach. In this assessment, initiated in 2008, one field is used as a control (F19) and the other field (F18) is a test site. Sixty-two adult animals are placed on the test field for 30 days in November and/or December every second year. An electric fence restricts the cattle to the test field. At the request of the producer, cattle are brought into the confined feedlot in the yard site by January to start calving. Analysis of runoff, soil and residue samples will determine the impacts of this practice on water quality.





Small reservoirs

Two in-stream reservoirs were monitored for their effectiveness in reducing downstream nutrient and sediment loading and flood peaks. As the outlet for the Steppler sub-watershed, the Steppler reservoir (shown in this photo) also provided a downstream point for monitoring farm runoff and nutrient output, as well as for monitoring the cumulative impact of all of the BMPs in this study, except the tillage BMP. In an adjacent sub-watershed (see map on page 2), the Madill reservoir was monitored to provide additional data on the performance of this practice.. The dams and associated reservoirs were found to significantly reduce downstream nutrient and sediment loading, while mitigating the risk of downstream flooding. The reservoirs were found to decrease the average annual downstream export of total P, total N and sediment by 11%, 17% and 70%, respectively. The two dams successfully reduced peak flow as runoff was routed through their reservoirs.

Additional Biophysical Studies

Other studies have been conducted using the STC data set. These studies quantified the effect of BMPs on water quality and increased knowledge of the effect of various factors on BMP performance. These studies included:

Cumulative effect of multiple BMPs – Water quality and runoff at the outlet of the Steppler sub-watershed were compared to measurements at the outlet of a control sub-watershed where no BMPs were applied. Two BMPs applied in the Steppler sub-watershed were monitored individually—the holding pond and the conversion of annual cropland to forage. The collective impact of three other BMPs—riparian area and grassed waterway management, grazing management and nutrient management—was monitored at the watershed outlet. Both watershed outlets were also monitored for water quality and runoff prior to BMP implementation. The evaluation indicated that the BMPs reduced total N and P exports by 41% and 38%, respectively. Of the BMPs implemented, the holding pond and nutrient management using recommended fertilizer application appear to provide the largest proportion of nutrient reduction.

Factors affecting field-scale nutrient losses in spring runoff – Researchers assessed the factors affecting N and P exports from a small sub-watershed. Results indicated that the most important factors controlling nutrient concentrations and loads were the volume of runoff (including snow water equivalent), flow rate and runoff duration.

V-notch weir at monitoring station Ms11

Sediment fingerprinting – Sediment samples collected from the stream were compared with those from streambank profiles and the surface soil of farm fields and riparian areas in order to identify the sources of sediment and P. Findings indicated that about 80% of sediments in the STC Watershed result from in-stream erosion processes and not from agricultural field erosion. This knowledge is essential for designing BMPs that will effectively address sediment and sediment-bound nutrient issues. This study is ongoing.

Dr. David Lobb explains his sediment sourcing research using suspended sediment collectors (pictured) and radionuclides at a field tour of the South Tobacco Creek Watershed

Customized soil data and maps – Maps of soil organic carbon and soil test N and P were developed with new methods based on a combination of digital elevation, landform analysis and other properties such as soil texture. Soil series in the Steppler sub-watershed were mapped and used in conjunction with landform analysis to locate baseline samples for future assessments of the impact of BMPs, topography and soil properties on water quality.

Monitoring

Monitoring of various parameters at the field, sub-watershed and watershed levels is essential in assessing the impact of the implemented BMPs. The monitoring helps researchers to better understand the hydrology and contaminant transport processes within the watershed, which in turn allows for a clearer understanding of the effect of the BMPs on the environment. Monitoring at the STC Watershed includes: runoff (annual hydrograph); water quality (sediment, nutrients and pathogens); soil, residue and snow sampling; agronomic data collection; movement and source of sediment; climate data collection (rainfall, snow survey, and wind speed and direction); and soil moisture tracking.

Runoff monitoring and water sampling are conducted at 18 sites. Two of the sites located in the larger STC Watershed are part of the Environment Canada hydrometric station network (see foldout map). For the purposes of facilitating water quality monitoring, these hydrometric stations are equipped with automatic water samplers.

Circular flume at monitoring station Ms6

Flow is monitored at 16 monitoring sites using circular flumes, comprised of one-metre horizontal pipe containing a 30-centimetre vertical pipe, or by using wooden v-notched weirs. In both instances, the water level is monitored using a water-level instrument and a data logger, which captures and processes the data. In the event of a significant change in flow, the data logger activates an automatic water sampler. A field technician sends these samples to a laboratory daily for analysis of sediment and nutrients. Water levels in the Steppler reservoir are monitored using electronic water-level recorders. The levels are used to calculate the inflow and outflow rates, using reservoir hydraulic and bathymetric parameters.

Soil temperature and moisture data are collected throughout the growing season in fields F10 and F11. Continuous soil moisture monitoring is provided using moisture probes in conjunction with data loggers. To calibrate the instruments, manual soil samples are taken several times a year and the soil moisture is assessed.

Climate data, including rainfall depth (measured on a continuous basis), are collected at the Ms4 and Ms10 sites as well as at the winter in-field cattle feeding site and the Orchard holding pond. Producers within the STC Watershed also record daily rainfall accumulations on their farms. Air temperature and wind speed and direction data are also collected at the conservation tillage monitoring site at Ms10.

Soil and snow core sampling occurs on defined transects in fields F3 and F4, the conservation tillage and conventional tillage fields (F10 and F11), and the winter in-field cattle feeding fields (see map on centre page).Soil samples are collected during various times of the year, depending on the field, using a tractor-mounted coring sampler. Samples are collected at three depths, replicated and sent to a laboratory for nutrient analysis. Snow samples are collected in the spring, as close to the spring thaw as possible, thawed and sent to a laboratory for sediment and nutrient analysis.

A comprehensive collection of ***agronomic*** data exists for the STC Watershed as producers have been providing researchers with this information since 1992. Agronomic data include land use, fertilizer and herbicide application rates, cultivation practices, etc. Over 40 different variables have been collected for over 350 fields within the watershed.

Economics

Economic analysis evaluates the on-farm costs and benefits of implementing the various BMPs. Minimum tillage and in-field winter cattle feeding BMPs have been found to provide net benefit to producers. Other BMPs may be economical if downstream benefits are considered. Simulation modelling is being conducted to integrate and assess economic and environmental impacts occurring beyond the farm level.

Modelling

Integrated hydrologic-economic modelling was conducted and funded by WEBs for the STC Watershed to enable analysis of the costs and benefits of BMP implementation scenarios. The Soil and Water Assessment Tool (SWAT) was adapted to Canadian conditions such as snow redistribution, frozen soils and snowmelt. The adapted model—CanSWAT—used local field data to assess the processes by which nutrients and sediments are transported from agricultural land to receiving streams and the impact of these processes on BMP performance. CanSWAT was integrated with an economics model to enable users to assess the environmental and economic effects of BMPs at the watershed scale. A cell-based, fully distributed hydrologic model (imWEBs) was developed to evaluate BMP effects at the field and farm scale. These decision-support tools can help identify which combination of BMPs can provide the best method for reducing the impact of agriculture on water quality for the lowest cost, both on-farm and downstream.

Between 2004 and 2013, this project was funded under a multidisciplinary Agriculture and Agri-Food Canada (AAFC) program called the Watershed Evaluation of Beneficial Management Practices (WEBs). Current funding for the STC project (2013-2016) comes from AAFC's AgriInnovation Program, under Growing Forward 2, a five-year (2013-2018) policy framework for Canada's agricultural and agri-food sector.

Further Information

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To find out more about the South Tobacco Creek Watershed project from 2004-2013, visit www.agr.gc.ca/webs

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