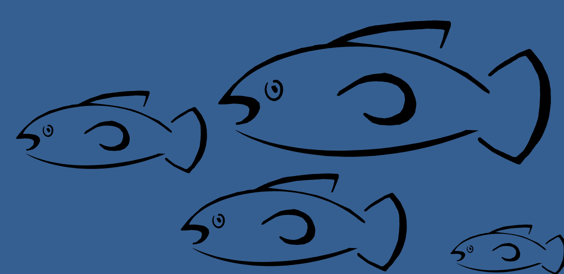
ECOLOGICAL MONITORING OF THE PINE RIVER AND CLARK CREEK

FUNDED BY
THE MINISTRY OF THE ENVIRONMENT
THROUGH THE ONTARIO COMMUNITY
ENVIRONMENT FUND



SAUGEEN CONSERVATION

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INTRODUCTION

The Province established the Ontario Community Environment Fund to channel money collected through environmental penalties into projects located in the watersheds in which the violations occurred.

Past monitoring in the Pine River and Clark Creek watersheds demonstrated elevated phosphorous and nitrogen-containing contaminants, as well as biological impairments to the benthic invertebrate community. Impairments of the aquatic ecosystem in these catchments may be more widespread than presently understood.

Through the use of a Geographic Information System and a modelling study, the Project will characterize the biological and chemical condition of Pine River and Clark Creek. The study will help to understand the relationships, if any, between catchment land-uses and land-cover, and various biological and chemical indices of ecosystem condition. A variety of different sampling techniques were used to provide the required predictor- and response-variables that were used to investigate relationships between catchment land-use or land-cover and ecological condition.

METHODS

Information was collected at twenty-one sites on the Pine River and three sites on Clark Creek (see maps Appendix A).

Chemical samples: Grab samples were collected from the sites on April 27th and 28th under low-flow conditions (not immediately post rainfall). A private chemistry lab was retained to analyze the samples for major ions, nutrients and metals (*E. Coli*, silver, aluminum, alkalinity, arsenic, boron, barium, beryllium, bismuth, calcium, calcium carbonate, cadmium, chloride, cobalt, conductivity, chromium, copper, iron, fluoride, hardness, potassium, lithium, magnesium, manganese, molybdenum, sodium, ammonia + ammonium, nickel, nitrates total, nitrite, nitrite + nitrate total, phosphorus, lead, pH , antimony, selenium, silicon, tin, strontium, sulphate, titanium, total Kjeldahl nitrogen, thallium, phosphorus, residue particulate, uranium, vanadium, tungsten, yttrium, zinc, chloride).

Benthic-invertebrate samples: Samples were collected 18 and 19 May 2010, using methods of the Ontario Benthos Biomonitoring Network (Jones et al., 2004). One sample per site was collected in a riffle area and preserved in ethanol. These samples were randomly searched for invertebrates, to yield 300-counts of specimens, which were ethanol preserved in glass vials. The consulting firm Zaranko Environmental Assessment Services Inc. (ZEAS) was retained to make detailed taxonomic diagnoses of collected specimens (most animals assigned to their genus or species).

Fish samples: A fisheries consultant was retained to collect the fish samples according to the Ontario Stream Assessment Protocol (Stanfield et al., 2005). Fish sampling for this project was completed by Josh Clark and Fred Manning, of C&M Aquatics Ltd., between 4 and 5 May 2010. Sampling locations were selected, where possible, such that a riffle-pool-riffle sequence was contained within the 50-metre site. Sampling was limited to a single pass survey of 50 metres of stream at each sampling location. All fish captured during sampling where enumerated and identified (typically species), before being released.

QHEI - Qualitative Habitat Evaluation Index: The QHEI assessment was completed by Ed Gazendam, Ph. D candidate at the University of Guelph. According to the QHEI, habitat quality is scored as the sum of a series of visually assessed measures of the stream system. These measures consider the following attributes:

- Substrate
- In-stream cover
- Channel morphology

- Riparian zone and banks
- Pool/glide quality and riffle/run quality
- Local channel slope

The reach is given a rating for each of the subcategories, which are then summed giving an overall QHEI score out of 100 (the higher the score, the better the habitat).

Geomorphic Assessment: Several stream-morphology measurements were made at each site, including:

- Channel cross-sections
- Longitudinal channel profile; and
- Substrate-particle size

These field measurements permitted the determination of bankfull width, bankfull depth, width-depth ratio, maximum depth, floodplain width, entrenchment ratio and bankfull slope at each site. Through air photo interpretation channel sinuosity, meander wavelength, and radii of curvature were determined. This data enabled reaches to be classified (i.e., using Rosgen's system, which is based on channel form and substrate type).

Data Modelling and Analysis: Multiple regression was used to model observed biological responses. Several classes of x-variables were considered, including those summarizing water chemistry, QHEI, stream size and geographic position, and catchment physiography. Before models were run, Principal Components Analysis was used to decompose the X-matrix into a manageable number of orthogonal composite variables. Y-variables included several univariate and multivariate summaries of fish- and benthic-invertebrate-community composition. Many combinations of X and Y variables were modeled (resulting in a total 264 linear regressions). To allow ecological patterns to be visualized, longitudinal patterns in biological index values were mapped, and the benthic-invertebrate, fish, and benthic-invertebrate-plus-fish communities were ordinated using Correspondence Analysis. A full correlation matrix, which included all X and Y variables, was used to assist interpretation of models, maps, and ordinations.

Northern Pike (*Esox lucius*)

RESULTS

These chemistry samples were taken during a period of low flow. Much higher concentrations would likely be observed during peak flows.

Phosphorus – There were 10 sites with phosphorus concentration exceeding the Provincial Water Quality Objectives (PWQO). Even at low flows, phosphorus concentrations indicate a level of impairment at all sites.

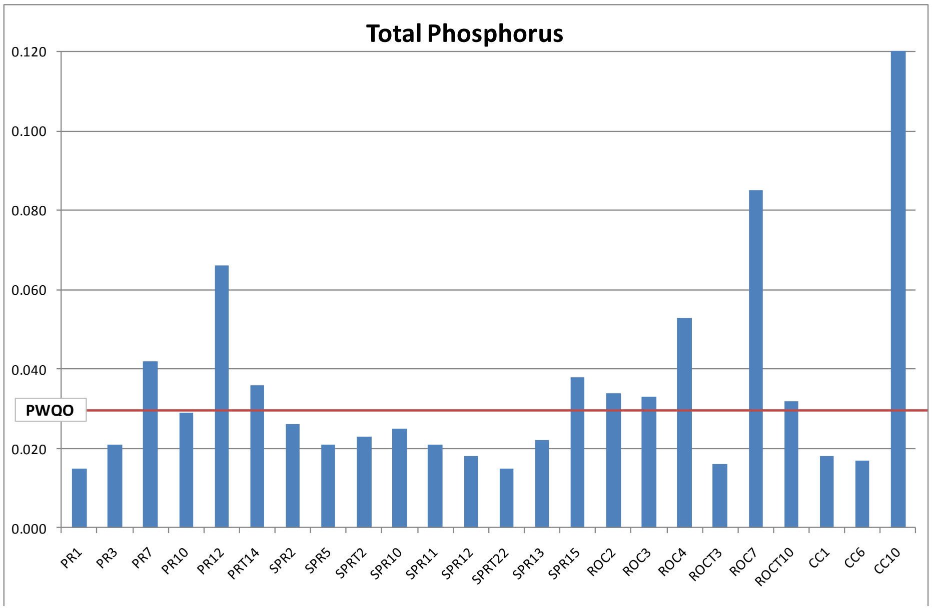

Figure 1. Phosphorus concentrations by site

Nitrate - There were 2 sites with nitrate concentrations exceeding the Canadian Water Quality Guidelines (CWQG).

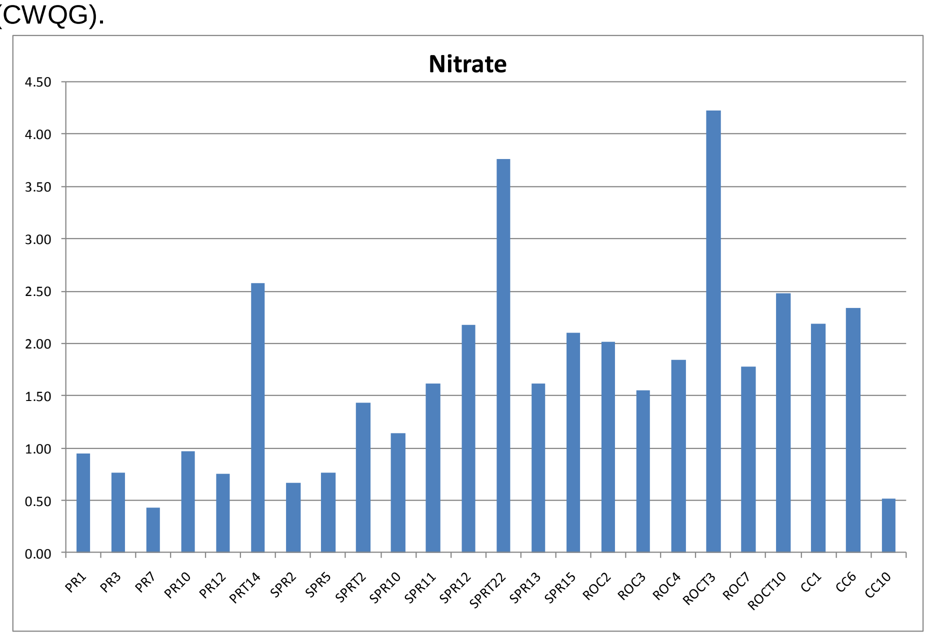

Figure 2. Nitrate concentrations by site

Total Suspended Solids – There are no objectives for total suspended solids however highly turbid water is undesirable for fish and aquatic life. Suspended solids can transport significant quantities of organic and inorganic trace contaminants.

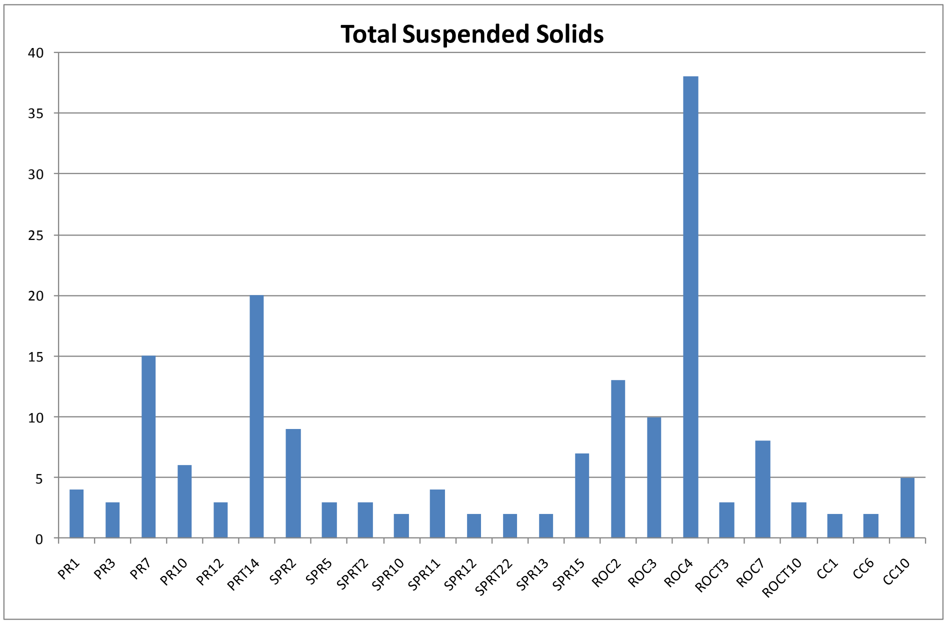

Figure 3. Total suspended solids concentration by site

***E. coli* –** There were 3 sites with concentrations of E. coli exceeding the provincial recreational water quality objectives.

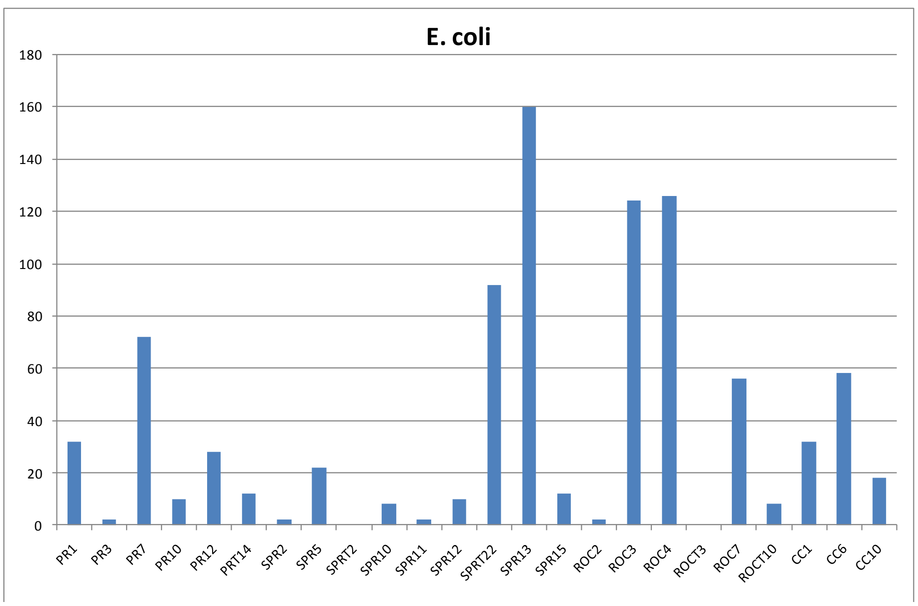

Figure 4. *E. coli* concentration by site

Table 1. Benthic Invertebrate Index values for each site

River Name	Site	CA1	CA2	Simpson's	Shannon-Wiener	Pielou's	% EPT	% Chironomidae	% CIGH	% FC	% GC	% P	% Sc	% Sh	Hilsenhoff FBI	Rarefied Richness
Clark Creek	CC1	-0.176	1.242	0.202	1.223	0.416	16.720	21.865	33.441	0.965	79.100	2.251	0.000	8.682	7.020	15.585
	CC6	0.839	0.330	0.133	1.563	0.531	19.064	21.739	27.090	1.003	60.201	21.070	0.334	6.020	6.165	17.608
	CC10	0.665	0.788	0.429	0.314	0.127	10.922	11.945	63.481	0.000	77.816	20.137	0.000	1.365	6.876	11.093
Royal Oak Creek	ROC2	-0.275	-2.830	0.171	1.385	0.455	1.603	0.641	10.897	1.282	58.974	28.526	9.615	0.641	6.903	17.416
	ROC3	0.521	-0.640	0.348	0.533	0.181	4.620	16.172	55.446	0.660	88.779	8.251	0.990	1.320	7.624	15.925
	ROC4	0.762	2.162	0.362	0.612	0.246	21.405	58.528	1.338	0.000	76.589	0.669	0.000	22.074	5.694	10.224
	ROC7	0.884	1.154	0.228	1.133	0.419	7.117	22.776	23.843	0.712	85.409	7.829	0.712	1.423	7.439	14.047
	ROCT10	1.143	-0.480	0.394	0.292	0.099	60.993	10.638	11.702	2.128	28.369	64.894	1.064	0.000	3.891	16.966
	ROC2	-0.275	-2.830	0.171	1.385	0.455	1.603	0.641	10.897	1.282	58.974	28.526	9.615	0.641	6.903	17.416
	ROCT3	1.347	-0.441	0.255	0.756	0.252	45.845	3.725	17.765	1.146	29.513	48.138	4.011	0.573	4.400	17.486
South Pine River	SPR2	-1.628	-0.476	0.180	1.107	0.353	35.354	11.448	7.744	6.734	14.141	29.966	41.077	7.744	4.141	20.678
	SPR5	-0.535	-0.044	0.456	0.162	0.054	8.458	8.458	66.667	4.478	79.602	6.965	3.980	4.975	7.104	19.970
	SPR10	-2.072	1.098	0.155	1.398	0.434	39.298	12.281	16.842	7.368	25.965	10.526	24.211	5.965	5.251	22.261
	SPR11	-0.796	-0.661	0.704	0.036	0.012	5.046	3.440	83.945	0.917	88.073	3.440	3.670	3.899	7.500	13.726
	SPR12	-0.954	0.104	0.158	1.244	0.378	10.211	28.521	32.746	0.000	75.000	14.789	5.634	1.761	6.823	24.238
	SPR13	0.865	0.428	0.145	1.435	0.464	9.589	41.438	17.808	0.685	66.781	20.205	0.000	7.534	6.438	19.535
	SPR15	1.266	0.431	0.446	0.219	0.074	66.216	8.446	6.081	0.338	26.689	70.608	0.000	1.014	3.692	15.618
	SPRT2	0.815	-1.287	0.318	0.683	0.241	28.082	6.507	48.973	3.767	61.986	32.192	0.685	0.000	6.014	15.438
	SPRT22	-1.083	0.953	0.211	0.973	0.310	5.862	60.000	2.069	1.724	70.690	10.000	10.690	5.517	6.540	20.540
Pine River	PR1	-1.570	-0.319	0.124	1.490	0.447	26.429	40.000	11.071	3.214	71.071	17.500	4.643	1.429	6.047	25.527
	PR3	-0.248	-0.683	0.362	0.320	0.109	19.231	1.748	58.392	2.448	66.783	26.224	2.448	2.098	6.283	17.673
	PR7	0.377	0.622	0.200	1.197	0.393	44.118	12.745	32.353	4.902	50.654	15.359	1.961	26.144	5.204	18.288
	PR10	0.391	-1.406	0.301	0.631	0.196	29.565	4.058	55.942	2.609	57.971	28.986	7.826	2.029	5.977	21.159
	PR12	0.353	0.271	0.277	0.680	0.258	5.594	55.245	0.000	1.049	84.266	10.490	1.399	0.699	7.093	13.572
	PRT14	0.666	0.484	0.186	1.354	0.445	32.248	30.619	23.127	0.651	57.003	32.248	0.977	4.560	5.594	17.458

Table 2. Summary of Fish Species by Site

Species Name	Rainbow Trout	Brown Trout	Northern Pike	Spotfin Shiner	Common Shiner	River Chub	Emerald Shiner	Rosyface Shiner	Northern Redbelly Dace	Bluntnose Minnow	Fathead Minnow	Western Blacknose Dace	Longnose Dace	Creek Chub	White Sucker	Brown Bullhead	Brook Stickleback	Mottled Sculpin	Rock Bass	Smallmouth Bass	Rainbow Darter	Least Darter	Johnny Darter	Logperch	Blackside Darter	Round Goby	Cyprinid spp. (juvenile or YOY)
CC1	1	0	0	0	7	0	80	0	4	11	5	22	4	45	42	0	4	0	0	0	3	0	27	0	0	6	20
CC6	0	0	0	0	5	0	0	0	133	7	23	46	63	76	51	0	18	0	0	0	0	0	6	0	0	0	119
CC10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	19	0	0	0	0	0	0	0	0	0	0
ROC2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	1	0	0	33	8	0	0	0	0
ROC3	0	0	0	0	29	0	0	0	0	41	3	0	0	23	27	0	1	0	4	0	0	18	46	0	1	0	7
ROC4	0	0	0	0	40	0	0	0	3	16	2	0	0	112	78	0	2	0	1	0	0	1	15	0	6	0	15
ROC7	0	0	0	0	4	0	0	0	23	0	0	0	0	85	21	0	9	0	0	0	0	0	1	0	0	0	0
ROCT10	0	0	0	0	0	0	0	0	2	0	0	0	0	21	0	0	41	0	0	0	0	0	0	0	0	0	0
ROCT3	0	0	0	0	0	0	0	0	0	0	33	0	0	67	45	0	19	0	0	0	0	0	0	0	0	0	0
SPR2	0	0	0	0	0	0	0	0	0	4	0	0	0	0	4	0	0	0	0	0	8	0	30	0	1	0	0
SPR5	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	1	0	5	57	0	2	0	0
SPR10	0	0	0	0	4	11	0	0	0	0	0	0	0	1	2	0	0	0	1	0	8	0	70	0	1	0	0
SPR11	0	0	0	0	2	0	0	0	0	4	0	0	0	2	2	0	0	2	3	0	6	1	19	0	2	0	0
SPR12	0	0	0	0	4	0	0	0	1	0	0	3	0	10	15	0	3	17	0	0	22	0	19	0	0	0	0
SPR13	0	0	0	0	0	0	0	0	118	8	2	53	0	93	7	0	57	0	0	0	0	2	1	0	0	0	0
SPR15	0	0	0	0	1	0	0	0	0	0	2	2	0	31	0	0	5	0	0	0	0	0	0	0	0	0	0
PR1	0	3	0	4	1	0	13	1	0	5	0	0	28	0	36	2	0	0	0	6	32	0	6	4	2	0	0
PR3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	3	0	1	2	16	0	1	0	0
PR7	0	0	0	0	32	0	0	0	0	7	1	0	0	80	111	0	28	0	0	0	0	0	18	0	4	0	1
PR10	0	0	0	0	0	0	0	0	0	12	9	0	0	4	11	0	0	0	0	0	0	4	18	0	0	0	0
PR12	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	5	0	0	0	0	0	0	0	0	0	0
PRT14	0	0	0	0	2	0	0	0	74	11	18	0	0	86	40	0	1	0	0	0	0	5	14	0	0	0	119
SPRT2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SPRT22	0	0	0	0	3	0	0	0	3	10	0	113	0	30	5	0	3	0	0	0	10	2	18	0	0	0	0

Table 3. QHEI Scores by site

SITE	Substrate	Origin	Quality	Best Types	SUBSTRATE	Instream Cover	Amount	INSTREAM COVER	Sinuosity	Development	Channelization	Stability	CHANNEL MORPHOLOGY	Erosion	Riparian Width	Floodplain Quality	EROSION & RIPARIAN	Max Depth	Channel Width	Flow Velocity		Riffle Depth	Run Depth	Riffle/Run Substrate	Embeddedness	P/G AND R/RUN QUALITY	Gradient	GRADIENT	TOTAL QHEI SCORE
	X1	X2	X3	X4		X5	X6		X7	X8	X9	X10		X11	X12	X13		X14	X15	X16		X17	X18	X19	X20		X21		
CC1	13.0	1.0	-1.5	2.0	14.5	6.0	3.0	9.0	2.5	5.0	6.0	2.0	15.5	1.5	2.0	2.0	5.5	2.0	2.0	3.0	7.0	2.0	1.0	1.5	1.5	6.0	6.0	6.0	63.5
CC6	13.0	1.0	-0.5	0.0	13.5	3.0	3.0	6.0	3.0	5.0	3.0	2.0	13.0	2.5	1.0	0.5	4.0	4.0	2.0	3.0	9.0	2.0	1.0	1.0	1.0	5.0	6.0	6.0	56.5
CC10	13.0	1.0	0.0	0.0	14.0	1.0	1.0	2.0	2.0	4.0	3.0	2.0	11.0	2.0	1.5	0.5	4.0	1.0	2.0	3.0	6.0	1.0	1.0	1.0	2.0	5.0	5.5	5.5	47.5
ROC2	4.0	1.0	-3.0	2.0	4.0	8.0	3.0	11.0	3.5	4.0	6.0	2.0	15.5	2.5	2.5	0.5	5.5	6.0	2.0	2.0	10.0	2.0	1.0	1.5	-0.5	4.0	9.0	9.0	59.0
ROC3	10.5	1.0	-2.0	0.0	9.5	5.0	3.0	8.0	3.0	1.0	1.0	1.0	6.0	1.0	0.0	0.0	1.0	4.0	2.0	4.0	10.0	2.0	1.0	2.0	2.0	7.0	6.0	6.0	47.5
ROC4	10.5	1.0	-4.0	0.0	7.5	2.0	1.0	3.0	4.0	1.0	1.0	1.0	7.0	1.0	0.0	0.0	1.0	2.0	2.0	2.0	6.0	1.0	1.0	0.0	-0.5	1.5	8.0	8.0	34.0
ROC7	10.5	1.0	-2.0	0.0	9.5	2.0	3.0	5.0	2.0	3.0	3.0	1.0	9.0	2.0	0.0	0.0	2.0	2.0	2.0	2.0	6.0	1.0	1.0	0.0	0.0	2.0	10.0	10.0	43.5
ROCT10	10.5	1.0	-2.0	0.0	9.5	3.5	3.0	6.5	2.0	3.0	3.0	1.5	9.5	2.5	0.0	0.0	2.5	2.0	2.0	3.0	7.0	1.0	1.0	0.5	0.0	2.5	10.0	10.0	47.5
ROCT3	9.5	1.0	-2.5	0.0	8.0	3.0	3.0	6.0	2.0	3.0	3.0	2.0	10.0	2.5	0.5	1.0	4.0	2.0	2.0	2.0	6.0	1.0	1.0	2.0	1.0	5.0	10.0	10.0	49.0
SPR2	9.0	1.0	-1.5	2.0	10.5	5.0	3.0	8.0	2.5	4.0	6.0	2.0	14.5	2.0	0.5	2.0	4.5	4.0	2.0	3.0	9.0	2.0	1.0	1.0	1.0	5.0	5.5	5.5	57.0
SPR5	13.0	1.0	-2.0	0.0	12.0	9.0	7.0	16.0	3.0	4.0	5.0	1.0	13.0	2.0	3.0	0.0	5.0	4.0	2.0	3.0	9.0	1.0	1.0	0.0	0.0	2.0	10.0	10.0	67.0
SPR10	11.5	1.0	-2.0	2.0	12.5	9.0	7.0	16.0	3.0	6.0	5.0	2.0	16.0	2.5	3.0	0.0	5.5	6.0	2.0	3.0	11.0	2.0	1.0	1.0	1.0	5.0	8.0	8.0	74.0
SPR11	12.5	1.0	-2.0	2.0	13.5	9.0	7.0	16.0	3.0	6.0	6.0	2.5	17.5	1.5	4.0	1.5	7.0	6.0	2.0	4.0	12.0	2.0	1.0	1.0	1.0	5.0	10.0	10.0	81.0
SPR12	11.5	1.0	0.0	2.0	14.5	6.0	5.0	11.0	3.0	5.0	6.0	2.0	16.0	2.5	0.5	0.5	3.5	2.0	2.0	3.0	7.0	2.0	2.0	1.5	1.5	7.0	10.0	10.0	69.0
SPR13	9.5	1.0	-3.0	0.0	7.5	4.0	3.0	7.0	2.0	3.0	3.0	1.5	9.5	2.0	3.0	0.0	5.0	2.0	2.0	2.0	6.0	1.0	1.0	1.0	1.0	4.0	7.0	7.0	46.0
SPR15	11.5	1.0	-2.0	0.0	10.5	5.0	7.0	12.0	2.0	3.0	3.0	2.0	10.0	2.5	0.0	0.0	2.5	2.0	2.0	3.0	7.0	1.0	1.0	1.0	2.0	5.0	4.0	4.0	51.0
PR1	14.0	1.0	-1.0	2.0	16.0	9.0	3.0	12.0	3.0	5.0	6.0	2.0	16.0	1.5	4.0	1.5	7.0	4.0	2.0	3.0	9.0	2.0	1.0	1.0	0.5	4.5	8.0	8.0	72.5
PR3	11.5	1.0	-0.5	2.0	14.0	5.0	3.0	8.0	3.5	5.0	6.0	2.5	17.0	2.5	3.0	0.5	6.0	4.0	2.0	3.0	9.0	2.0	2.0	2.0	1.5	7.5	10.0	10.0	71.5
PR7	13.0	1.0	-2.0	0.0	12.0	5.0	7.0	12.0	3.5	5.0	4.0	1.0	13.5	2.0	0.5	0.0	2.5	2.0	2.0	2.0	6.0	2.0	1.0	0.5	0.0	3.5	9.5	9.5	59.0
PR10	11.5	1.0	-2.0	0.0	10.5	6.0	7.0	13.0	3.0	4.0	3.0	2.0	12.0	2.5	0.0	0.0	2.5	2.0	2.0	2.0	6.0	2.0	2.0	1.5	0.5	6.0	8.0	8.0	58.0
PR12	14.0	1.0	0.0	2.0	17.0	5.0	11.0	16.0	3.0	5.0	4.0	2.0	14.0	3.0	1.0	0.0	4.0	2.0	2.0	2.0	6.0	1.0	1.0	1.5	1.0	4.5	6.0	6.0	67.5
PRT14	12.0	1.0	-2.5	2.0	12.5	3.0	3.0	6.0	2.5	3.0	3.0	1.5	10.0	2.5	0.0	0.0	2.5	2.0	2.0	2.0	6.0	1.0	1.0	1.0	0.0	3.0	10.0	10.0	50.0
SPRT2	9.0	1.0	-3.0	0.0	7.0	6.0	7.0	13.0	3.0	5.0	6.0	1.5	15.5	3.0	3.5	0.5	7.0	2.0	2.0	2.0	6.0	2.0	1.0	1.0	1.0	5.0	9.0	9.0	62.5
SPRT22	10.5	1.0	-1.0	0.0	10.5	3.0	3.0	6.0	3.0	3.0	6.0	1.0	13.0	2.5	1.0	1.0	4.5	2.0	2.0	2.0	6.0	1.0	1.0	0.0	0.5	2.5	10.0	10.0	52.5

Table 4. Summary of Geomorphic Characteristics

SITE	Bankfull Width	Bankfull Depth	Bankfull Area	Width-Depth Ratio	Maximum Depth	Floodprone Width	Entrenchment Ratio	Channel Materials - D50	Water Surface Slope	Sinuosity	Stream Type (Rosgen)
CC1	12.69	0.48	6.11	26.34	0.71	15.69	1.24	68.33	0.0032	1.05	B3c
CC6	4.01	0.27	1.07	14.95	0.34	10.17	2.53	20.13	0.0025	1.29	C4
CC10	2.02	0.11	0.21	18.94	0.27	3.19	1.58	0.63	0.0011	1.04	B5c
ROC2	11.17	0.65	7.28	17.13	1.14	61.98	5.55	25.28	0.0026	1.63	C4
ROC3	7.25	0.49	3.53	14.86	0.95	16.41	2.27	36.88	0.0022	1.33	C4
ROC4	8.8	0.64	5.62	13.75	0.95	25.12	2.85	4.76	0.0031	1.68	C4
ROC7	3.51	0.33	1.15	10.68	0.61	10.85	3.09	16	0.0021	1.04	C4
ROCT10	3.29	0.27	0.9	11.99	0.46	5.32	1.62	3.5	0.0081	1.23	B4c
ROCT3	5.67	0.5	2.84	11.34	0.82	22.86	4.03	0.75	0.0208	1.02	E5b
SPR2	8.78	0.44	3.86	20	0.94	14.5	1.65	24.95	0.0024	1.06	C4
SPR5	5.98	0.47	2.82	12.65	0.73	10.42	1.74	1.5	0.0106	1.33	B5c
SPR10	7.4	0.46	3.4	16.08	0.72	15.54	2.1	57.67	0.0064	1.02	C4
SPR11	8.56	0.47	4.01	18.41	0.7	20.2	2.35	3	0.0023	1.5	C4
SPR12	8.76	0.38	3.32	22.98	0.89	45.72	5.22	11.3	0.0096	1.09	C4
SPR13	3.77	0.57	2.15	6.62	1	11	2.92	16	0.014	1.35	E4
SPR15	1.35	0.32	0.43	4.27	0.52	5	3.69	0.18	0.0197	1.04	E5
PR1	28.55	1.08	30.7	26.54	1.83	60.96	2.13	90	0.0074	1.25	C3
PR3	9.06	0.38	3.45	23.78	0.55	13.33	1.47	16	0.0003	1.4	B4c
PR7	2.11	0.45	0.94	4.73	0.6	14.5	6.88	6.47	0.0001	1.29	E4
PR10	3.26	0.14	0.47	22.77	0.24	6.09	1.87	10.47	0.0126	1.8	B4c
PR12	1.95	0.57	1.12	3.4	1.37	9.59	4.91	14.83	0.0098	1.09	E4b
PRT14	3.58	0.38	1.37	9.31	0.67	30.48	8.53	14.83	0.0082	1.09	E4
SPRT2	2.93	0.33	0.97	8.82	0.55	7.6	2.6	1	0.0167	1.27	E5
SPRT22	4.09	0.27	1.13	14.9	0.59	5.43	1.53	13.65	0.0102	1.14	B4c

Table 5. Summary of the most significant models (34 of 264 completed)

Ref #	Xs	Y	Method	# X	Predictors in best model					n	F	abs(r)	AIC	p
1	All Non-DA-related Xs (as PCA axes) + DA	CA1 benthos	Stepwise, Fwd Selection	3	X5:QHEIPC1	X4:ChemPC4	X3:ChemPC3			24	2.2	0.79	52.4	0.1220
2	Chem PC1-4	CA1 benthos	Stepwise, Fwd Selection	2	X3:ChemPC3	X4:ChemPC4				24	5.6	0.61	63.0	0.0121
3	QHEI PC1-4	CA1 benthos	Stepwise, Fwd Selection	1	X1:QHEIPC1					24	23.7	0.72	54.8	0.0001
4	DA	CA1 benthos	Simple Linear Regression	1	DA					24	13.0	-0.61	61.1	0.0016
5	All Non-DA-related Xs (as PCA axes) + DA	CA2 Benthos	Stepwise, Fwd Selection	4	X7:QHEIPC3	X5:QHEIPC1	X8:soilPC2	X2:ChemPC2		24	4.0	0.70	65.0	0.0174
6	QHEI PC1-4	CA2 Benthos	Stepwise, Fwd Selection	2	X3:QHEIPC3	X1:QHEIPC1				24	3.5	0.51	70.0	0.0510
7	All Non-DA-related Xs (as PCA axes) + DA	Rarefied Richness, benthos	Stepwise, Fwd Selection	4	X10:landusePC2	X2:ChemPC2	X8:soilPC2	Entered: X4		24	2.8	0.77	120.9	0.0550
8	Chem PC1-4	Rarefied Richness, benthos	Stepwise, Fwd Selection	2	X4:ChemPC4	X2:ChemPC2				24	3.1	0.54	130.3	0.0654
9	QHEI PC1-3	Rarefied Richness, benthos	Stepwise, Fwd Selection	1	X1:QHEIPC1					24	4.7	0.42	132.1	0.0423
10	DA	Rarefied Richness, benthos	Simple Linear Regression	1	DA					24	7.5	0.51	129.6	0.0121
11	All Non-DA-related Xs (as PCA axes) + DA	%Chironomidae	Stepwise, Fwd Selection	2	X1:ChemPC1	X9:soilPC3				24	2.0	0.47	208.7	0.1584
12	Chem PC1-4	%Chironomidae	Stepwise, Fwd Selection	1	X1:ChemPC1					24	3.6	0.38	208.9	0.0709
13	All Non-DA-related Xs (as PCA axes) + DA	%CIGH	Stepwise, Fwd Selection	1	X3:ChemPC3					24	3.4	0.31	221.9	0.0805
14	Chem PC1-4	%CIGH	Stepwise, Fwd Selection	1	X3:ChemPC3					24	3.4	0.36	221.9	0.0805
15	All Non-DA-related Xs (as PCA axes) + DA	%FC	Stepwise, Fwd Selection	5	X3:ChemPC3	X4:ChemPC4	X10:landusePC2	X2:ChemPC2	X8:soilPC2	24	2.4	0.83	87.9	0.0835
16	QHEI PC1-3	%P	Stepwise, Fwd Selection	1	X2:QHEIPC2					24	3.5	0.37	208.8	0.0755
17	QHEI PC1-3	%Sc	Stepwise, Fwd Selection	1	X1:QHEIPC1					24	3.1	0.35	177.1	0.0950
18	All Non-DA-related Xs (as PCA axes) + DA	%Sh	Stepwise, Fwd Selection	1	X2:ChemPC2					24	6.5	0.48	156.7	0.0183
19	Chem PC1-4	%Sh	Stepwise, Fwd Selection	1	X2:ChemPC2					24	6.5	0.48	156.7	0.0183
20	QHEI PC1-3	%Sh	Stepwise, Fwd Selection	1	X2:QHEIPC2					24	3.5	0.37	159.4	0.0744
21	All Non-DA-related Xs (as PCA axes) + DA	CA1 Fish	Stepwise, Fwd Selection	1	X3:ChemPC3					24	5.0	0.45	76.1	0.0356
22	Chem PC1-4	CA1 Fish	Stepwise, Fwd Selection	1	X4:ChemPC4					24	9.8	0.56	75.2	0.0050
23	QHEI PC1-3	CA1 Fish	Stepwise, Fwd Selection	3	X2:QHEIPC2	X1:QHEIPC1	X3:QHEIPC3			24	4.6	0.87	54.8	0.0139
24	All Non-DA-related Xs (as PCA axes) + DA	CA2 Fish	Stepwise, Fwd Selection	1	X11:DA					24	11.4	0.59	65.3	0.0028
25	Chem PC1-4	CA2 Fish	Stepwise, Fwd Selection	1	X1:ChemPC1					24	3.3	0.37	72.0	0.0819
26	All Non-DA-related Xs (as PCA axes) + DA	Rarefied Richness (fish)	Stepwise, Fwd Selection	1	X5:QHEIPC1					24	5.0	2.23	86.1	0.0366
27	Chem PC1-4	%Highly Sensitive (fish)	Stepwise, Fwd Selection	1	X3:ChemPC3					24	7.6	0.52	218.0	0.0116
28	Chem PC1-4	%Cyprinidae	Stepwise, Fwd Selection	1	X3:ChemPC3					24	9.4	0.56	219.8	0.0059
29	QHEI PC1-3	%Cyprinidae	Stepwise, Fwd Selection	1	X1:QHEIPC1					24	8.8	0.54	220.2	0.0074
30	Chem PC1-4	%Percidae	Stepwise, Fwd Selection	2	X3:ChemPC3	X4:ChemPC4				24	6.9	0.64	222.0	0.0052
31	QHEI PC1-3	%Percidae	Stepwise, Fwd Selection	3	X1:QHEIPC1	X2:QHEIPC2	X3:QHEIPC3			24	3.2	0.78	214.3	0.0477
32	All Non-DA-related Xs (as PCA axes) + DA	CA1 fish + benthos	Stepwise, Fwd Selection	3	X5:QHEIPC1	X6:QHEIPC2	X3:ChemPC3			24	5.2	0.87	44.3	0.0089
33	Chem PC1-4	CA1 Fish+Bugs	Stepwise, Fwd Selection	2	X3:ChemPC3	X4:ChemPC4				24	6.7	0.65	62.8	0.0058
34	QHEI PC1-3	CA1 Fish+Bugs	Stepwise, Fwd Selection	2	X1:QHEIPC1	X2:QHEIPC2				24	7.4	0.83	47.8	0.0040
35	QHEI PC1-3	CA2 Fish+Bugs	Stepwise, Fwd Selection	1	X3:QHEIPC3					24	4.9	0.43	70.5	0.0385
36	QHEI PC1-3	Rarefied Richness Fish+Bugs	Stepwise, Fwd Selection	1	X1:QHEIPC1					24	6.5	0.48	142.7	0.0186
37	DA	Rarefied Richness Fish+Bugs	Simple Linear Regression	1	DA					24	8.9	0.54	140.7	0.0070

DISCUSSION

- All sites within the two watersheds are showing a degree of impairment with some sites worse than others. These two rivers systems are subject to low to zero flows in the summer months.
- Stream communities are strongly influenced by land-use, in particular by agricultural practices in their catchments. Decreasing phosphorus and total suspended solids is correlated with increasing richness of biological communities. In-stream habitat, nutrients, and sedimentation were the best drivers of composition of the many variables we tested having obvious implications for restoration work.
- Models indicated that biological communities responded strongly to channel alterations and nutrient additions. Fish richness is predicted by QHEI - high QHEI values predict high richness. Low nitrate and high QHEIs are associated with sensitive fish communities. Benthic-invertebrate communities can be predicted by QHEI, soil, and chemistry. Some of the variables implicated by the correlations, and thus subject to mitigation, are some elements of in-stream channel form, and in part, by various land-uses (erosion), cover and entrenchment, various metals, and suspended solids.
- Some patterns of impact-recovery occurred, suggesting that biological communities were responding to land-use-related stressors.

Engineering students from the University of Guelph have been involved in this project. Based on model results, they have designed a restoration project for ROC4. ROC4 is exposed to many stressors that are pervasive within the Pine/Clark watershed. Their project design — which excludes livestock from the channel, naturalizes the streamside corridor, and restores channel form — demonstrates restorative techniques that are broadly applicable within this agricultural system.

CONCLUSIONS

The objectives of the project have been met. We have concluded that:

- There is no predictable pattern to biodiversity as you move downstream through these systems, even though according to models like the "River Continuum Concept (Vannote et al 1980), there should be. This suggests that stressor exposure overrides natural processes governing biodiversity.
- Stream communities are strongly influenced by land-use, in particular by agricultural practices in their catchments.
- Because QHEI and water chemistry were important predictors, restoration should aim to improve in-stream habitat, reduce erosion, and reduce inputs of phosphorus and nitrogen.

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- Ed Gazendam, Ph. D candidate at the University of Guelph, who completed the QHEI and geomorphic assessments
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- Chris Jones, Benthic Biomonitoring Scientist with the Ministry of the Environment, Dorset Environmental Science Centre who completed the data modeling and analysis
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APPENDIX A

Figure 5. Map of sampling locations in the Pine River watershed.

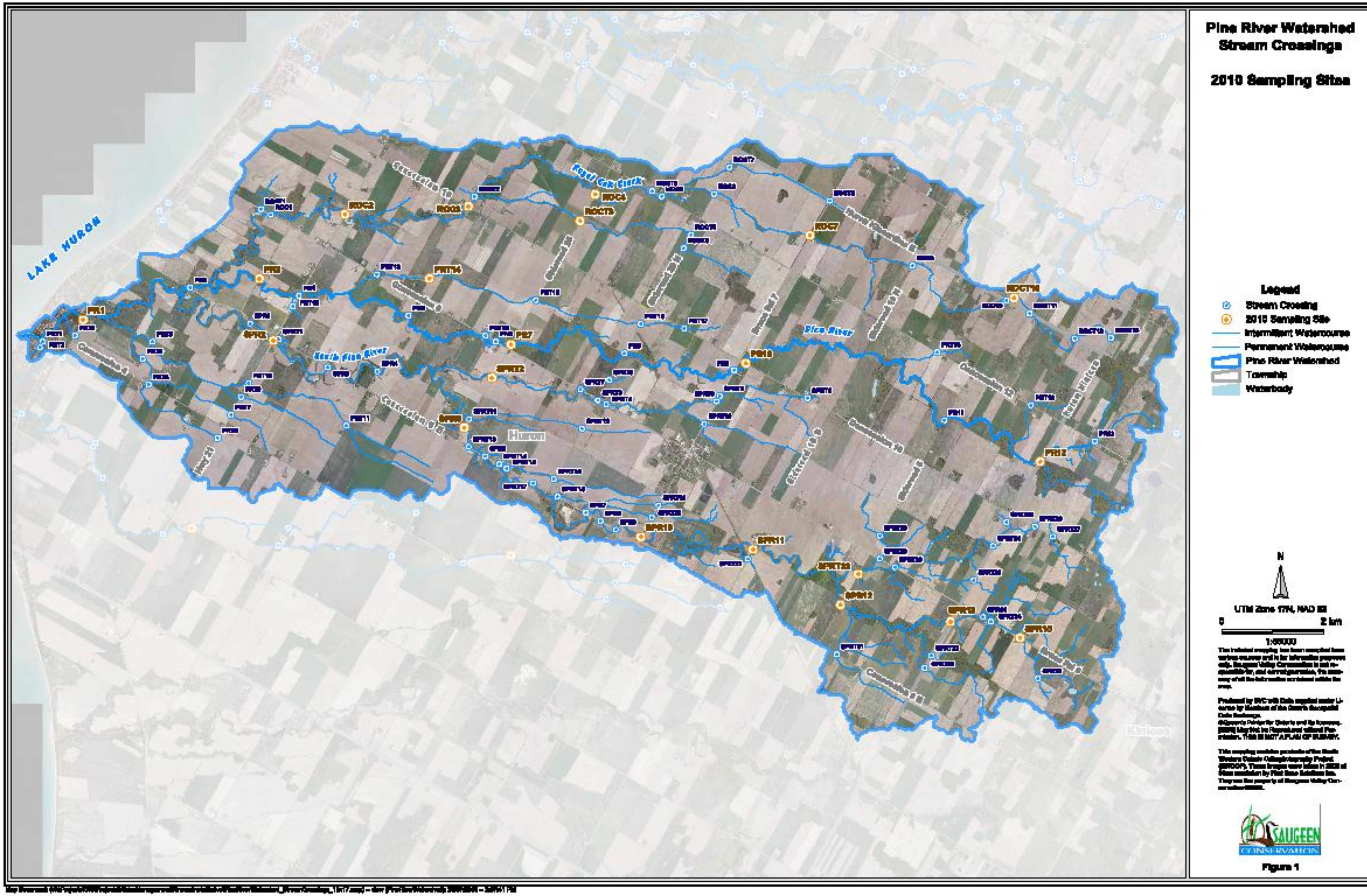

Figure 6. Map of sampling locations in the Clark Creek watershed.