Water quality and agriculture: What we don't know.

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Background:

There is increasing concern among the general public and agricultural producers alike about the impact that agriculture may be having on the environment. One area of particular concern has been the potential impact on water quality. In an effort to understand agriculture's impact on surface water quality in Saskatchewan the Ministry of Agriculture, Policy Branch has initiated a project to review the state of knowledge surrounding this topic, with a special focus on non-point sources of contamination. This presentation will discuss available historic data, knowledge gaps, recent research initiatives and potential areas for future collaboration.

Over the past two years the Saskatchewan Ministry of Agriculture has employed an Environmental Science Research Officer within the Policy Branch, Environmental Unit. The key role of this position is to review, analyze, and develop complex technical material on agri-environmental science, primarily as it involves agriculture's impact on the environment. The results from these activities are communicated to other staff to ensure that the best available science is used in policy development.

To date the primary focus of this position has been the exploration and analysis of existing historical data, a review of the literature, and on-going consultation with other agencies and researchers in an effort to establish the current state of knowledge and to identify relevant knowledge gaps. Initially identified knowledge gaps are being addressed through the development of research collaborations and the implementation of a new water quality monitoring program that will complement those of other agencies.

Need for data:

It is apparent that we have a need for quantitative information to support 1) any response to critics of agriculture, 2) the development of proactive policies and programs, 3) inter-governmental negotiation and program support and 4) the development and promotion of science based beneficial management practices (BMPs).

Our review of the literature confirms that non-point source runoff from agriculture fields is a source of low-level contamination of surface waters in Saskatchewan. Based on a limited number of articles, surface water quality parameters rarely exceed maximum allowable concentrations for pesticides, nutrients, major ions or fecal coliforms and current levels do not significantly threaten human, animal or aquatic life.

However, connections between land use / management practice and water quality are weak and more research is required to quantify these links. In Saskatchewan, there is a lack of comprehensive studies that could help provide definitive answers to the question, "How does agriculture impact water quality?" While there exist many smaller studies which explore either water quality parameters or the impact of localized management practice at individual sites over a limited time frame, there does not exist a comprehensive picture of the impact of agricultural practice on surface waters.

Saskatchewan is not alone in lacking data that directly addresses the potential impact of agriculture on the environment. Across North America researchers are actively attempting to characterize highly variable water quality parameters that are subject to a set of environmental and management influences that vary across space and time.

Water Quality Database Exploration:

In conjunction with our literature review we also chose to explore the two major publicly available water quality databases for Saskatchewan. We chose to look at the data for two watersheds whose waters arise within the province in the hopes that the water quality data would tell us something about the differences in land use between the two watersheds.

Our watersheds of interest were the Carrot River Watershed and the Assiniboine River Watershed. We explored two data sources:

a. Saskatchewan Environment, Environmental Management System (SEEMS) database

   This database contains the results from multiple sampling points within all the watersheds across the province. Unfortunately the database suffers from several weaknesses that severely limit its usefulness as a diagnostic tool for our purposes:
   - The majority of sampling sites are downstream of urban settings (collected as part of a program to monitor effluent release from urban lagoons).
   - There has been limited sampling within years – generally once in the spring and once in the fall.
   - There are many gaps between years in which the sites were sampled.

   Given these limitations we have low expectations of usable results from this dataset. Work continues in an effort to extract the maximum amount of information from this data. [Figure 1].

b. Prairie Provinces Water Board (PPWB) database

   The PPWB monitors the quantity and quality of flow in the major rivers entering and leaving the province. In the southern cultivated portion of the province there are three sites monitoring inflowing waters and three sites monitoring outflow. The data is collected and maintained by Environment Canada. [Figure 1].

   We examined data from the single PPWB site on the main stem of the Carrot River near Turnberry, SK and data from the single PPWB site on the main stem the Assiniboine River downstream of Kamsack, SK. In both cases the sampling locations are at the downstream end of their respective watersheds, near the point where the rivers leave the province.

While the samples collected at these locations might be considered to summarize the upstream watershed influences it must be remembered that the results are derived from a mixture of (urban and non-urban) land uses. In addition, the samples collected from the main stem of the river are subject to greater dilution effect than the smaller upstream reaches, thus concentrations measured in the main stem cannot be directly extrapolated to field loss measurements.

Data exploration revealed that the majority of water quality parameters showed great similarity between the two watersheds. Some minor differences were observed between the watersheds for total nitrogen, total phosphorus, and total dissolved solids. Of greatest note overall was the fact that total phosphorus exceeded the interim water quality objective of 0.1 mg L^{-1} throughout the growing season at the Kamsack sampling location, while this threshold was exceeded only in the April samples taken from the Carrot River location.

The continuous monthly data records for these sites allowed for the exploration of increasing or decreasing trends in the data. Given the obvious seasonality associated with water quality data, the data were grouped to reflect the spring runoff period and the remainder of the growing season. While some water quality parameters showed statistically significant seasonal trends, the trend magnitude was very small, resulting in minimal change when projected over the next 20 years.

The results of our data exploration support the findings from the literature review. For the most part, the water quality parameters in the Carrot and Assiniboine Rivers do not regularly exceed the guidelines for the protection of aquatic life. Exceedences do occur however, and these are generally short lived, primarily associated with spring runoff. Currently we are unable to separate agricultural, urban, and background signals in the data.

As indicated above, the levels of total phosphorus in the Assiniboine River at Kamsack routinely exceeded the water quality guideline throughout the growing season (data principally within the 0.1-0.3 mg L^{-1} range). However, it is widely acknowledged that Prairie surface waters have been nutrient rich historically, as such the interim guideline of 0.1 mg L^{-1} may be unrealistic. Further research into this topic is needed.[1] [Figure 2].

As with total phosphorus, there is no clearly defined and accepted guideline for total nitrogen in Saskatchewan waters. Total nitrogen and total phosphorus is not considered toxic in themselves; however, therefore there are no firm guidelines in this regard. Interim guidelines have been established by some jurisdictions (1.0 mg L^{-1} total-N for Alberta) to indicate nutrient levels that should warrant further investigation, i.e., concentrations greater than the interim guideline may be an indicator of a problem and further research is advised. [Figure 3].

Pilot Monitoring Program:

Given the existing limitations of the SEEMS and PPWB datasets to define the impact of agriculture on water quality, and given that Saskatchewan Environment future water quality monitoring will be focused on twenty-four sites along the major rivers, we have initiated a pilot

[1] Harker, D., McConkey, B. and McDuffie, H. 2003. Cropping Systems and Water Quality Concerns. Journal of Crop Production. Vol. 9 (19), 329-359.

water quality monitoring program that is designed to provide data from agricultural landscapes while supporting the existing Environmental Group Farm Plans in the province. [Figure 4].

Two sampling sites have been identified in each of the eight existing Group Plans. Each site is in conjunction with an existing flow monitoring station maintained by the Saskatchewan Watershed Authority thereby facilitating the calculation of mass loads carried by the stream. All sites are upstream of urban influence on smaller order streams, thus ensuring that the data collected will better reflect the surrounding agricultural land use.

The first samples were collected in October 2007. Discussions are currently underway to have the Saskatchewan Watershed Authority take over data collection for the 2008 field season. As more Group Plans are developed it is anticipated that additional sampling points will be added to the network. It is our hope that this program will continue well into the future providing a much needed water quality base line for Saskatchewan agricultural landscapes.

Non-contributing Drainage Areas:

One of the many unresolved issues with respect to agriculture's impact on water quality is how to treat the influence non-contributing drainage areas. As estimated from the image produced by the PFRA [Figures 5 and 6] [http://www.agr.gc.ca/pfra/gis/watershed/non_e.htm] approximately 50% of the Saskatchewan grain belt can be defined as not contributing runoff to a river system in an average year. (The PFRA image is based on a flood return of 2 years.)

Where Next?

Currently there are existing research projects in southern Alberta and Manitoba under the federal WEBs program (Watershed Evaluation of Beneficial Management Practices) that are measuring water quality with respect to land use practices. Projects in east-central and south-east Saskatchewan (Smith Creek and Pipestone Creek respectively) are undertaking similar types of studies but using different methodologies and looking at different management practices. Additional water quality related research is going on at the St. Denis site near Saskatoon, and the Brightwater Creek site near Kenaston. All these Saskatchewan sites could be potential candidates for future projects and offer a sound base from which to compete for WEBs II future funding.

Our efforts to understand agriculture's impact on water quality have pointed out some areas for future research; these are listed below. We will continue to work with the research community and producers to identify specific knowledge gaps and have them addressed.

- Impact versus concentration level?
- Is there a tipping point?
- Separate agricultural, urban and natural sources.
- Need for improved monitoring.
- How and where to measure the impact of management change.
- Address the impact on wetlands.
- Improved generalization of site specific research results

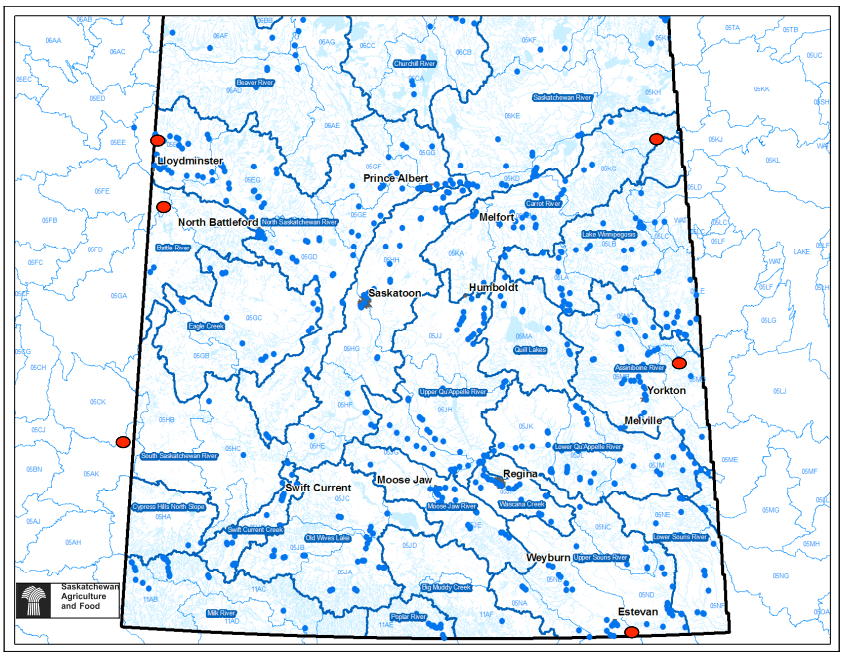

Figure 1. Saskatchewan watersheds showing SEEMS sample collection sites (blue dots) and PPWB collection sites (larger red dots).

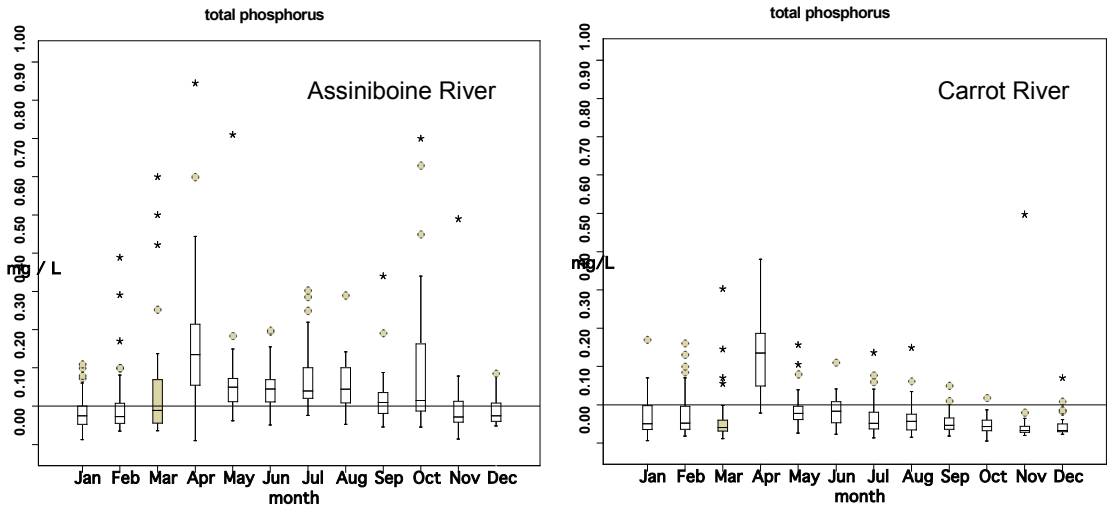

Figure 2. Monthly distribution of total phosphorus in the Assiniboine River at Kamsack and the Carrot River at Turnberry. The horizontal line indicates 0.1 mg/L, the total phosphorus maximum objective for the protection of aquatic health used by the Saskatchewan Watershed Authority. Note that the CCME, Alberta Environment, and Manitoba Conservation utilize a maximum objective of 0.05 mg/L.

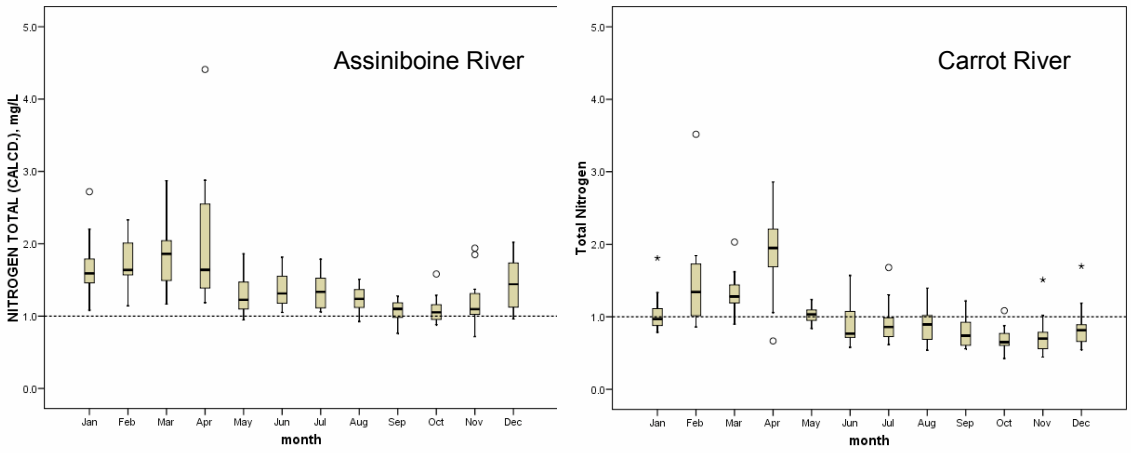

Figure 3. Monthly distribution of total nitrogen (calculated) in the Assiniboine River at Kamsack and the Carrot River at Turnberry, 1994-2006. Due to a change in laboratory methods in October 1993, earlier data is not included. No maximum objective for total nitrogen has been established by the CCME or Saskatchewan provincial agencies as a guideline for the protection of aquatic health. Alberta Environment uses a maximum objective of 1.0 mg/L as an indicator of water quality with respect to the protection of aquatic health.

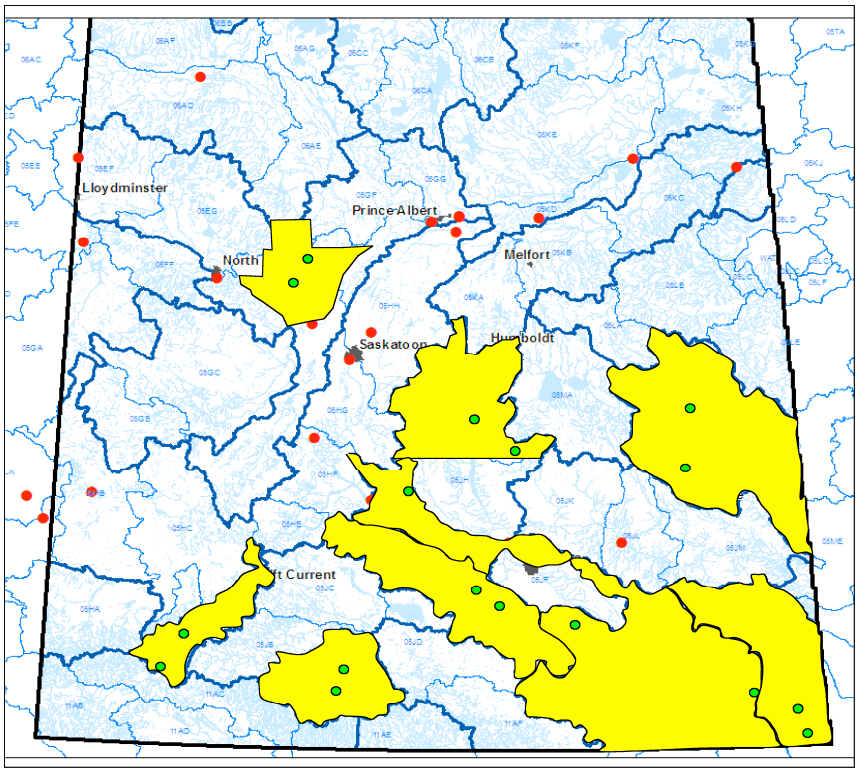

Figure 4. Existing Environmental Group Farm Plans (yellow shading), PPWB sites (red), future Saskatchewan Environment primary monitoring sites (red) and new water quality monitoring sites (pilot program) established by Saskatchewan Agriculture (green).

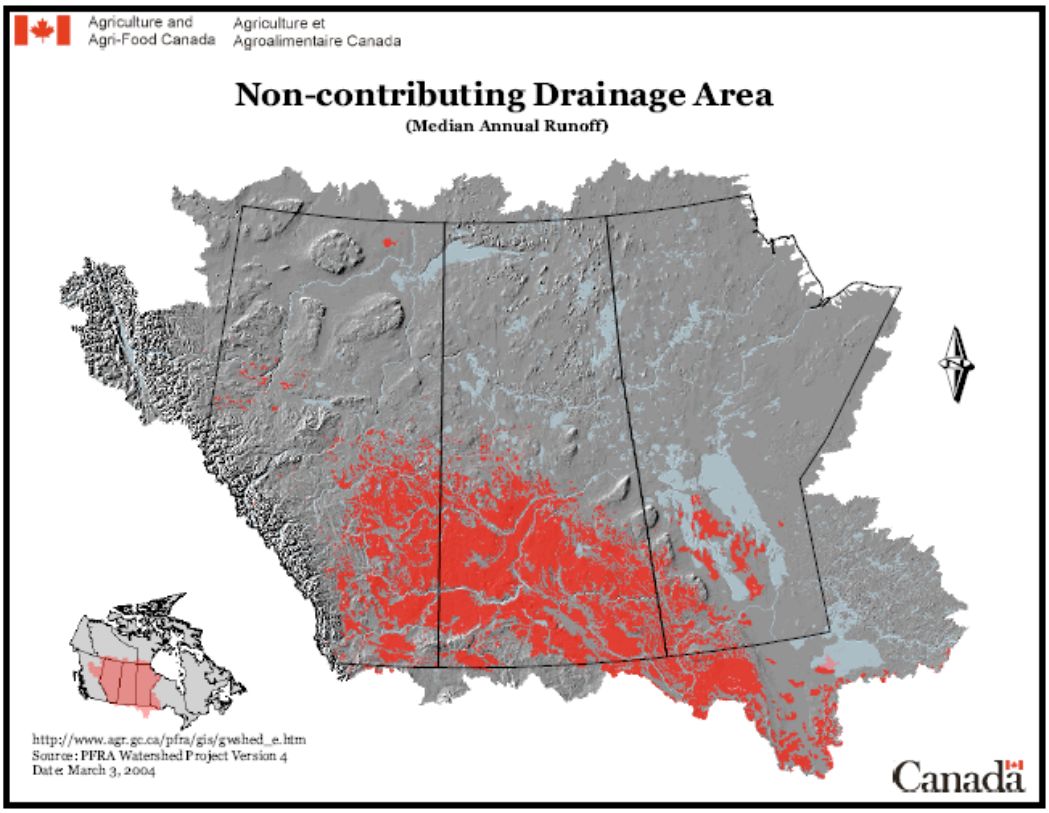

Figure 5. Image showing the extent of non-contributing drainage areas within the Prairie Pothole Region. (Original image produced by the PFRA.)

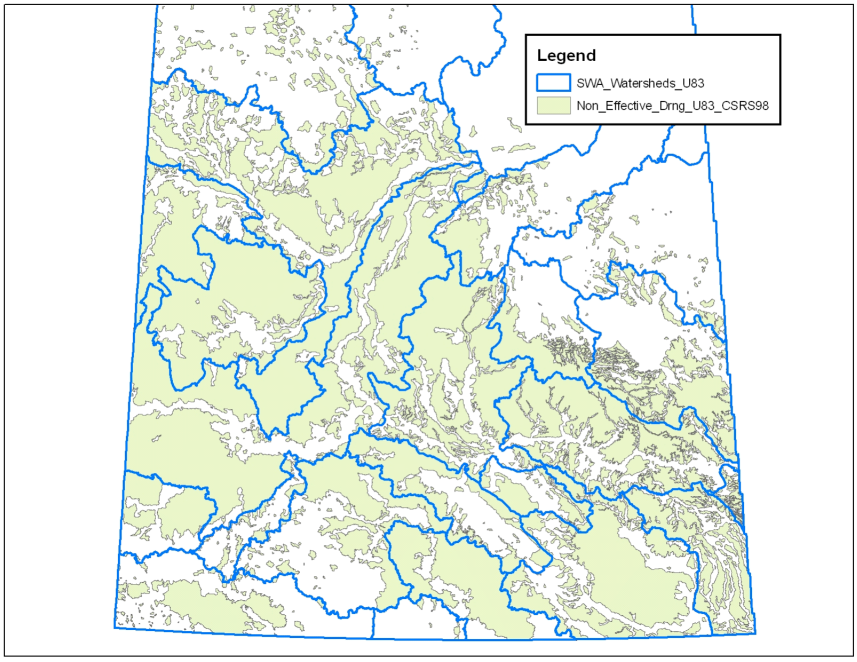

Figure 6. Saskatchewan watersheds. Non-contributing areas identified by green tone. This image based on a two-year flood return. (Original image produced by the PFRA.)