INVESTIGATING SPATIOTEMPORAL CHANGES IN WATER QUALITY ACROSS A NESTED SYSTEM OF INTENSIVELY MANAGED PRAIRIE WATERSHEDS

Amber Penner, Genevieve Ali, Halya Petzold

Department of Geological Sciences, University of Manitoba; Manitoba's Watershed Systems Research Program; Centre for Earth Observation Science (CEOS), Winnipeg, Manitoba, Canada

INTRODUCTION

The study of spatial and temporal patterns of watershed properties can provide a greater understanding of the drivers of hydrologic change. This is especially true for water quality dynamics that are known to vary: 1) temporally as a function of antecedent conditions (wet, intermediate, dry), seasons (spring, summer, fall), and events (snowmelt-driven, rainfall-triggered), and 2) spatially as a function of adjacent and upstream land-use practices and topographical characteristics. **Those spatiotemporal dynamics are especially understudied in cold and intensively managed Prairie landscapes.** Here we focused on a typical, mixed use Prairie watershed for which weekly average nutrient concentrations are available for the 2013 open water season: weekly correlation coefficients were calculated between nutrient concentrations and watershed characteristics such as land use and land cover proportions, mean watershed slope, and soil properties. This week-specific correlation analysis was done to allow the assessment of **a) which landscape characteristics influence water quality the greatest, and b) whether the influence exerted by specific landscape characteristics varies from week to week.**

STUDY SITE DESCRIPTION

The 642 km^2 Catfish Creek Watershed (CCW) is located in the Canadian Prairies (Manitoba, Canada) in a region that experiences an open water season from approximately late-April (spring thaw) to early-November (fall freeze-up). Although snowfall is not a major hydrologic input for this prairie region, snowmelt is a critical hydrological process. During the spring, when melt initiates, infiltration allows snow to recharge soil moisture and groundwater storage, and surface runoff replenishes surface water bodies. Spring flooding is also commonplace as available melt water often exceeds the infiltration capacity of frozen soils and overland flow occurs. The CCW includes a near even mix of forest and agriculture land (Figure 4); it has a heterogeneous topography (e.g., flat, hilly, see Figure 3) and contains a number of surface drains in both its agricultural and forested portions (Figure 5). The majority soil constituent is organics (Figure 6). Two main man-made drainage channels in the CCW are appropriately titled Main Drain 1 and Main Drain 2. The watershed also has additional smaller order drains, including: Side Drain, Heckert Drain (Figure 1), Hiebert Drain (Figure 2), and Stead Drain. 12 water quality sampling sites were selected based on outlets of 12 delineated sub-watersheds within the larger CCW.

Figure 1 (left) – Heckert Drain (Site 11, agricultural) on July 5, 2013; the drain is mostly dry by this time in the field season.

Figure 2 (right) – Hiebert Drain (Site 10, forested) on August 13, 2013.

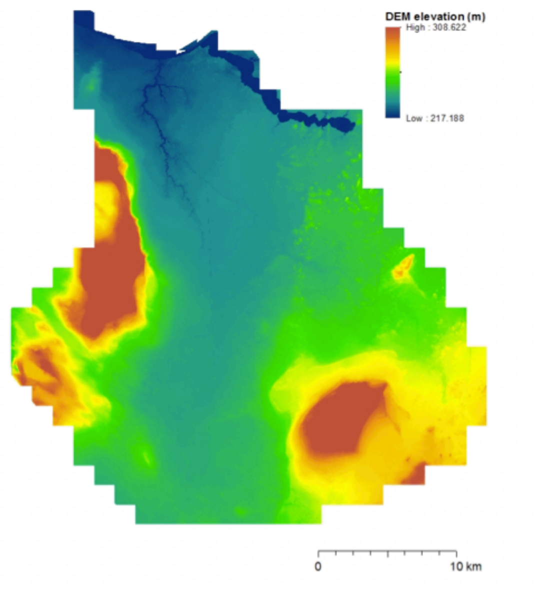

Figure 3 (left) – LiDAR-derived DEM (Digital Elevation Model) of the CCW acquired in spring 2012

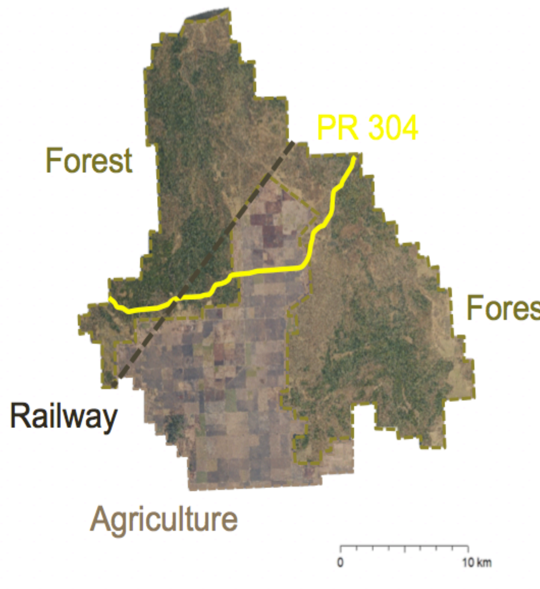

Figure 4 (right) – Land use and land cover map of the Catfish Creek Watershed in the CCW.

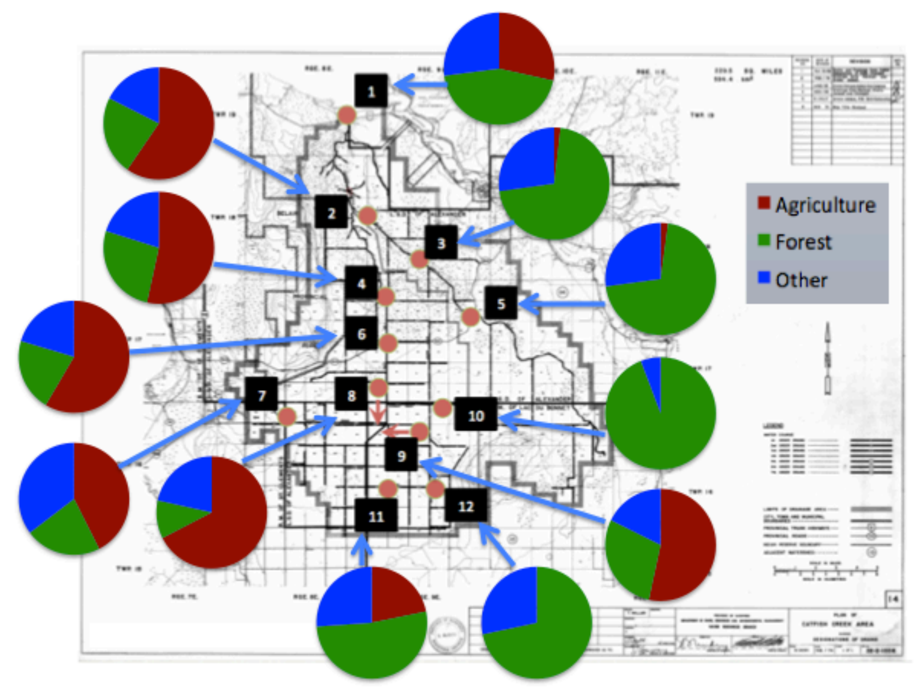

Figure 5 – Study sites (n = 12). Each site has a pie graph indicating the percentage of land use that is agricultural, forested, or other (including exposed land, developed land, water, wetland, and shrub lands). The basemap is a Water Resources Branch map of the CCW constructed drains (MIT, 2012).

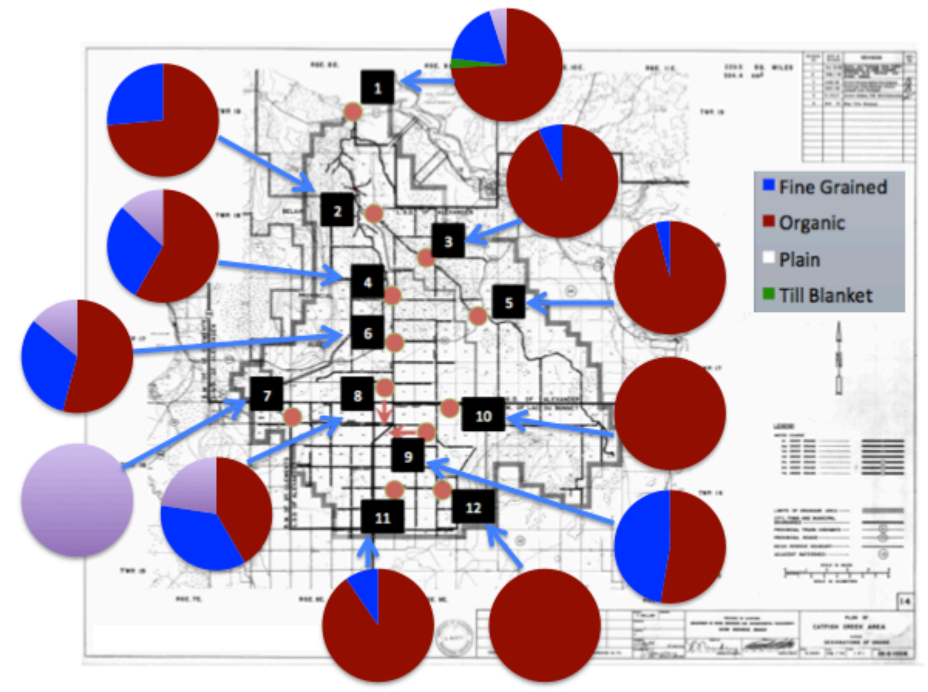

Figure 6 – Study sites (n = 12). Each site has a pie graph indicating the percentage of soil that is fine grains, organics, plains, or till blankets. The basemap is a Water Resources Branch map of the CCW constructed drains (MIT, 2012).

METHODOLOGY

Surface water quality was monitored from spring thaw to winter freeze-up using three different types of sites: i) high-intensity in-stream sites (n = 1), ii) moderate-intensity in-stream sites (n = 2), and iii) low-intensity in-stream sites (n = 9). At the low-intensity sites, surface water samples were collected manually. At the high- and moderate-intensity sites, auto-samplers were installed to allow fixed-interval water sample collection. Site 1 was a high-intensity site (1 sample every 7 hours), while Sites 2 and 5 were moderate-intensity sites (1 daily composite sample). The other nine sites were low-intensity sites (1 sample every 14 days). All collected samples were tested for pH, temperature, electrical conductivity (EC), total dissolved solids, turbidity, phosphate and nitrate concentrations. All data collected was averaged weekly for each site (27 weeks in total). For each week, Spearman rank correlation coefficients were computed between the averaged concentrations and sub-watershed characteristics (Table 1). The resulting correlation coefficients were defined as high (r > 0.7), moderate (0.4 < r < 0.7), and low (r < 0.4). Only correlation coefficients with p-values < 0.05 were deemed statistically significant.

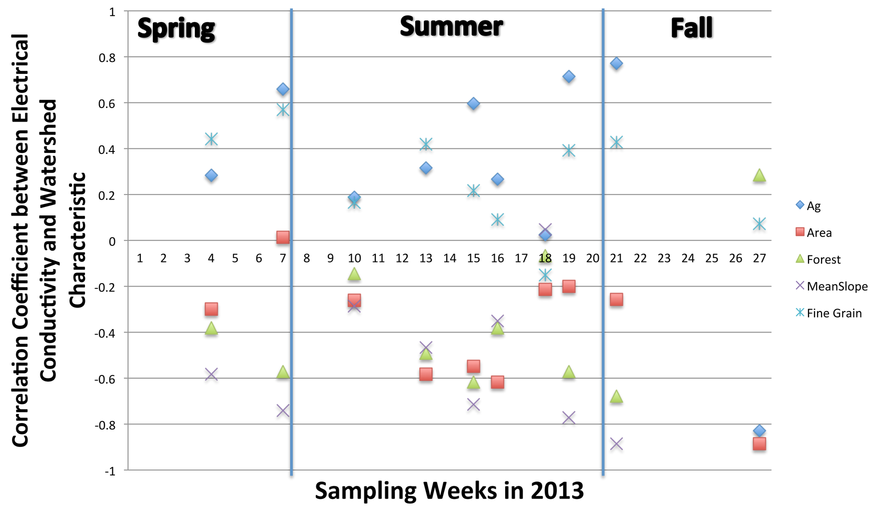

Figure 7 – Temporal evolution of the correlation coefficient between electrical conductivity and watershed characteristics. Week 1 is April 28-May 4, 2013.

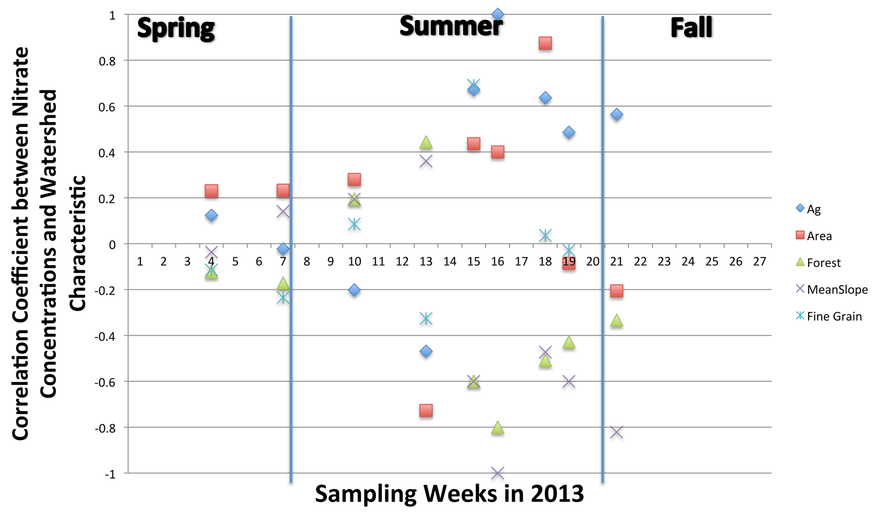

Figure 8 – Temporal evolution of the correlation coefficient between nitrate concentrations and watershed characteristics. Week 1 is April 28-May 4, 2013.

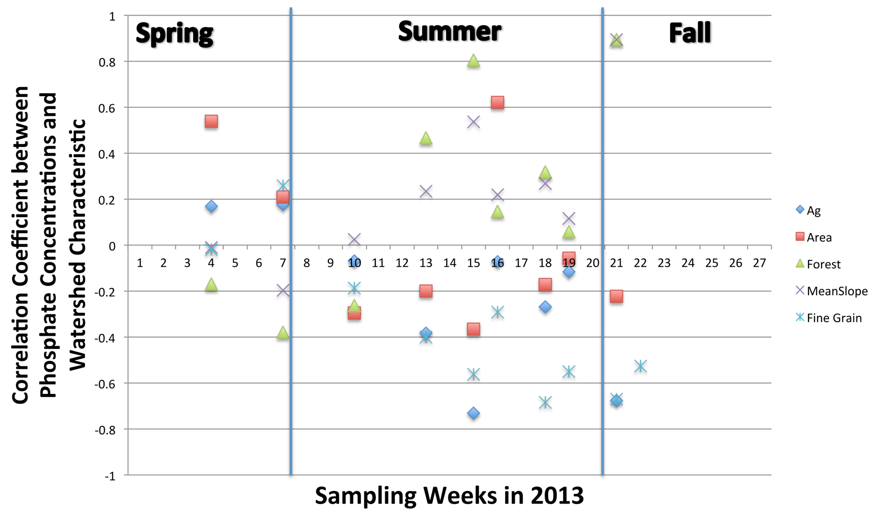

Figure 9 – Temporal evolution of the correlation coefficient between phosphate concentrations and watershed characteristics. Week 1 is April 28-May 4, 2013.

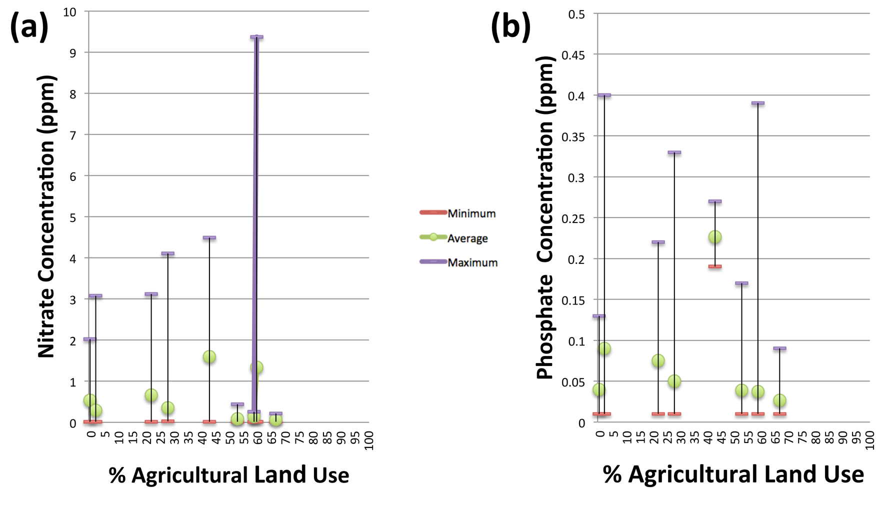

Figure 10 – Summary of 2013 nitrate (a) and phosphate (b) concentrations as a function of % agricultural land use in the sub-watersheds.

Table 1 – Summary statistics of watershed characteristics across the 12 sites.

	Drainage Area (km^2)	% Watershed Mean Slope	% Agricultural Land Use	% Forest Land Use	% Fine Grains in Soil	% Organics in Soil
Minimum	0.56	1.70	0.00	10.99	0.00	0.00
Maximum	642.43	3.51	67.45	94.19	47.27	100.00
Mean	162.36	2.40	32.44	44.70	17.17	68.82
Standard Deviation	174.24	0.53	25.36	25.61	15.41	28.61

RESULTS & DISCUSSION

Electrical Conductivity

- Figure 7
- High positive correlation with % fine grains.
- High negative correlation with watershed mean slope.
- Moderate positive correlation with % agricultural land use.
- Moderate negative correlation with watershed area.
- High negative correlation with % forest land use.

Turbidity

- Only tested turbidity after June 30, 2013.
- Low negative. correlation with % agricultural land use (-0.17) and low positive correlation with % forest land use (0.26).
- The correlation coefficients between turbidity and watershed area, % agricultural land use, and % fine grains were the highest in mid-summer (August 11-17, 2013). Inversely, the correlation coefficients between turbidity and % forest land use and watershed mean slope were the lowest in mid-summer.

Nitrate

- Figure 8
- Sites with greater % agricultural land use have greater maximum nitrate concentrations, and generally greater average nitrate concentrations (Figure 11(a)).
- No correlation with % fine grains.
- Moderate positive correlation with % agricultural land use.
- Moderate negative correlation with % forest land use and watershed mean slope.
- Week 13 had a very high spike in nitrate concentration at Sites 11 and 12: this appears to have interrupted patterns in correlation with watershed area, % agriculture land use, % forest land use, and watershed mean slope.

Phosphate

- Figure 9
- The greatest average phosphate concentrations occur at sites with smaller percentages of agricultural land use (Figure 11(b)).
- Moderate negative correlation with fine grains
  - Average -0.53 for mid- to late summer weeks (July 21-September 21, 2013)
- Moderate negative correlation with % agricultural land use, inverse to % forest land use.
- Moderate positive correlation with watershed mean slope.

CONCLUSION

- The % agricultural land use and % fine grains have similar effects on EC (i.e. correlation coefficients with EC increase and decrease together), with the exception of Week 15 when Site 8 was associated with an unusually high EC value.
- The effect of % forest land use and % agricultural land use are inverse of each other: this is understandable considering that they are two competing land use practices in the CCW.
- The effect of % fine grains and % organics are also inverse of each other: this is also understandable considering that they are the two major soil components in the CCW.
- The % forest land use and watershed mean slope have a similar effect on water quality parameters.
- Greater sampling frequency might be required for a better understanding of the effect of watershed characteristics on water quality.

ACKNOWLEDGEMENTS

We are grateful for the generous support of Manitoba Infrastructure and Transportation, specifically Paul Graveline and Ron Richardson, our research assistant Cody Ross and the Clayton H. Riddell Faculty of Environment, Earth, and Resources scholarship and endowment funds.

Manitoba Infrastructure and Transportation · Watershed Systems Research Program · University of Manitoba · CEOS