Huron Chain of Lakes Watershed Water Quality Monitoring Program:
Analysis of Results: 2003-2012

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The Huron Chain of Lakes Stream Monitoring Program is a project of the Livingston County Watershed Advisory Group -- a watershed-based partnership of local, county and state governments, academic institutions, and concerned citizens working to prevent pollution in the Huron Chain of Lakes Watershed and meet federal water quality standards for Brighton, Ore and Strawberry Lakes and effectively manage stormwater discharges to surface waters.

2008-2012 Volunteer Stream Monitors

On behalf of the Livingston County Stormwater Advisory Group, the Huron River Watershed Council would like to thank the following volunteers for providing their time and energy toward the collection of this valuable monitoring data. We could not have conducted this analysis and gained this understanding without them.

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APPENDICES

1. INTRODUCTION

Value of the Program

The Huron Chain of Lakes Stream Monitoring Program was developed in response to community interest in establishing a baseline water quality dataset within the Chain of Lakes Watershed system. The data are intended to lead to a better understanding of nutrient and sediment contributions from non-point sources and stormwater runoff in this portion of the watershed. An improved understanding of sources will help the Livingston Watershed Advisory Group (WAG) to focus and track pollution reduction efforts to meet the phosphorus TMDLs for Brighton, Ore and Strawberry Lakes and to determine stormwater management effectiveness and discover potential pollutant hot spots.

This Monitoring Program is designed to complement monitoring conducted by the Michigan Department of Environmental Quality (MDEQ), the Cooperative Lakes Monitoring Program at Brighton, Ore and Strawberry Lakes, and other programs. The monitoring sites are visited twice monthly from April to September and all of the parameters measured were measured also by MDEQ. Data are collected from stream locations that facilitate the establishment of relationships between land cover and ecological stream health. The locations were selected based on their proximity to the Huron River and/or a TMDL area, likelihood of significant sub-watershed phosphorus loading based on modeling, and capturing the range of sub-watershed and upstream conditions.

Program Description and Expectations

The Program was launched in late August, 2010, modeled after the successful monitoring program in operation by the HRWC in Washtenaw County. There are six established long-term, baseline sites and 3-4 additional “investigative” sites at any one time, located upstream of the baseline sites. There are 2 long-term sites located at points on the river which are also USGS-monitored sites. The other four sites are located on major tributaries to the river or at inflow/outflow points to the TMDL areas. Water samples are collected and water quality parameters are measured at every long-term site during each field visit.

All long-term sites have continuous water level sensors installed, or permanently fixed (USGS) sensors in place. This provides for sample collection during high-flow periods or wet-weather events to obtain nutrient data outside of baseflow conditions. A programmable autosampler was also donated to the program to allow for manageable storm-event sampling. Current plans are to continue baseline monitoring at the current sites, continue to collect storm event samples, and add new sites for investigation of nutrient sources.

Monitoring Program Partners

Realization of the Monitoring Program requires ample resources, from providing volunteer training and coordination to analyzing water samples and entering and interpreting the results. Many friends of the Huron River and Chain of Lakes watershed dedicated their time, expertise and equipment to the project.

The monitoring program coordinators are grateful for the generous contributions from the following partners who enabled the initiation and growth of this important research and stewardship program.

City of Brighton Waste Water Treatment Plant provided all lab analysis of water samples.

Livingston County Drain Commissioner donated an autosampler for use in storm sampling.

University of Michigan, Occupational Safety and Environmental Health Department, provided sample bottles in 2008 to the Middle Huron Stream Monitoring Program, which have been recycled and shared with the Huron Chain of Lakes Monitoring Program.

Monitoring Program Sites

Monitoring is being conducted at two Huron River sites and four tributary sites, which are located on major tributaries draining to the Huron River between Kent and Strawberry Lakes and represent a mix of land uses and communities.

Long-term monitoring site locations and their designations are listed below and also shown on a map in Figure 1:

Creek/River	Designation	Monitoring Site
Huron River	HR03	downstream of Kent Lake dam
Woodruff Creek	WC01	at Grand River Avenue
S. Ore Creek	SO01	at S. Third St., Brighton
S. Ore Creek	SO06	downstream of Brighton Lake dam
Davis Creek	COL02B	at Silver Lake Road
Huron River	COL01	at Hamburg Road

Note: The Huron River at Hamburg Road and Davis Creek sites were previously included in the Middle Huron monitoring program during the 2008-2009 field seasons as a pilot effort. During that time, the sites were monitored from May – September, and water sample analysis was done by the Ann Arbor Water Treatment Plant. Results from those sites are included in the discussion section.

The afore-described monitoring locations are considered long-term sites, which are revisited annually to take water samples and make water quality measurements to gather seasonal and wet-weather information and trends over time. There is also another type of monitoring site we include in our studies which is called an "investigative" site. Investigative sites are typically located upstream of long-term sites and chosen each year based on program goals. For the 2011 field season, 3 investigative sites were selected for water sampling only on each of the three tributaries to the Huron: Woodruff Creek, South Ore Creek and Davis Creek. In 2012, three additional investigative sites were selected as listed below. These sites may be located on smaller streams that feed into the larger tributaries, and often will have different names than their receiving waters. Below is a list of the investigative sites included in this study:

2011

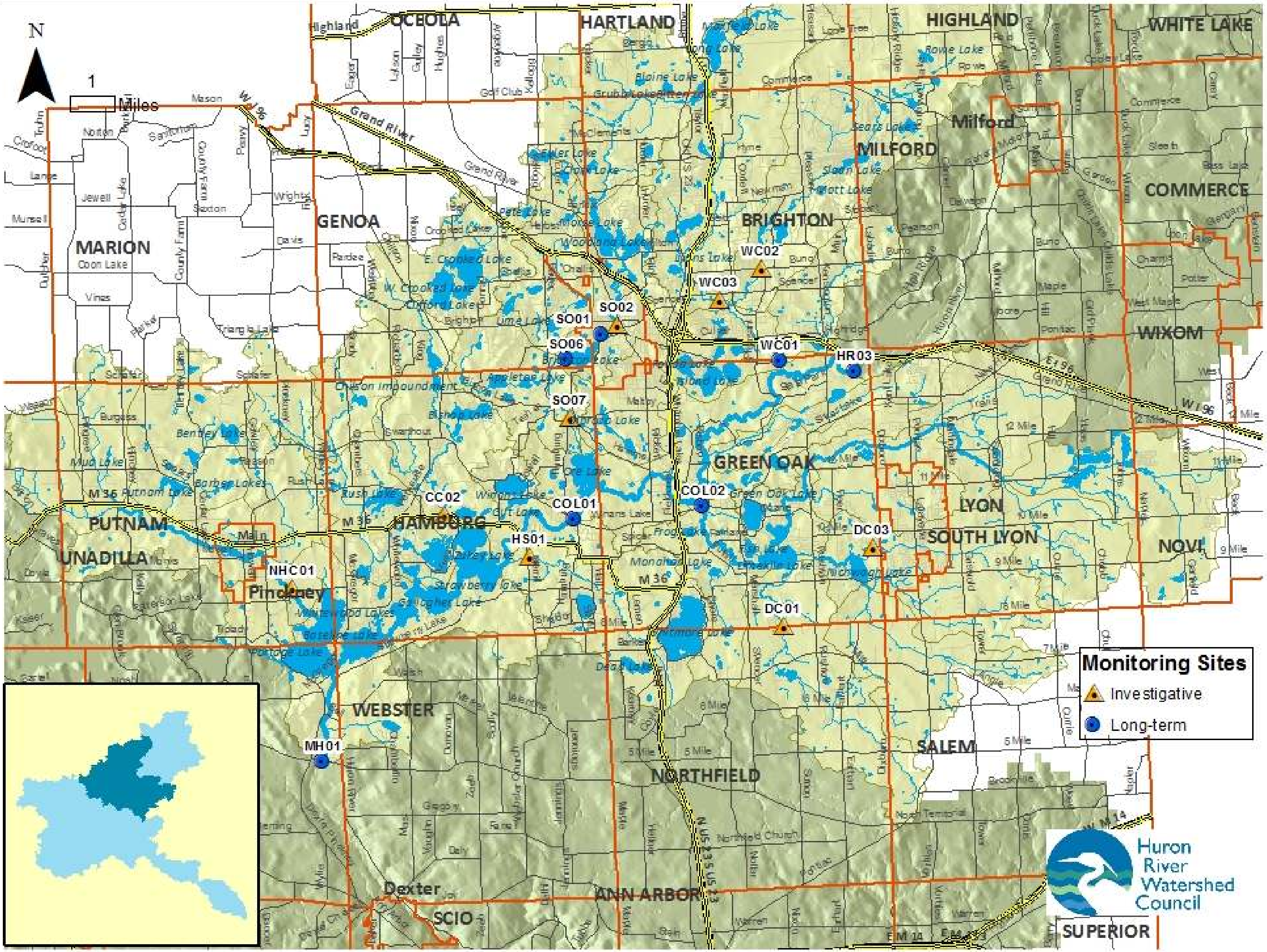
Tobin Drain	DC02	8 Mile Rd, east of Spencer Rd
Mann Creek	WC02	Buno Rd, west of Pleasant Valley Rd
South Ore Creek	SO02	at North St, City of Brighton

2012

Davis Creek	DC03	Bridgewater Dr, south of 10-Mile Rd
Mann Creek	WC03	Kennicot Trail, south of Spencer Rd
South Ore Creek	SO07	at Hamburg Rd, west of Maltby Rd junction

Three additional sites were sampled in this study and are also considered investigative sites, but were not upstream of long-term sites. The sites discharge into a major water body and are of stormwater management interest due to their potential nutrient inputs to the Huron River and Strawberry Lake. These investigative sites were located on Horseshoe Creek (off Merrill Rd), Chilson Creek (sampled between Oneida and Zukey Lakes, south of M36), and (North) Honey Creek (at Darwin Rd, south of Pinckney High School). Chilson Creek is being considered for long-term monitoring site, and consequently water quality parameter measurements were also made at that site.

Figure 1. Huron Chain of Lakes Monitoring Sites



2. STREAM MONITORING METHODS

The procedures used in this monitoring program have been reviewed and approved by the Michigan DEQ. Complete procedures are documented thoroughly in the program's Quality Assurance Project Plan (QAPP). The QAPP was written and approved by DEQ in 2008 and again revised and approved in 2010. The following is a summary of those methods and procedures.

<u>Stream Monitoring Field Teams and Training</u>

With any new field program that has limited staff resources, engaging the public is extremely important to the success and continuation of the program. Launching the Huron Chain of Lakes monitoring program was no different. Because the program start-date was later in the summer of 2010 with only 3 scheduled monitoring dates remaining in the field season, the first few volunteer recruits were people who had previous volunteer experience with the HRWC and/or had a vested interest in one of the lakes. For subsequent field seasons, the composition of the volunteer monitoring teams was diverse, ranging from both working and retired professionals, teachers and a firefighter to interested high school and college students.

HRWC typically provides two types of training for our water quality stream monitoring programs: 1) a classroom-style session to give volunteers an overview of the program and a demonstration of equipment that they would be using in the field and 2) hands-on field training during season-opening site visits. For the 2010 season, this training regimen was conducted back to back with only a one day time lapse in between training and fieldwork. In 2011 and 2012, the overview session was held 3 weeks prior to the start of the field season, after which monitoring teams were introduced to their sites and taken through field training.

With each site visit, team members committed approximately 2 ½ hours to conduct fieldwork. Volunteers were given a pre-determined baseline monitoring schedule, with field visits usually scheduled on Mondays – Wednesdays on alternating weeks from April through September. This schedule was set up in advance with the Brighton Wastewater Treatment Lab to ensure they could accommodate our water sample load.

Storm-event sampling was also conducted in an effort to determine if pollutant concentrations or loadings are significantly higher during storms. Storm event sampling is by nature unpredictable and therefore cannot be prescheduled. This work was done by HRWC program interns and staff using an autosampler. For all unscheduled sampling events, the lab staff was notified ahead of time and had no problems accommodating the additional samples.

Stream Monitoring Protocol

Stream monitoring was conducted monthly from April through September at the designated long-term monitoring sites described in the Introduction. The monitoring teams, after picking up equipment at the HRWC offices (or other designated locations), traveled to the site and first completed a field datasheet that documents the location, date, time, team members and weather conditions for the current and previous days (Appendix A). The field datasheet also was used to record information about the water samples and the water quality measurement results. If stream flow was also measured during a field outing, a separate stream flow datasheet was filled out to record that activity and velocity measurements. Upon completion of the fieldwork, the monitoring team delivered water samples to the Brighton WWTP laboratory for analysis and returned equipment to the HRWC office.

Below are descriptions of the water quality sampling and stream flow methods, and the water quality parameters measured. All field equipment was used as recommended by the equipment manufacturers.

Water Sampling

Collection of water samples was completed first at each site to minimize the disturbance of the stream substrate, which could artificially raise the amount of suspended matter in the water column. For all samples, the team member followed the same “grab” sampling protocol in accordance with the method prescribed in the 1994 MDEQ field procedures manual for wadeable streams. For greater detail, reference the following sections of the manual:

Section 4.A.2 General Sampling Considerations, pp. 4.A.-1
Section 4.A.3.a Grab Sample, pp. 4.A.-2
Section 4.C.2.a.3 Selection of Sampler, pp. 4.C.-5
Section 4.C.2.a.5 Grab Sampling from a River Bank, pp. 4.C.-6 & 7

As suggested in the manual, when water levels were low or on smaller tributaries, it was appropriate to collect samples by hand rather than with a bucket or the more technical sampling equipment.

In-stream samples were collected upstream and at arm’s length from where the team member was standing. Where stream depth permitted, water was taken from the middle of the water column and in the middle of the stream cross-section. Exceptions to this method occurred at the “Huron River at Hamburg Bridge” site where samples were collected from the bridge using the bucket method. The bottles were rinsed with stream water prior to taking the baseline sample. Samples were labeled and placed in a cooler with ice packs until they were delivered to the laboratory for analysis.

Baseline samples were collected to measure 1) Total Phosphorus (TP) and 2) Total Suspended Solids (TSS). HDPE plastic bottles were used for stream sampling. If TP samples could not be analyzed within the method-specified holding period after delivery to the lab, they were treated with preservative.

Rain Event Sampling

In 2010, a programmable auto-sampler was purchased and donated to the program by the Livingston County Drain Commission. Utilizing an auto-sampler provides a means to sample streams during very high flow conditions and during the nighttime, when it would otherwise be too difficult or unsafe for monitoring teams to obtain water samples. A storm-sampling protocol was developed and piloted using the auto-sampler. Refinements to the protocol were made for based on operational observations and experience gained during the pilot period.

The auto-sampler was placed at a target site prior to runoff from a rain event. A 48-hour antecedent dry period (no more than 0.10" of precipitation) is required prior to a 24-hour rainfall of at least 0.25" for a sampling event to be considered. The auto-sampler was typically programmed to draw samples once per hour through the duration of the storm. When the event was over and the auto-sampler was retrieved, 6-7 samples were selected for lab analysis. Grab sample duplicates for analysis were also taken either at the time of deployment and/or at the end of the sampling time period. Samples were then delivered to the laboratory for analysis. The analytical results were used to generate a flow-weighted average for the event, known as an Event Mean Concentration (EMC).

Water Quality Testing

Three water quality parameters were measured as part of the monitoring program. Water quality measurements for pH, temperature, and conductivity were made using a Horiba U-10 Water Quality Checker. For all measurements, the multi-probe instrument was placed in the water at the appropriate submerged level at arm's length distance and upstream from the team member. The results were read from the digital displays and recorded on the field data sheet.

Water Flow Measurements

The measurement of water velocity at the monitoring sites, when combined with water samples that are analyzed for nutrient concentration, allows for calculating the "load" of a particular nutrient for a specific moment in time. A "load" is a measure of the amount of a substance entering a water body over a given time period, such as a day or year. Concentration, when coupled with stream discharge, can be used to estimate the export rates of phosphorus (or other nutrients) for the sub-watershed, and to estimate the loading rates of phosphorus in receiving waters.

Water velocity was measured directly in the stream after water samples were collected and water quality testing was completed. Flow velocity was measured at each site by team members across a range of measured water levels. Where stream discharge instrumentation or a water level gage was in place, discharge measurements can be charted against water level to establish a "rating curve." Once established, the rating curves were used to estimate discharge from water level readings. Additional discharge measurements are made periodically to recalibrate the curve. Figure 2 depicts the rating curve for Davis Creek. USGS water-level sensors are located on the Huron River below the Kent Lake dam and on the Huron River at the Hamburg Bridge. Water-level sensors maintained by HRWC were located at other long-term sites over the course of the program.

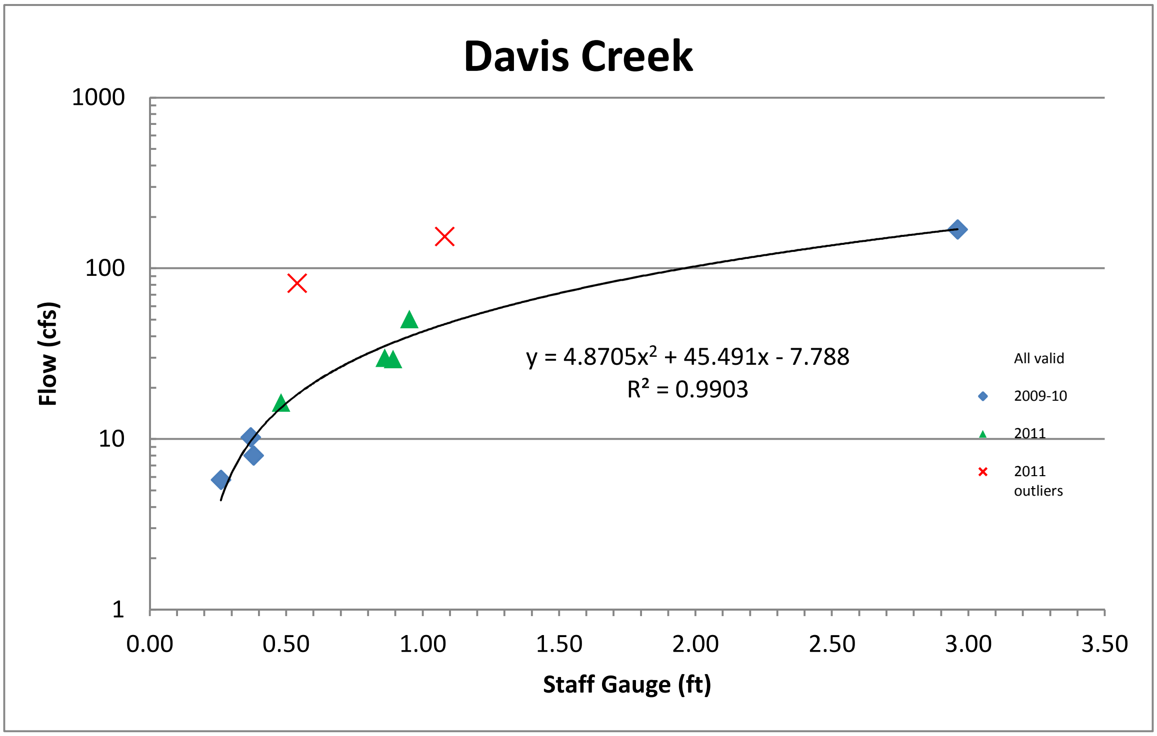


Figure 2. Staff gage rating curve with discharge measures shown.

Flow measurements were recorded by team members on a flow data sheet (Appendix A).   Team members selected a cross-section representative of the river or tributary where they measured the distance across from water's edge to water's edge. Depth measurements were taken at regular intervals for at least fifteen points along the transect with more measurements taken depending on stream channel variability. At each point along the transect, water velocity was measured using a flow meter. Data is used to compute water discharge values at each long-term monitoring site over the course of the field season.

<u>Field Equipment</u>

Horiba™ U-10 Water Quality Checker
Parameters measured: pH, temperature, specific conductivity

pH: range 0-14 pH; resolution 0.1 pH; accuracy +/- 0.05 pH

temperature: range 0-50° C; resolution 1° C; accuracy +/- 3° C

specific conductivity: range 0-100 mS/cm; resolution 1 mS/cm; accuracy +/- F.S. (within measurement range)

Marsh McBirney Portable Flo-Mate™ Model 2000
Parameter measured: flow velocity
range: -0.5 to +20 ft/s; accuracy +/- 2% of reading

Teledyne ISCO 6712 programmable autosampler

3. MONITORING RESULTS AND DISCUSSION

Following is a summary discussion of the most important findings regarding the status at each of the monitoring locations, as well as general findings across the Huron Chain of Lakes Watershed. A compendium of graphic results for each tributary is included in Appendix B.

Total Phosphorus (TP)

The most important aspect of this monitoring effort was the analysis of Total Phosphorus (TP) data. Phosphorus is an essential nutrient for all aquatic plants. It is needed for plant growth and many metabolic reactions in plants and animals. In southern Michigan, phosphorus is typically the growth-limiting factor in fresh water systems. Total Phosphorus (TP) is a measure of all forms of phosphorus present in a water sample. The typical background level of TP for a Michigan river is 0.03 mg/L or ppm.

Further, phosphorus is the main parameter of concern in eutrophic lake and stream systems for its role in producing blue-green algae. Excessive concentrations of this element can quickly cause extensive growth of aquatic plants and algae. Abundant algae and plant growth can lead to depletion of dissolved oxygen in the water, and, in turn, adversely affect aquatic animal populations and cause fish kills. This nuisance algal and plant growth interferes with recreation and aesthetic enjoyment by reducing water clarity, tangling boats, and creating unpleasant swimming conditions, foul odors, and blooms of toxic and nontoxic organisms.

Figure 3 below illustrates the TP concentration ranges for each of the long-term monitoring sites. Because the monitoring program is still in its infancy, there has not been enough data collected to run meaningful quantitative trend analyses. However, several observations are noted. There was a significant decrease in mean TP concentrations for the two sites established in 2008, which are the Huron River at Hamburg and Davis Creek at Silver Lake Rd. The mean TP concentrations have decreased by almost half since 2008-2009 time period at both sites, and the Huron River at Hamburg remained fairly stable through the 2011 and 2012 seasons at levels below 0.03 mg/L. Davis Creek was observed to have similar TP concentrations, but exceeded the 0.03 mg/L threshold once each year in 2011 and 2012. It was still at or below 0.03 mg/L for most of the season. The Chilson Creek site, upstream of Zukey Lake was also well below that threshold for all of 2011-12, with a mean TP concentration of 0.015 mg/L.

Other long-term monitoring sites have shown mixed results. All samples from all sites were close to the 0.03 mg/L target, with no single sample yielding a TP concentration above 0.07 mg/L. However, a greater number of samples in 2012 exceeded the 0.03 mg/L target in 2012 than in 2011 or the end of 2010. This may have been due to the drier conditions in 2012. Overall, mean TP concentrations over the entire 2010-2012 monitoring period range from 0.038 mg/L at South Ore Creek below Brighton Lake to 0.02 mg/L at the Huron River at Hamburg Road. TP concentrations continue to be higher downstream of

Brighton Lake than at the site above the lake (mean TP of 0.27 mg/L). This suggests that Brighton Lake is serving as a source of phosphorus since concentrations going into the lake are much lower. Since there is often a correlation between TP and TSS levels, an examination of that relationship will be undertaken to see if that might provide a plausible explanation for the current conditions just downstream of Brighton Lake (see later section of this chapter).

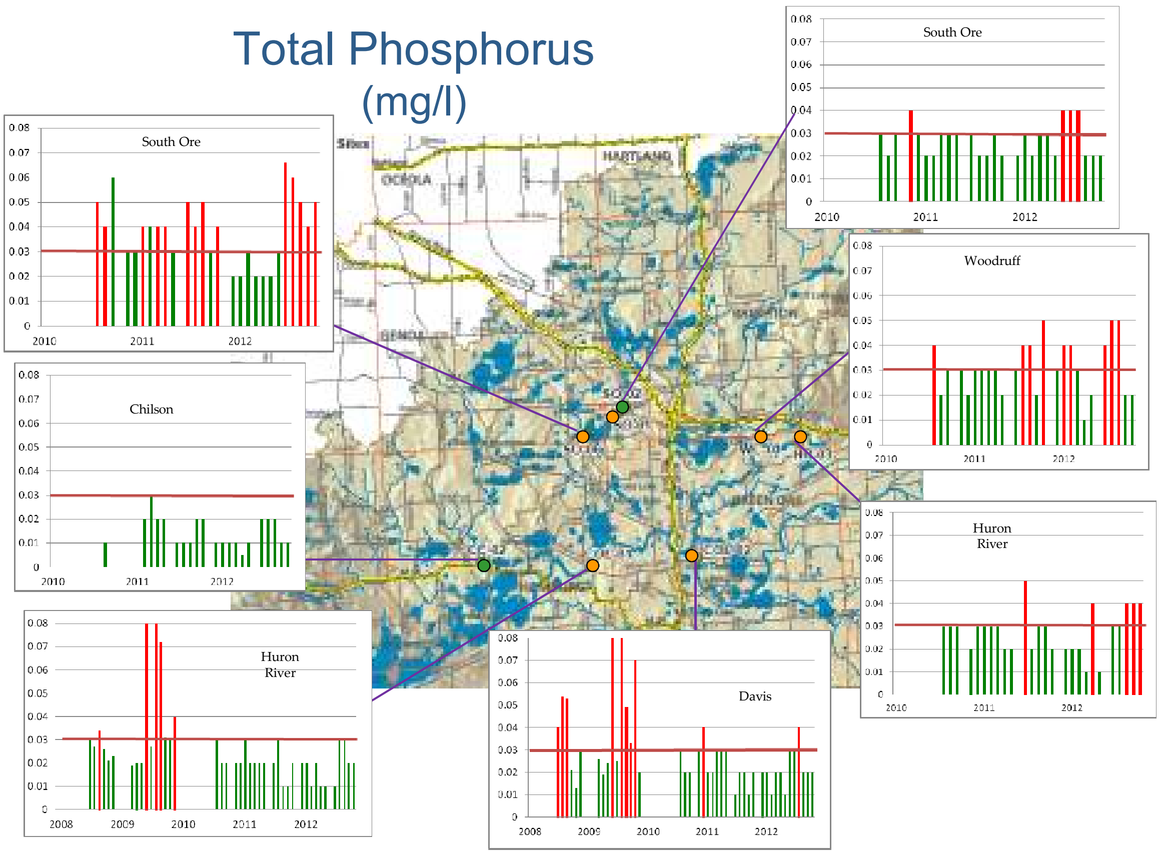


Figure 3. Total Phosphorus concentrations over time at sites in the Huron Chain of Lakes Watershed. The TMDL target level of 0.03 mg/l is indicated. Values in red match or exceed this threshold.

Monitoring was also done at a number of sites that were located upstream of existing long-term monitoring sites. These short-term "investigative" sites (see map in Figure 1) were sampled within an hour of their downstream counterparts so that the paired results could be compared. The sites were selected to separate sections of the contributing watershed by different land uses or stormwater system contributions. The intent of this strategy was to determine if pollutant hot spots could be discovered within the watershed. As such, investigative sites were only monitored a few times each and then replaced by a new site in the program. The number of investigative sites monitored at any point in time was limited by the analytical laboratory's capacity to accept samples.

Comparative results for investigative sampling of TP are displayed in Table 1. Only the two Davis Creek investigative sites had a mean concentration above the downstream site. Investigative site DC02 was located on Tobin Drain, several miles upstream of the Davis Creek long-term site. The surrounding area is very rural, with agriculture as the primary land-use. In particular, there are horse pastures on both sides of the stream and a riding stable and farm along the eastern stream bank. Stormwater runoff coming from these farms may partially explain why the phosphorus levels are so much higher in this specific area of the watershed. Areas upstream of the Tobin Drain site should be investigated for potential application of agricultural best management practices (BMPs). Given the high TP results at that site, and the agricultural land uses upstream, testing for bacterial concentrations would be advisable.

Site DC03 is located in a residential development just upstream of Nichwagh Lake and downstream of South Lyon. Urban and suburban phosophorus sources are more likely the nutrient contributors to this site.

Table 1. Results of Total Phosphorus analysis at investigative sites as compared with long-term sites downstream.

Creek	Site ID	Mean TP (mg/l)	Mean Difference from downstream (mg/l)	Percent Difference	n (# samples)
South Ore	SO02	0.03	0.00	0%	7
South Ore	SO07	0.05	0.00	0%	7
Davis	DC02	0.07	**0.05**	**273%**	8
Davis	DC03	0.07	**0.04**	**186%**	3
Woodruff	WC02	0.04	-0.01	-14%	9
Woodruff	WC03	0.04	0.00	-6%	4

Three other investigative sites were established on tributaries that did not have paired long-term sites. These sites were used to investigate the tributary phosphorus concentrations and determine if there were potential hot spots upstream. Table 2 summarizes the results from these sites. Concentrations at Chilson Creek and North Honey Creek were all quite low with no single concentration exceeding 0.030 mg/L. TP concentrations at the Horseshoe Creek, however, were quite a bit higher, with a mean concentration above the target for the Strawberry Lake TMDL. Horseshoe Lake is upstream of this site and may be serving as a phosphorus source. Also, the creek at the sample site is slow-moving and flows through tributary wetlands, which may allow phosphorus concentrations to build up in the water. Other areas upstream should be investigated for potential sources.

Table 2. Total Phosphorus concentration statistics for unpaired investigative sites.

Creek	Site ID	Mean TP (mg/l)	Median TP (mg/l)	Maximum TP (mg/l)	n (# samples)
Chilson	CC02	0.017	0.020	0.030	10
Horseshoe	HS01	0.035	0.035	0.040	6
N. Honey	NHC01	0.017	0.020	0.030	7

Total Suspended Solids (TSS)

Total suspended solids include all particles suspended in water which will not pass through a filter. As levels of TSS increase in water, water temperature increases while levels of dissolved oxygen decrease. Fish and aquatic insect species are very sensitive to these changes which can lead to a loss of diversity of aquatic life. While Michigan's Water Quality Standards do not contain numerical limits for TSS, a narrative standard requires that waters not have any of these physical properties: turbidity; unnatural color; oil films; floating solids; foam; settleable solids; suspended solids; and deposits. Water with a TSS concentration <20 mg/L (ppm) is considered clear. Water with levels between 40 and 80 mg/L tends to appear cloudy, and water with concentrations over 150 mg/L usually appears muddy. In streams that have shown impairments to aquatic life due to sedimentation, TSS is used as a surrogate measure for Total Maximum Daily Load (TMDL) regulation, since large amounts of sediment can bury potential habitat for aquatic macroinvertebrates. Suspended solids may originate from point sources such as sanitary wastewater and industrial wastewater, but most tends to originate from nonpoint sources such as soil erosion from construction sites, urban/suburban sites, agriculture and exposed stream or river banks. Michigan DEQ generally uses the following TSS ratings to evaluate the sedimentation impact on a stream's biota:

- Optimum = ≤ 25 mg/l
- Good to Moderate = >25 to 80 mg/l
- Less than moderate = >80 to 400 mg/l
- Poor = >400 mg/l

TSS concentrations for each of the monitoring sites is shown below in Figure 4. Note that all samples had TSS concentrations below the "optimum" level of 25 mg/l. Most of the samples were collected during dry conditions, but a number were collected following storm events, so it appears that COL streams are quite low in sediments. Erosion does not appear to be a significant issue in COL streams. That is not surprising given that there is little elevation difference across the watershed. Again, since monitoring has only been conducted for 2.5 seasons for the long-term sites, not enough data have been collected for trend analysis.

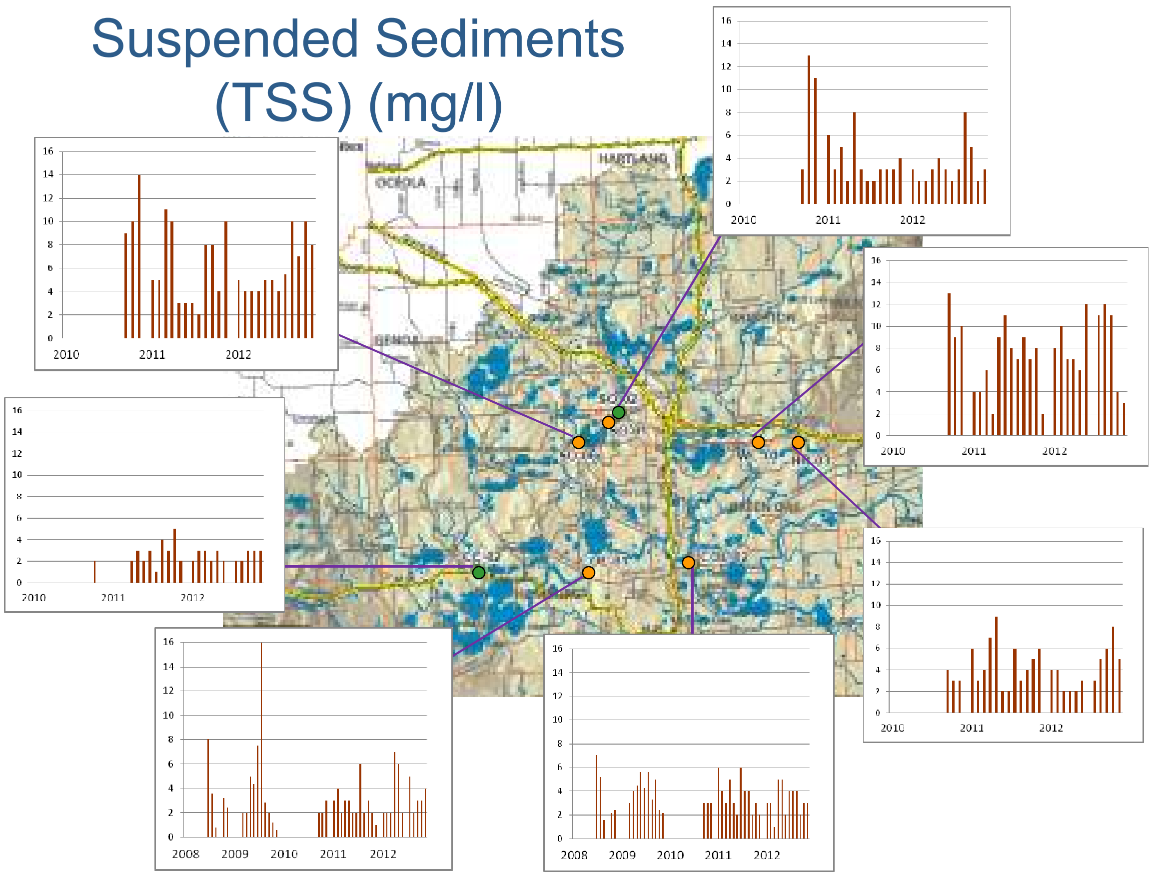


Figure 4. TSS levels at Huron Chain of Lake sites, 2010-2012. Data from 2008-2009 included for Huron River at Hamburg and Davis Creek. All levels are below the target threshold of 25 mg/L.

Sediment-phosphorus relationship

Since phosphorus binds to soil particles, it is important to try and understand whether the phosphorus in the streams is coming along with sediment or not. To do this, one can examine TP concentrations with corresponding TSS concentrations. If they are well correlated, then there is some evidence that phosphorus is moving through the stream with sediments. If not, some amount of phosphorus may be moving through the system in dissolved form, unbound to sediment particles. In these cases, while there is some relationship between TP and TSS loads, there is much more variation. Further, TSS is generally low to begin with. This suggests that much of the phosphorus coming by these monitoring points is not bound to sediment.

All of the sampling sites showed some relationship between phosphorus and sediments, but the degree of correlation was highly variable between sites. Overall, correlations between TP and TSS ranged from 0.10 on the low end (South Ore Creek @ Third St) to 0.46 (South Ore Creek @ Brighton Lake dam). This suggests that erosion may be contributing to TP concentrations more below the dam, especially at higher flows. However, much of the phosphorus may be coming in dissolved form from lake upwelling. See Appendix B for TSS-TP relationships for all long-term monitoring sites.

Streamflow, Storms and Pollutant Loads

Ultimately, pollutant concentrations can vary widely due to many environmental variables. One important variable is the amount of total discharge of water or flow moving through a measurement site. Storms result in increased flow and can also wash material including soil and pollutants into the stream channels. Further, it is the total load of a pollutant entering the system that water resource managers are ultimately concerned with. Pollutant load is a calculated value based on the concentration and water flow at a given point in time, and it is expressed as pounds or tons per year, taken over an entire year or a season. Measuring the phosphorus load, for example, gives an idea of how much phosphorus is being transported downstream from tributaries to Brighton or Strawberry Lake over the growing season or entire year. Gaining an understanding of load dynamics can help to target management practices and measure their collective impact. By adding wet-weather sampling to the program, it became possible to assess the immediate runoff effects when compared to simple flow relationships measured semi-randomly.

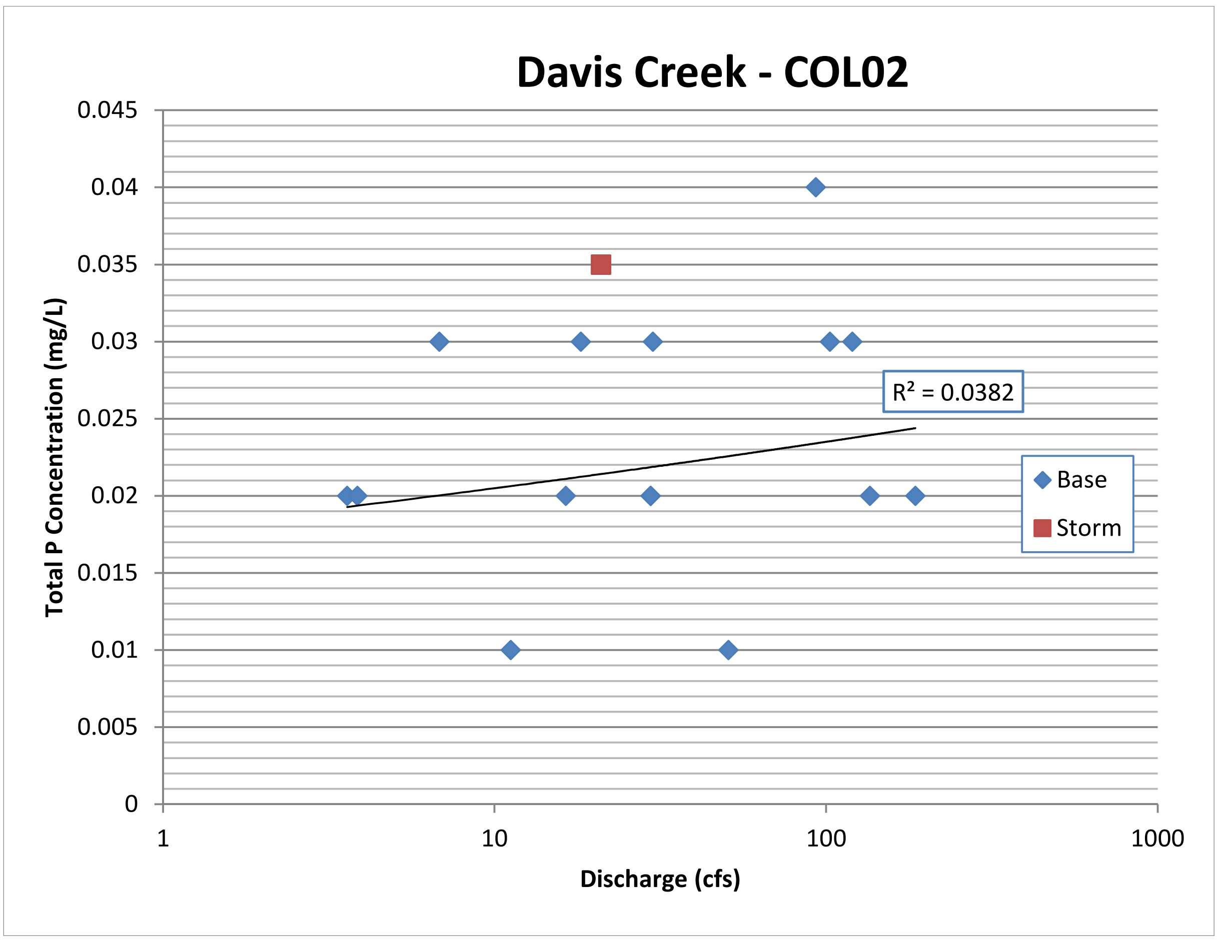


Figure 5. Relationship between discharge and TP concentrations in Davis Creek, showing both standard measures and storm event mean concentration.

All of the long-term monitoring sites exhibit weak relationships between TP concentration and stream discharge. Figure 5 shows the relationship for Davis Creek. Discharge alone can explain only 4% of the variability (R^2) in the data. With this site, as the discharge increases, so does the mean TP concentration, though only a bit. This is a bit counterintuitive, because, given a constant pollutant input, increased flow should serve to dilute the concentration. The positive relationship suggests that stormwater runoff or streambank erosion is contributing phosphorus as runoff increases. Some other sites exhibit flat or negative relationships with discharge

Storm samples were collected across 4-6 points in time for six wet weather events at three different sites. The resulting TP concentrations were flow-weighted and compiled into Event Mean Concentrations (EMC), or flow-weighted average concentrations over the entire wet weather event. These EMCs can then be compared to concentrations estimated from the standard set of single grab samples. At Davis Creek, the EMC was a bit higher than what would be estimated from the best-fit curve from the baseline monitoring samples (see Figure 5). However, at both South Ore Creek sites, the storm EMCs were lower than estimates from the baseline curve. At this point, it is uncertain if it can be reasonably assumed that estimates made from regular sampling across varying flow conditions (single sampling) are reasonably accurate at predicting event concentrations (and loads) from wet weather events in the tributaries sampled.

Based on these discharge-concentration relationships, and accounting for the time of year that samples were collected, loading estimates were derived for each of the tributaries using LOADEST software developed by the United States Geological Survey[1]. Table 3 shows the loading estimates for all long-term monitoring sites along with the estimate range and correlation of the discharge-concentration relationship model selected by the program. These models suggest that little phosphorus is moving through the South Ore Creek and Davis tributaries, but much is being contributed by Woodruff Creek. The estimates also suggest that an amount of phosphorus (11.4 lbs/day) is being added to the Chain of Lakes system before it gets to Strawberry Lake. It should be noted that these estimates are based on the small amount of data collected by the monitoring program to date. More data is needed to improve the reliability of estimates.

[1] Runkel, R.L., Crawford, C.G., and Cohn, T.A., 2004, **Load Estimator (LOADEST): A FORTRAN Program for Estimating Constituent Loads in Streams and Rivers**: U.S. Geological Survey Techniques and Methods Book 4, Chapter A5, 69 p.

Table 3. Estimates of daily Total Phosphorus loads for long-term monitoring sites.

Stream	Site ID	TP Load Estimate (lbs/day)	TP Load Range (lbs/day)	R-square of relationship
South Ore	SO01	3.46	3.0 – 4.0	0.48
South Ore	SO06	5.41	4.9 – 6.0	0.63
Davis	COL02	6.70	5.4 – 8.2	0.67
Woodruff	WC01	17.93	14.1 – 22.5	0.40
Huron @Kent Lake	HR03	21.17	17.8 – 25.0	0.18
Huron @ Hamburg	COL01	32.60	26.9 – 39.1	0.27

Other Important Measures – pH, conductivity, dissolved oxygen, and nitrogen

Three basic water quality parameters are routinely measured in stream and lake waters and have also been monitored over the course of the Huron Chain of Lakes Monitoring program: pH, conductivity, and temperature. HRWC uses these parameters to identify potential short-term impairments that may suggest problems upstream. With one exception, there does not appear to be a long-term issue with any of the water quality constituents. All samples have been within state water quality standards, or other published water quality recommendations, and thus, those parameters do not warrant concern. The exception is conductivity (see Figure 7). Two sites have high conductivity ranges that exceed the recommended conductivity level. This warrants further investigation, as conductivity is a broad indicator of water quality and could suggest the presence of high amounts of salts, metals, or even naturally occurring minerals.

pH

Measuring pH provides information about the hydrogen ion concentration in the water. pH is measured on a logarithmic scale that ranges from 0-14, so river water with a pH value of 6 is 10 times more acidic than water with a pH value of 7. Organisms that live in rivers and streams can survive only in a limited range of pH values. Michigan Water Quality Standards require pH values to be within the range of 6.5 to 9.0 for all waters of the state. In Michigan surface waters, most pH values range between 7.6 and 8.0. The pH of rivers and streams may fluctuate due to natural events, but inputs due to human activities can also cause ‘unnatural’ fluctuations in pH.

The graph below depicts pH values measured during the monitoring seasons from 2010-2012 for each of our long-term sites, including Chilson Creek, and also includes data from the 2008-2009 field seasons for the Huron River at Hamburg bridge and Davis Creek. All results were within the acceptable range to meet state water quality standards.

Figure 6. pH levels recorded at long-term monitoring sites, with state water quality standards indicated by red lines.

Conductivity

Conductivity is a measure of the ability of water to pass an electrical current, and is a general measure of water quality. Conductivity is affected by temperature: the warmer the water, the higher the conductivity. As such, conductivity is reported as conductivity at 25ºC. Conductivity in surface waters is affected primarily by the geology of the area through which the water flows. In Michigan, values for a healthy river or stream habitat range between 100 and 800 µS/cm. Low values are characteristic of oligotrophic (low nutrient) lake waters, while values above 800 µS/cm are characteristic of eutrophic (high nutrient) lake waters where plants are in abundance. High values are also indicative of high mineral concentrations. There are a number of potential sources of minerals and some natural variation, but consistent results above 800 µS would be unexpected from natural sources. Anthropogenic sources can include winter road salts, fertilizers, and drinking water softeners.

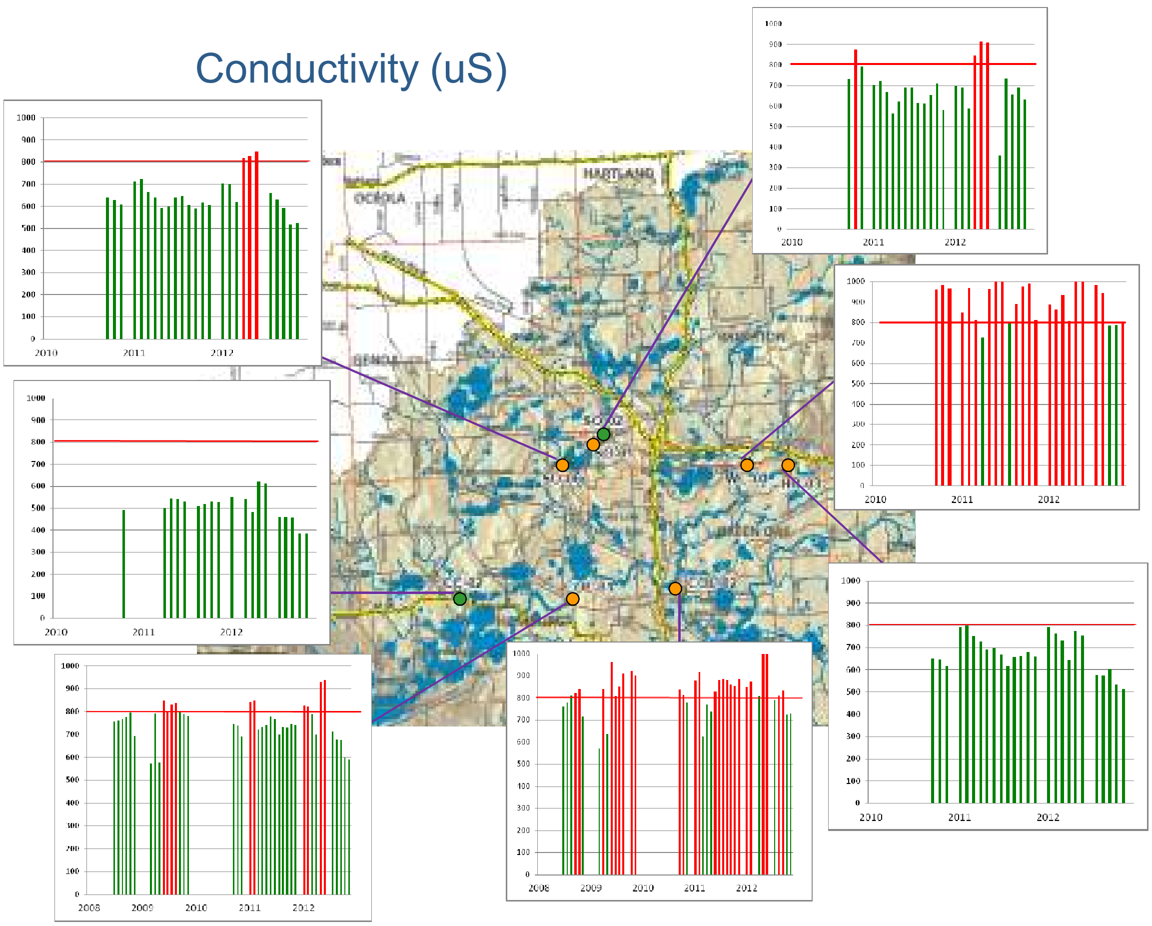


Figure 7. Conductivity levels recorded at long-term monitoring sites, with a biological impact threshold indicated by red lines.

The conductivity results are presented for all sites over the monitoring seasons in a similar fashion as was done for pH (see Figure 7). The mean values for conductivity exceeded the upper limit for healthy waters (800 µS)[2] for five of the seven monitoring sites. Only the Huron River below Kent Lake and S. Ore Creek below Brighton Lake were below that ecological impact value. Coincidentally, both these sites are located in protected areas: one is within a state park and the other is within a conservation area. The sites with the highest mean values are all proximate to heavily traveled roads, connecting suburban and urban areas or are commercial routes between major highways. Conductivity values were higher in the spring, particularly at Davis and Woodruff Creeks, when there were heavy rains which could have washed off road salt residues from the winter roadway snow/ice treatments. Davis Creek has a potential additional input from the rusting bridge ballisters that are situated just above the monitoring site. These potential sources should be further investigated, and it should also be determined which specific elements are contributing to high conductivity levels.

Temperature

Figure 8 presents the temperature data gathered for each monitoring site on every field day. The data is not analyzed for impact on biota, but is measured and presented for context. Water temperature can be quite variable and dependant on the time of sampling. The figure presents a rough idea of temperature variability at each site. Generally, temperatures should be below 27°C to provide good conditions for most native biota.

[2] From Wiley, Michael J., et al. "Regional Ecological Normalization Using Linear Models: A Meta-Method for Scaling Stream Assessment Indicators, " Chapter 12 in *Biological Response Signatures: Indicator Patterns Using Aquatic Communities.* CRC Press LLC. 2003. (see page 213)

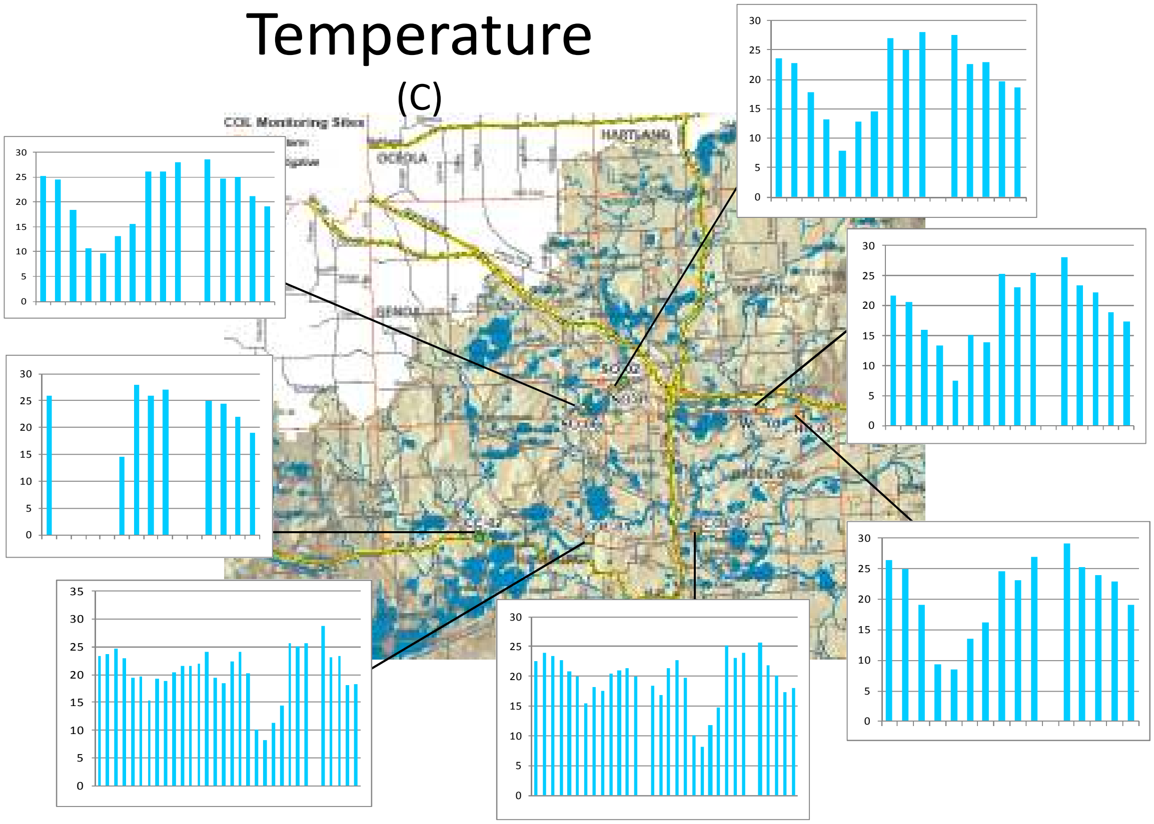


Figure 8. Temperature Data for Huron Chain of Lake monitoring sites from 2010-2011 monitoring seasons.

Successes and Challenges

This year marked the successful completion of the second full monitoring season in the Huron Chain of Lakes watershed. The 2012 season began in April, and seven long-term baseline sites were fully established, with three of those sites having continuous water level sensors installed. Each long-term site was sampled and water quality data was collected a total of 12 times over the 6-month field season. Program staff and volunteers were also able to collect flow or water discharge data at all of the sites under over a range of seasonal flow conditions. Water flow measurements were conducted at 4 of the long-term sites, with two others being USGS-monitored sites. These important data will provide the basis for understanding site hydrology and also be used for TP and TSS load calculations. While the dataset collected thus far represents a small snapshot in time, it provides the most comprehensive picture of water quality in the Huron Chain of Lakes to date. HRWC and watershed stakeholders now have an initial assessment of phosphorus and sediment conditions and loading to use in assessing progress to date and planning future management activities. This analysis has already been incorporated into management plans for Brighton Lake and Strawberry Lake Watersheds.

In addition to collecting high quality baseline water quality data, storm events were successfully monitored at three sites: South Ore Creek at Third St., South Ore Creek below the Brighton Lake dam (off Hartford Way) and Davis Creek. Continuous water level sensors were installed at each of these locations so that we would be able to sample the stream using the autosampler at regular intervals over a 24 hours period and determine the water levels and discharge values at the time of sampling. Pairing the use of the autosampler with the water level sensors also provided greater precision in targeting samples at key points across the storm hydrograph. A key challenge in 2012 was the lack of rain. Only one storm met the parameters needed for a measurable runoff event.

Another important aspect of this program was establishing a volunteer participation program and developing relationships that foster water quality stewardship within the surrounding communities. Since this was a new program, explaining the scope of work and the importance of the help the volunteers would provide was essential to accomplishing our goals for the program. The time commitment necessary to carry out the fieldwork did not suit everyone who had an interest in the program. However, through recruitment and field training efforts, program staff were able to assemble a core group of volunteers that were dedicated and well-trained by mid-summer and who conducted the monitoring tasks in a professional manner. In 2012, 11 volunteers regularly participated in the monitoring program and learned about its connection to watershed management and sources of water quality impairment. Some of these volunteers have asked about other ways to get involved in watershed stewardship. This level of participation is considered a qualified success for the young program.

Key challenges for the program centered mainly around logistics: matching volunteer availability for fieldwork with the lab's availability and capacity to accept/analyze samples, and having access to equipment and supplies at the storage location in Livingston County.

4. SUMMARY AND CONCLUSIONS

The following general conclusions can be drawn from the analysis of the data collected under the Huron Chain of Lakes Monitoring Program from 2010 through 2012:

Measured values for **Total Phosphorus concentration** varied widely from site to site and from month to month. Taken together, the concentrations are generally low and close to the TMDL targets, on average. The investigative sites in Davis Creek on Tobin Drain and upstream of Nichwagh Lake are exceptions. Ultimately, TP concentrations can vary widely due to many environmental variables.

Total Phosphorus loading estimates have been made major drainages in the watershed. Loading from South Ore and Davis Creeks appear low, while loading from Woodruff Creek appears high. However, these are early estimates that would be improved by continued data collection.

All long-term sites had measured **pH values** that are within the expected range for Michigan surface waters.

Two of the seven sites had average **conductivity** values that exceed targets for healthy conditions for aquatic biota.

Mean concentrations of **Total Suspended Solids** from the monitoring sites are relatively low at all sites across the watershed. TSS and TP do not seem to be strongly correlated. Phosphorus may be from runoff sources that deliver phosphorus in dissolved form.