Middle Huron Watershed
Water Quality Monitoring Program:
Summary of Results: 2003-2013

Written by:

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The Middle Huron Water Quality Monitoring Program is a project of the Middle Huron Partnership and the Middle Huron Stormwater Advisory Group (SAG). The Partnership is a voluntary watershed-based group of businesses, academic institutions, and local, county and state governments working since 1996 to prevent pollution in the middle Huron River Watershed and meet federal water quality standards for Ford and Belleville lakes. The SAG is a watershed-based group of local municipalities and agencies within the middle section of the Huron River Watershed working to coordinate and implement best management practices to improve the quality and regulate volume from stormwater.

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1. MONITORING PROGRAM DESCRIPTION

Value of the Program

The Middle Huron Water Quality Monitoring Program was developed in response to community interest in increasing the data available on nutrient contributions to the middle section of the Huron River. The data are intended to lead to a better understanding of pollution contributions from non-point sources in this portion of the watershed. An improved understanding of sources will help the Partners of the Middle Huron Initiative to focus and track pollution reduction efforts as they strive to meet the phosphorus TMDL for Ford and Belleville lakes.

This monitoring program was designed to complement a monitoring program conducted by the Michigan Department of Environmental Quality (MDEQ) at Ford and Belleville lakes. The MDEQ program was conducted through 2006, with additional sampling in 2009 and 2012. Through 2006, the sites were visited monthly from May to September and all of the parameters measured were measured also by MDEQ. Beginning in 2008, site visits were increased to twice monthly and since 2011 the field season runs from April to September.

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 use by MDEQ, the HRWC Adopt-A-Stream volunteer stream monitoring program, likelihood of significant sub-watershed phosphorus loading based on modeling, and capturing the range of sub-watershed and upstream conditions.

Program History and Expectations

The Program began with the 2002 field season pilot during which only six sites and four months were studied. In 2003, four additional sites were added to the program and all ten sites were studied for five months. This schedule continued through 2006, with the exception of the Millers Creek site, which was dropped due to access issues. In 2007, storm events were targeted at four sites (Allens, Traver, Malletts and Swift Run) where fixed water level sensors were established. This was done to provide additional data on nutrient conditions during high-flow events. In 2008, a new monitoring location on Millers Creek was selected.

Storm event sampling continued in 2008 with a more rigorous protocol piloted at Honey Creek. A continuous water level sensor was installed and samples were collected at four points during a rain event. In 2009, another water level sensor was installed at Fleming Creek and a programmable autosampler was obtained from the City of Ann Arbor Wastewater Treatment Plant. This simplified logistics and allowed for storm event sampling at Mill, Malletts, Fleming and Honey Creeks – all sites with continuous water level sensors. In subsequent years, water level sensors were installed at different tributary sites on an annual rotating basis. Autosamplers were utilized strategically to characterize multiple storms at each site and compare with results that would be predicted from scheduled sampling.

Also in starting in 2010, several "investigative" sites located upstream of selected long-term sites, were added for sampling to gain a better understanding of upstream conditions regarding pollutant sources. In 2013, bacteria studies were started at Mill Creek, continuing as part of a study started in 2012 at Honey Creek. These studies included volunteer sampling for *Escherichia coli* (*E. coli)* to identify likely sources of bacteria in combination with genetic Bacteria Source Tracking (BST). The results of this study were compiled in a separate report. Current plans are to continue baseline monitoring at 10 long-term sites, continue to collect storm event samples, and add new sites for investigation of nutrient and bacteria 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 dedicated their time, expertise and equipment to the project. The Partners of the Middle Huron Initiative are grateful for the generous contributions from the following partners who enabled the continuation and growth of this important research and stewardship program.

> City of Ann Arbor Water Treatment Plant provided all lab analysis of water samples.
>
> City of Ann Arbor Waste Water Treatment Plant donated an autosampler and Limnotech, Inc. refurbished it for use in storm sampling.
>
> University of Michigan, Occupational Safety and Environmental Health Department provided sample containers through 2005, and in 2008; and donated a depth-setting rod in 2005.

Monitoring Program Sites

Monitoring is now being conducted at one Huron River site and nine tributary sites, which are located on major tributaries to the middle reach of the Huron River and represent a mix of land uses and communities.

The following creeks, in addition to the Huron River site at N. Territorial Road (site #1), are monitored through this program (a map of the sites appear on the following page):

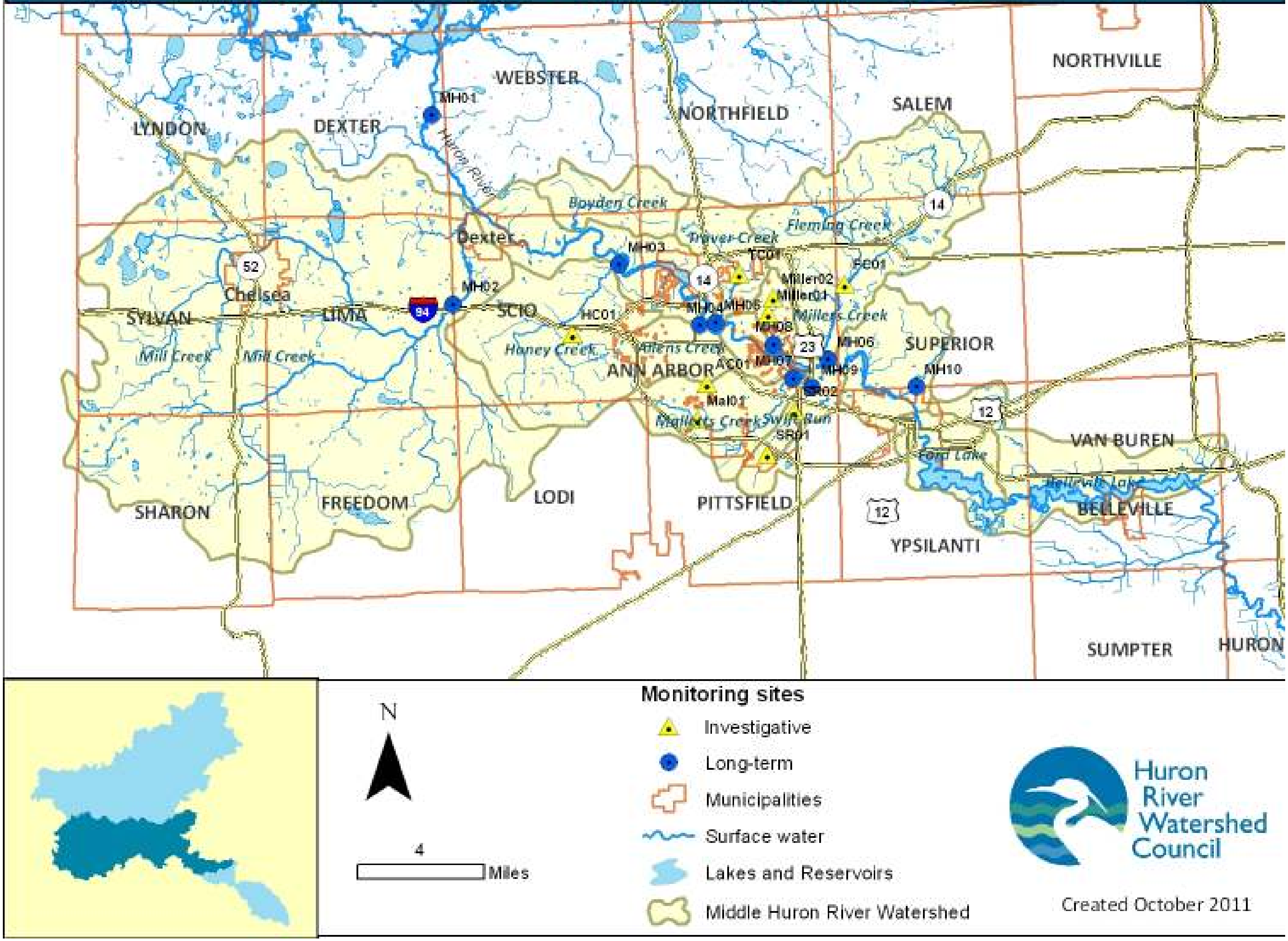
Creek	Site #	Monitoring Site
Allens Creek	4	at outfall to Huron River
Fleming Creek	6	at Parker Mill County Park

Honey Creek	3	at Wagner Road
Malletts Creek	7	at Chalmers Road
Mill Creek	2	at Jackson Road
Mill Creek	2B	at Parker Road
Millers Creek	8	at the Meadows (off Geddes Road)
Millers Creek	8B	at Huron High School (west of Huron Pkwy)
Superior Drain No. 1	10	at Clark Road
Swift Run	9	at Shetland Road
Traver Creek	5A	at Nielsen Court
Traver Creek	5B	at Broadway Rd.

Note that some of the data from Mill Creek was combined with a separate study conducted at the USGS station at Parker Road. This site is very close to the Jackson Road location and hydrologically very similar. Data collected in 2007 for Traver Creek and Swift Run was also collected from slightly different locations, as the original locations were not conducive to the installation of water-level sensors at that time. The Traver Creek station was moved to Broadway Road and the Swift Run location was moved to Salem Court. In 2008, monitoring for Swift Run was returned to the original location, where a water level gage was installed. Water level gages have now been installed at all 8 sites that do not have USGS-operated water level sensors. As discussed previously, monitoring has resumed on Millers Creek at a new location accessible on the Huron High School property.

Following early success of the Middle Huron program, starting in September 2008, water quality monitoring was conducted at sites in Livingston County and then Wayne County. Monitoring at these sites is coordinated through HRWC and used nearly identical protocols and shared some of the equipment. This sampling was funded by stormwater groups in each of those counties. Results from that monitoring are reported separately.

Figure 1. Middle Huron River 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 originally developed at the beginning of the program in 2003, and revised 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>

Over the years since the program's inception, the makeup of the volunteer monitoring teams has varied considerably. In the earlier years, teams were composed primarily of HRWC staff members and graduate students from University of Michigan School of Natural Resources and School of Public Health. In 2007, when the focus was on storm event monitoring, the teams consisted mostly of HRWC staff, and one volunteer at Malletts Creek. Since 2008, our program has brought out many more volunteers with diverse backgrounds and professional occupations, as well as undergraduate and graduate students. Student volunteers and interns change from year to year, but some returning, experienced volunteers have helped train the newest recruits and kept the program running smoothly and efficiently.

A few weeks prior to the beginning of the field season, HRWC provided a classroom-style training session to give the team members (volunteers) an overview of the program and a demonstration of equipment that they would be using in the field. The past couple of years the training session had been held outdoors at a pavilion in Island Park, along the Huron River in Ann Arbor. However, fieldwork is always the best form of instruction. With the addition of team members after the initial training, additional field training was conducted with trained volunteers paired with new volunteers.

With each site visit, team members committed approximately 2½ hours to conduct the fieldwork. In field seasons 2002-2006, a 4-day period beginning the third or fourth week of each month was designated as the monitoring week. Monitoring was scheduled such that each site would be visited at least once per month. This schedule was made in advance and coordinated with the Ann Arbor Water Treatment Plant (AAWTP) Laboratory so that they could plan for sample receipt. In 2007, only high flow events were targeted, so samples were collected on a weather-dependent basis. The lab was able to accommodate the unscheduled samples.

In the 2008 field season, baseline stream monitoring was increased to twice per month for selected sites, all 10 sites were monitored twice per month since 2009, pre-scheduled on alternating weeks during the month. Storm-event sampling was also conducted, beginning in 2008, in an effort to determine if pollutant concentrations or loadings are significantly higher during storms. Initial efforts were conducted manually, and all storm sampling since 2009 was conducted using an autosampler.

Over the 2002-2006 field seasons, fieldwork was limited to the morning hours due to equipment and laboratory limitations. The AAWTP lab needed samples to be delivered by 10 AM in order to be analyzed that day without the need for preserving the samples. Meeting that deadline was most difficult in the first month, but became easier to meet as all team members became accustomed to fieldwork procedures. However, no more than one team could conduct fieldwork at a time since the program had only one complete set of equipment. In 2007, the lab agreed to accept samples after hours and preserve them for analysis the next day without violating QAQC guidelines. This practice was carried over in the 2008/09 seasons and has become a part of our standard stream monitoring protocol. Furthermore, the program had unlimited access to a second flow meter, so that additional monitoring teams could be put together on an as-needed basis to conduct flow measurements necessary to fill data gaps when target water levels were achieved.

Stream monitoring was conducted twice 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 AAWTP 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 site where samples were collected fifteen feet from water's edge. 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), 2) Total Suspended Solids (TSS), 3) Nitrites (NO_2) and Nitrates (NO_3), and 4) *E. coli*. HDPE plastic bottles were used for TP, TSS and NO_2+NO_3 samples. If TP samples could not be analyzed within the method-specified holding period after delivery to the lab, they were treated with preservative. Sampling for *E. coli* required the use of sterile Whirl-Pak bags in order to not contaminate the water sample with bacteria from a sampler's hands.

Wet Weather (Rain Event) Sampling

In 2009, a programmable autosampler was donated to the program by the Ann Arbor Waste Water Treatment Plant. It was refurbished, with the help of LimnoTech, Inc., and used to sample storm events at Fleming, Honey, Malletts and Mill Creeks. These streams were targeted because we had access to real-time flow data upon which to base sample selection for lab analysis. That initial year provided a learning experience, but, more importantly, 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 autosampler. Refinements to the protocol were made for the next field season (2010) based on operational observations and experience gained during the pilot period.

The autosampler 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 autosampler was typically programmed to draw samples once per hour through the duration of the storm. When the event was over and the autosampler 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

Measuring water velocity at the monitoring sites, along with collecting 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, usually expressed as pounds per 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 observations. Additional measurements are made periodically each year to recalibrate the curve. Figure 2 depicts the rating curve for Traver Creek. USGS water-level sensors are located at the Malletts Creek and Mill Creek sites, and a similar sensor maintained by the City of Ann Arbor was placed at Allens Creek in 2007. That sensor was operational until 2010 when it stopped functioning. USGS took over its operation in 2012. Water-level sensors maintained by HRWC were located at other sites on a rotational basis with sensors installed at Swift Run and Fleming Creeks for the 2010 season, at Traver Creek, Fleming Creek and Swift Run in 2011, at Honey Creek and Traver Creek in 2012, and lastly at Fleming Creek and Honey Creek in 2013.

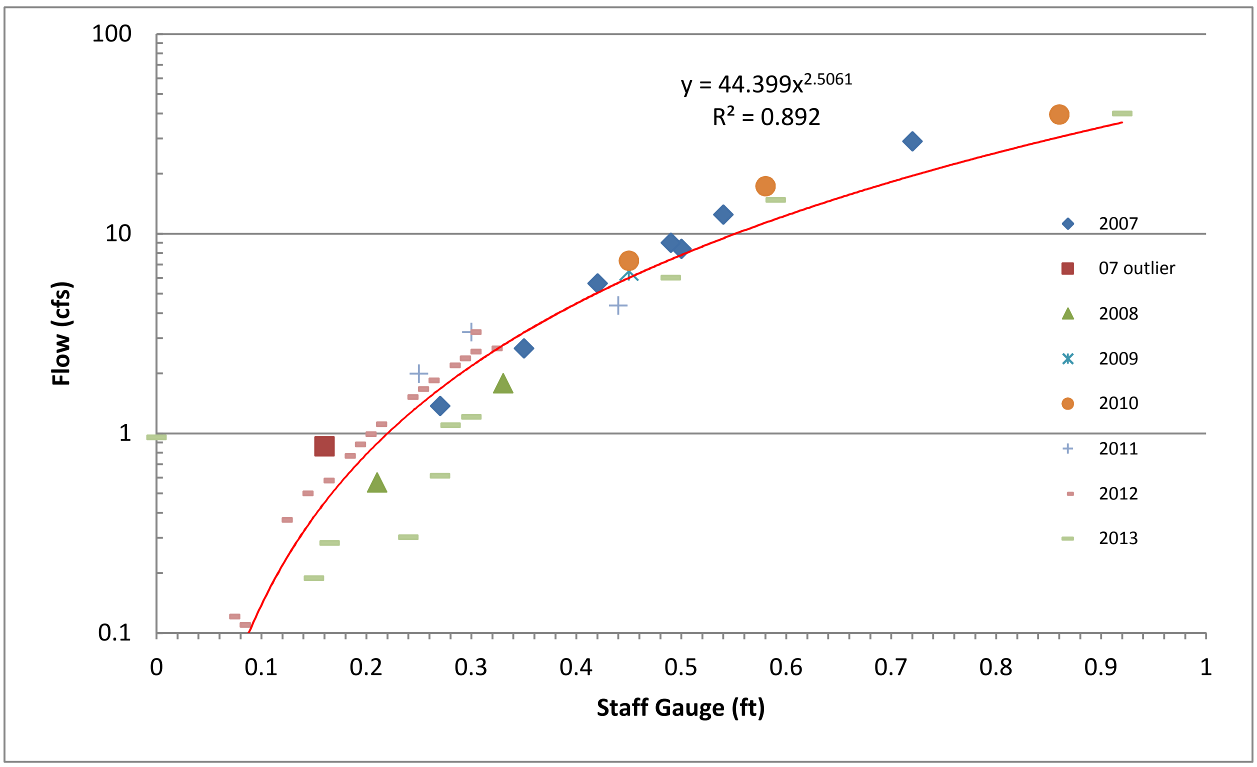


Figure 2. Staff gage rating curve for the Traver Creek site with annual discharge measures shown.

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.

Field Equipment

Horiba™ U-10 Water Quality Checker
Parameters measured: pH, dissolved oxygen, temperature

pH: range 0-14 pH; resolution 0.1 pH; accuracy +/- 0.05 pH
dissolved oxygen: range 0-19.9 mg/L; accuracy +/- 0.1 mg/L
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

Sigma 900 Standard Portable Sampler (programmable), Hach Company

3. MONITORING RESULTS AND DISCUSSION

The following is a summary discussion of the most important findings regarding the status and trends at each of the monitoring locations, as well as general findings across the middle Huron River Watershed. A compendium of graphic results for each tributary is included in Appendix B.

Successes and Challenges

Overall, the monitoring program delivered results that showed Middle Huron Partner and SAG investments made in the watershed (especially in the urbanized area of Ann Arbor) have contributed to a decrease in total phosphorus concentrations and loading. The monitoring data was used, not only to validate success with the partners, but also to educate local government representatives and state lawmakers as well. The program results were used to advocate for a statewide phosphorus fertilizer ban, which was eventually passed in 2010 and went into effect in 2012.

Unfortunately, the monitoring results also indicate that efforts to reduce periodic bacteria contamination in tributaries to the middle Huron River have not been successful. Because of this, in part, the Middle Huron Partners and SAG revised the TMDL implementation plan in 2011 to refocus efforts to address the bacterial impairment of the Huron River between Argo and Geddes Dams. An additional study and plan for Honey Creek and Mill Creek were developed and implemented. The study of Honey Creek began in 2012 and continued through 2013. The Mill Creek study was performed solely during the 2013 season. Plans were also developed or revised for other impairments in the middle Huron River watershed.

The results from the program were also presented to the Michigan DEQ to show progress toward meeting the TMDL for Ford and Belleville Lakes and encourage DEQ to re-evaluate the TMDL. While DEQ ultimately did not choose to revise the TMDL, they did alter their approach towards its implementation by stating that "any new or expanding permitted source that proposes to increase the loading of phosphorus above the [TMDL limits] would not be allowed unless there is a commensurate decrease in phosphorus loading from other permitted sources within the watershed." This decision represents a significant improvement in regulatory commitment. The decision letter also cited the monitoring results as evidence of progress made by watershed partners, which provided the basis for their decision. In addition, the letter cited monitoring results as contributing to movement toward passage of the phosphorus fertilizer ban.

Key challenges had to be overcome to develop the monitoring program to this successful state. When HRWC began the monitoring program, it included the collection of samples and flow measures once per month through the growing season. These samples represented a stratified random approach to monitoring across a range of flow conditions and seasonal changes. However, as the program developed, program coordinators determined that few true wet weather samples were being collected. In 2008, HRWC piloted a wet weather component that included manual grab sampling across storm events. This proved challenging, as required sample timing was unpredictable and often occurred in the middle of the night when it was hard to recruit volunteers and presented difficult, if not dangerous, sampling conditions.

In 2009, HRWC obtained an autosampler (Sigma 900) that was refurbished and put into use. This allowed for far greater logistical ease in sampling as well as greater precision in targeting samples at different points across the storm hydrograph. The autosampler proved challenging to program, but, once programmed, easy for volunteers to operate. Thus, a greater number of wet weather samples were obtained in 2009 through 2013 than in 2008.

Recruiting volunteers for wet weather sampling also proved to be a challenge. Most volunteers prefer a predictable schedule and weather in which to sample. While this desire was conducive to the baseline portion of the program, it was not conducive to wet weather sampling. However, HRWC benefited from help from two key areas. Key volunteers were discovered who enjoyed the excitement and importance of the wet weather sampling, and dedicated interns were able to keep flexible schedules to allow them the responsiveness necessary to effectively complete timely wet weather sampling. Communications around storm events also proved challenging. Once a likely storm was identified, HRWC often had less than an hour to alert a team and get them to a site to set up the autosampler. HRWC utilized a variety of media to send alerts to possible volunteers, and, in most cases, one or two would respond. In the end, HRWC staff, interns and volunteers got increasingly more efficient at responding to storm events. In total, 16 storm events were sampled through 2013.

Another challenge was working with scheduling limitations presented by the analytical laboratory. While the lab is staffed 24-hours, analytical staff were only available for a limited working week. The lab eventually made arrangements to allow off-hours staff to be available, with notice, to accept and process wet weather samples during weekends to avoid holding time violations. HRWC also worked out a change in process at the end of 2010 (which was instituted in 2011) to preserve phosphorus samples following wet weather events to extend their holding time.

At the end of 2010, HRWC also encountered changing detection limits being reported after the fact by the lab. This presented a serious concern about the reliability of analytical results. HRWC met with the lab in January 2011 and learned that, due to the lab’s necessity to process a flow of samples with vastly different nutrient contents, the mean detection limits were computed on a quarterly basis. Detection limits do not affect the accuracy of results themselves, but do affect the reporting resolution. This was determined to only be an issue with 2010 total phosphorus data, where detection limits varied between 10 and 50 µg/l. Following discussion with DEQ and other staff, it was decided that, for results that were reported as “below detection limits,” a value of 50% of the detection limit would be used.

A final challenge came with the addition of investigative sites starting in 2011. Generally, it was relatively convenient to sample an investigative site shortly following the sampling of its paired long-term site downstream. Some of these upstream sites, however, were difficult to access and, during dry months, exhibited periodic very low or no flow. It was impossible to sample at those times.

Total Phosphorus (TP) Concentrations

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. That is, if all the phosphorus present is used, then plant growth will cease no matter how much nitrogen is available. Total Phosphorus (TP) is a measure of all forms of phosphorus present in a water sample, and is the primary indicator of overnutrification in the middle Huron River watershed. The typical background level of TP for a Michigan river is 0.03 mg/L or ppm. The TMDL established for Ford and Belleville Lakes sets goals of 0.05 mg/L at Ford Lake and 0.03 mg/L at Belleville Lake.

Further, phosphorus is the main parameter of concern in eutrophic lake and stream systems for its role in producing blue-green algae. Phosphorus enters surface waters from point sources of pollution, such as wastewater treatment plants, and nonpoint sources of pollution, including natural, animal and human sources. Excessive concentrations of this element can quickly lead to 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.

Through 2009, HRWC observed a statistically significant decrease in mean TP concentrations from a number of tributaries to the middle Huron River. This result was significant because the decrease was coincident with the enactment of a phosphorus fertilizer ban by the City of Ann Arbor in 2007. Figure 3 illustrates the general finding, with median TP concentrations falling below the TMDL target concentration of 0.05 mg/l in 2008 and 2009. However, mean concentrations from 2010 through 2013 were quite different than the previous two years, with a much broader range of concentrations and mean TP concentrations ranging between 0.076 and 0.082 mg/l – well above the target concentration.

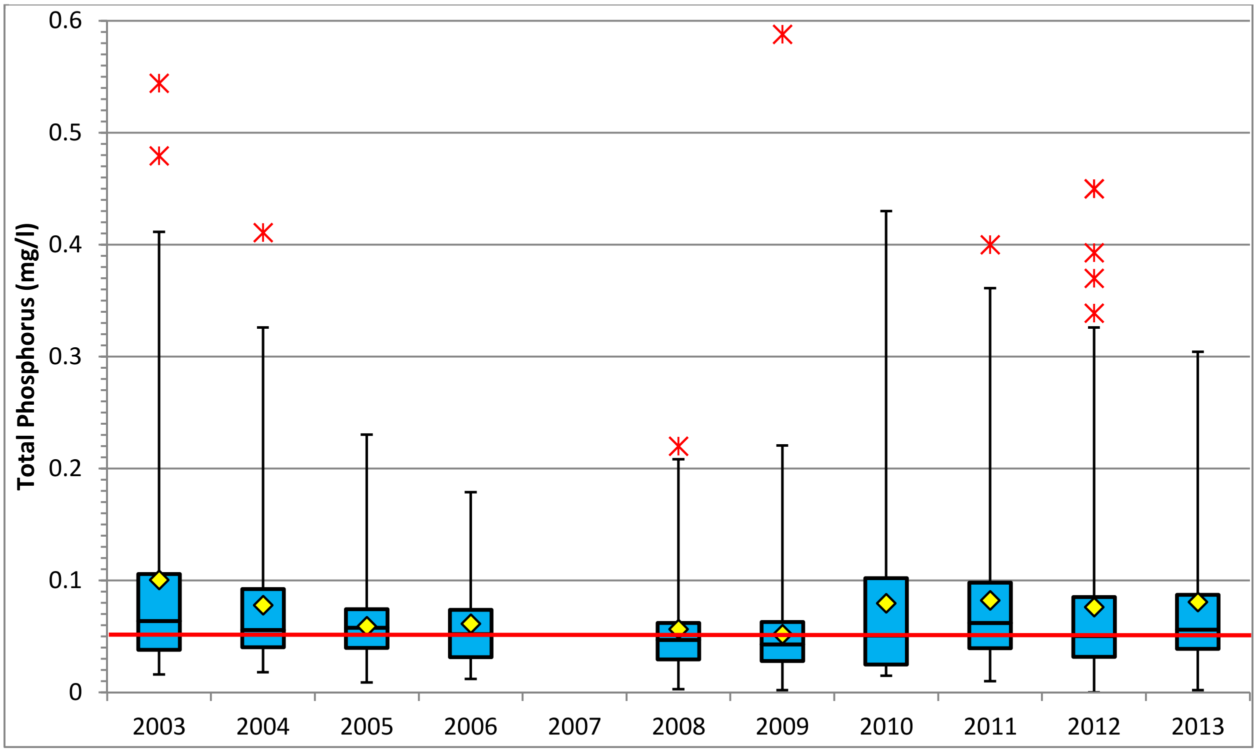


Figure 3. Annual range of total phosphorus concentrations across 10 long-term monitoring sites in the middle Huron River watershed. Boxes illustrate the interquartile range with the median; yellow points indicate the mean value; 3 x interquartile range illustrated by bars; outliers as red stars; and the TMDL target indicated by the red line. No baseline sampling was conducted in 2007.

It is difficult to explain why 2010 to 2013 results did not follow the previous declining trend in total phosphorus concentrations. One possible explanation is higher than average flows in those years, except for 2012 when the area experienced much lower rainfall. According to data from the USGS flow gage station in Ann Arbor at Wall Street, the mean monthly discharges were above average for almost all of the 2013 monitoring season. However, this was also the case in 2009, which did not generate such variable data. These years also produced some extreme rain events, which could drive up TP averages with high concentrations for single events. That hypothesis would not explain the rise in median concentration, though. Still, the median total phosphorus concentration in 2010 and 2012 was close to the TMDL target at 0.051 mg/l, with 2013 showing only a slight increase above the TMDL target at 0.56 mg/l.

It is more instructive to examine the results by individual tributary site, since sample results are more representative of tributary watersheds than the Middle Huron watershed as a whole. Figure 4 shows the mean TP concentrations for each middle Huron site for each of three time periods. First, the May-September means from the 1995 data collection used to develop the TMDL model are shown for comparison, followed by the 2003-06 (before the Ann Arbor fertilizer ordinance) and 2008-12 (after the ordinance implementation) means[1]. Initially, after analyzing the concentrations by site through 2009, six of the ten sites showed significant decreases between 2003-06 and 2008-09 periods. Further, when testing the change between these two time periods and comparing that change for sites with greater than 30% of their drainage area within the City of Ann Arbor to those outside[2], the Ann Arbor sites showed a significantly greater decline in TP concentrations.

Figure 4. Total Phosphorus concentrations at each of 10 sites in the middle Huron River watershed. Means for each of three time periods are shown.

The addition of 2010-13 results diminishes the effect, but does not eliminate it. Table 1 provides mean concentrations for each site and the Ann Arbor vs non-Ann Arbor site groupings for each of the two time periods. Table 2 shows these same concentrations, but statistically transformed to provide normalized means. The overall differences between the two time periods narrowed somewhat, but still remained

[1] Three monitoring sites (at Mill, Traver and Millers Creeks) were moved short distances for logistical reasons between 2006 and 2008. It is not believed that water quality characteristics are appreciably different between old and new locations.

[2] This grouping of tributaries was done to compare those drainages affected by City of Ann Arbor policies with those that would not be directly affected.

significant for Ann Arbor drainages. Two monitoring sites outside of Ann Arbor (i.e. Huron and Mill) had increased concentrations between the time periods. Concentrations in mostly agricultural Mill Creek have increased by 30%. Four sites (Honey, Malletts and Traver Creeks, and Swift Run) still had significant decreases in TP concentrations between the two time periods. All had TP concentration decreases of over 20%.

Overall, TP concentrations decreased within the City of Ann Arbor drainages by 20%, on average, whereas concentrations in tributaries outside the city dropped by only 9% (Table 2). Thus, the concentration results still indicate a significant decrease within the City of Ann Arbor post-fertilizer policy implementation when compared to outlying drainages. As of 2012, communities outside of Ann Arbor also came under the phosphorus fertilizer ban.

Table 1. Mean TP concentrations for long-term monitoring sites, ordered upstream to downstream.

Site(s)	[TP] (mg/l) 2003-06	[TP] (mg/l) 2008-13	% Reduction
Outside Ann Arbor	0.077	0.067	13
Ann Arbor	0.084	0.083	1
Huron above Mill	0.031	0.033	5
Mill Creek	0.052	0.067	(30)
Honey Creek	0.083	0.057	31
Allens Creek	0.086	0.085	1
Traver Creek	0.076	0.065	15
Millers Creek	0.062	0.087	(40)
Malletts Creek	0.091	0.084	8
Fleming Creek	0.092	0.056	40
Swift Run	0.103	0.093	10
Superior Drain	0.081	0.089	(10)

Note: Negative reductions ( ), represent an increase in TP concentration.

Table 2. Mean TP concentrations after statistical transformation for long-term monitoring sites, ordered upstream to downstream.

Site(s)	[TP] (mg/l) 2003-06	[TP] (mg/l) 2008-13	% Reduction	T-test [3]Probability
Outside Ann Arbor	0.054	0.050	9	0.17
Ann Arbor	0.072	0.057	**20**	**<0.01**
Huron above Mill	0.025	0.028	(10)	0.30
Mill Creek	0.045	0.052	(17)	0.14
Honey Creek	0.063	0.040	**37**	**0.01**
Allens Creek	0.070	0.061	13	0.19
Traver Creek	0.070	0.052	**26**	**0.02**
Millers Creek	0.055	0.043	23	0.11
Malletts Creek	0.077	0.062	**20**	**0.09**
Fleming Creek	0.051	0.043	15	0.26
Swift Run	0.092	0.072	**22**	**0.06**
Superior Drain	0.070	0.069	1	0.48

Note: tests with <0.10 probability indicated in bold. Negative reductions ( ) represent an increase in TP concentration.

The TP changes vary by site, but looking at overall TP trends (using a linear regression), only Honey Creek exhibited a significant trend. Since 2003-06, Honey Creek TP concentrations have continued to decline, with a 37% reduction between the comparable periods. Aside from Honey Creek, Traver Creek exhibited the second largest decline with a 26% reduction in TP. Whereas, mostly agricultural Mill Creek had the largest increased by 17% between the comparable periods.

[3] Two-sample T-tests, assuming unequal variances were run on LN-transformed TP data for the time periods indicated.

One of the factors that impacts TP concentrations is stream flow. As flows increase, TP concentrations tend to follow, though with wide variability. One way to remove the effect of stream flow is to evaluate flow-weighted mean concentrations. A discussion of that analysis is included in the nutrient loading section.

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. This is the case for Malletts Creek and Swift Run TMDLs. Those evaluations set the following targets for TSS:

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

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.

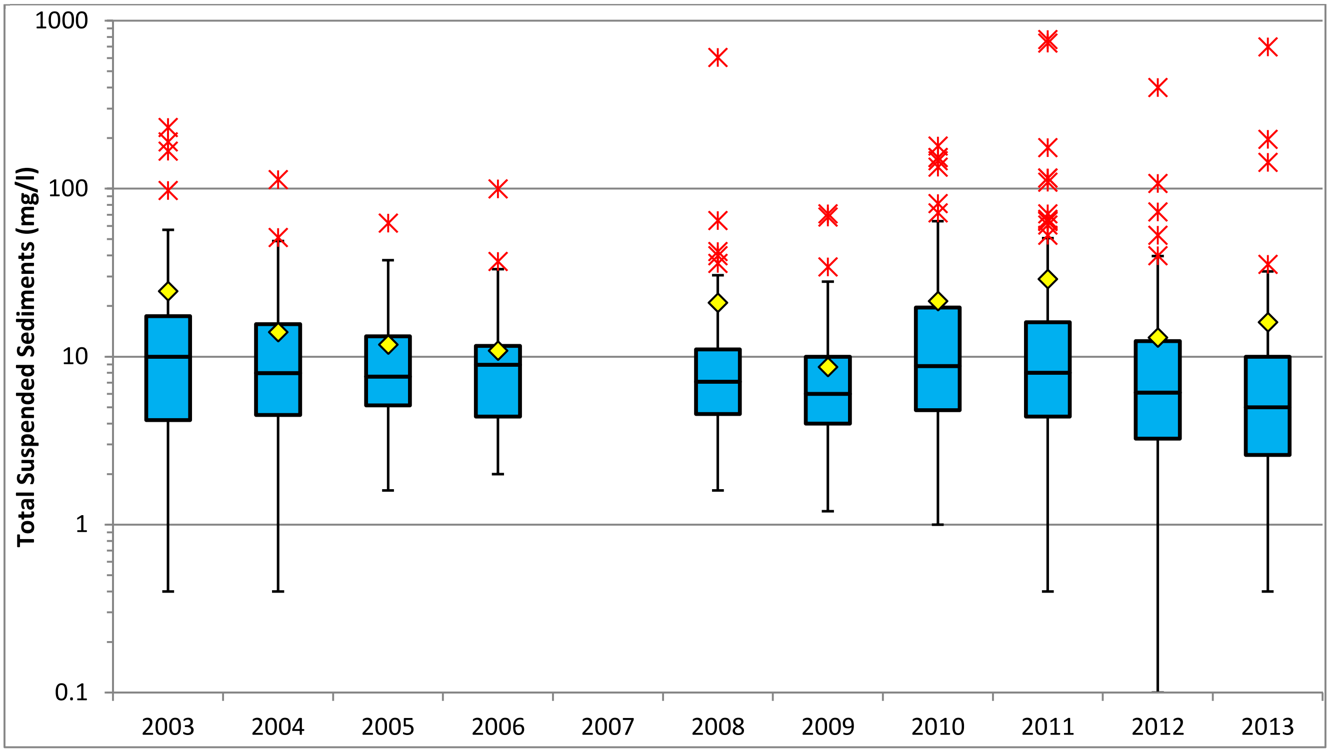


Figure 5. Annual range of total suspended sediment concentrations across 10 monitoring sites in the middle Huron River watershed. Boxes illustrate the interquartile range with the median; yellow points indicate the mean value; and 3 x interquartile range illustrated by bars. Red stars are extreme concentrations. No baseline sampling was conducted in 2007.

As with the TP results, mean concentrations of TSS from the monitoring sites show a consistent decrease year to year, until 2010 when concentrations began to increase through the 2011 season (see Figure 5). In 2012 and 2013, median and mean TSS concentrations decreased. The range of concentrations observed is quite broad, with high concentrations driving the mean out of the interquartile range in some years. Individual monitoring sites vary considerably. Viewed across the entire 2003-13 record, most of the monitoring sites all have mean TSS levels below 20 mg/L, with the exception of Fleming Creek (31 mg/L), Malletts Creek (21 mg/L), and Superior Drain (26 mg/L). Both Fleming Creek and Superior Drain were characterized by low concentrations throughout the bulk of the record, with occasional peak concentrations over an order of magnitude greater. Unlike previous years 2013 only produced one sample of 500 mg/L or greater at Fleming Creek. Year to year trends at most sites are flat or declining. Exceptions include Allens, Traver, Fleming, and Superior.

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 each TP concentration with its corresponding TSS concentration. 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. All of the tributaries (with the exceptions of Mill, Millers, and Fleming Creeks) showed significant correlations (R^2 greater than 0.30). Overall, correlations between TP and TSS ranged between 0.01 (Huron River) and 0.95 (Superior Drain). See Figure 6 for an example. In these creeks, 30% or more of the variance in TP can be explained by variance in TSS. This suggests that much of the phosphorus coming by these monitoring points is bound to sediment and likely due to channel or runoff erosion, especially at higher flows. However, much of the variance in TP cannot be explained by TSS, so there may be a significant portion of the TP load that exists in dissolved form. This could be explained by excessive fertilizer runoff.

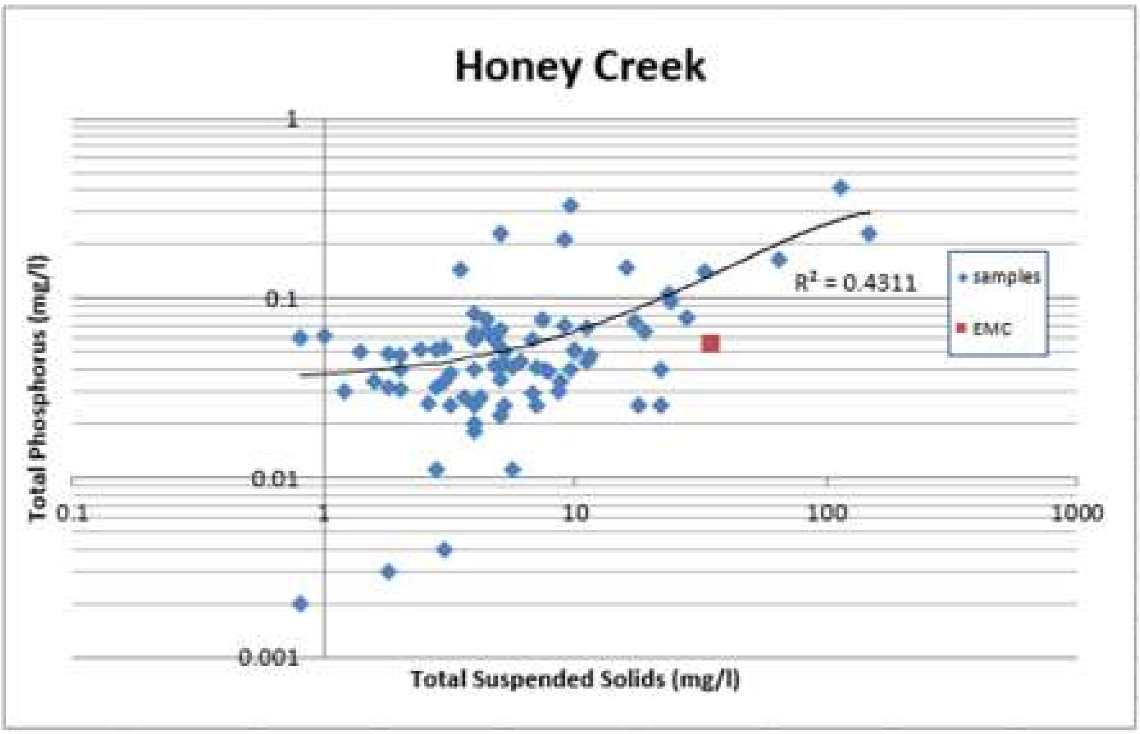


Figure 6. Paired sample results of TSS and TP concentrations at Honey Creek [including one wet weather event (EMC-Event Mean Concentration)].

<u>Bacteria</u>

Escherichia coli (*E. coli*) counts are measured from water samples as a broad indicator of the presence of pathogens found in the digestive tracts of warm-blooded animals. Their presence may indicate the presence of sewage or wastewater, but high counts can also result from other animal sources. These generalized bacterial counts are not specific enough to be directly indicative of health risks. However, consistently high levels serve as a warning of potential health risks and warrant further investigation to determine the source of bacterial outbreaks. The State of Michigan water quality standard for partial body contact is a monthly average of 130 counts per 100ml of water, while a single sampling event for waters protected for full body contact is <300 *E. coli* counts per 100 ml of water. Several reaches in the middle Huron are on the state's list of impaired waters due to bacterial contamination, including Honey Creek, and drainages to and including the Huron River between Argo and Geddes Dams.

Data collection for *E. coli* under the Middle Huron Monitoring Program began during the 2006 monitoring season. Some of the wet weather samples from 2010 and 2011 were also analyzed for *E. coli*. Baseline data is shown in Figure 7. Much additional data on *E. coli* has been collected by other organizations throughout the watershed on a more limited scope. That data is not reported here.

The majority of the measures significantly exceeded the water quality standards for both partial- and full-body contact, and in some cases by multiple orders of magnitude. The median values were greater than the full body contact standard at all sites except the Huron River and Fleming Creek, and only Huron's median value was below the full-body contact standard of a maximum of 100 *E. coli* per 100 ml for a single sample set. Most of the monitoring sites exhibit slight increases in *E. coli* counts over time. Malletts and Milers Creeks show trends toward lower bacteria counts. However, bacteria counts in the middle Huron continue to be an impairment of concern overall.

In 2012, HRWC began a study of bacteria levels in Honey Creek for development of a watershed management plan. That study went beyond single-site bacteria count results and included broad geographic sampling and genetic source tracking. More information on that project including sampling results can be found separately at www.hrwc.org/honey-creek.

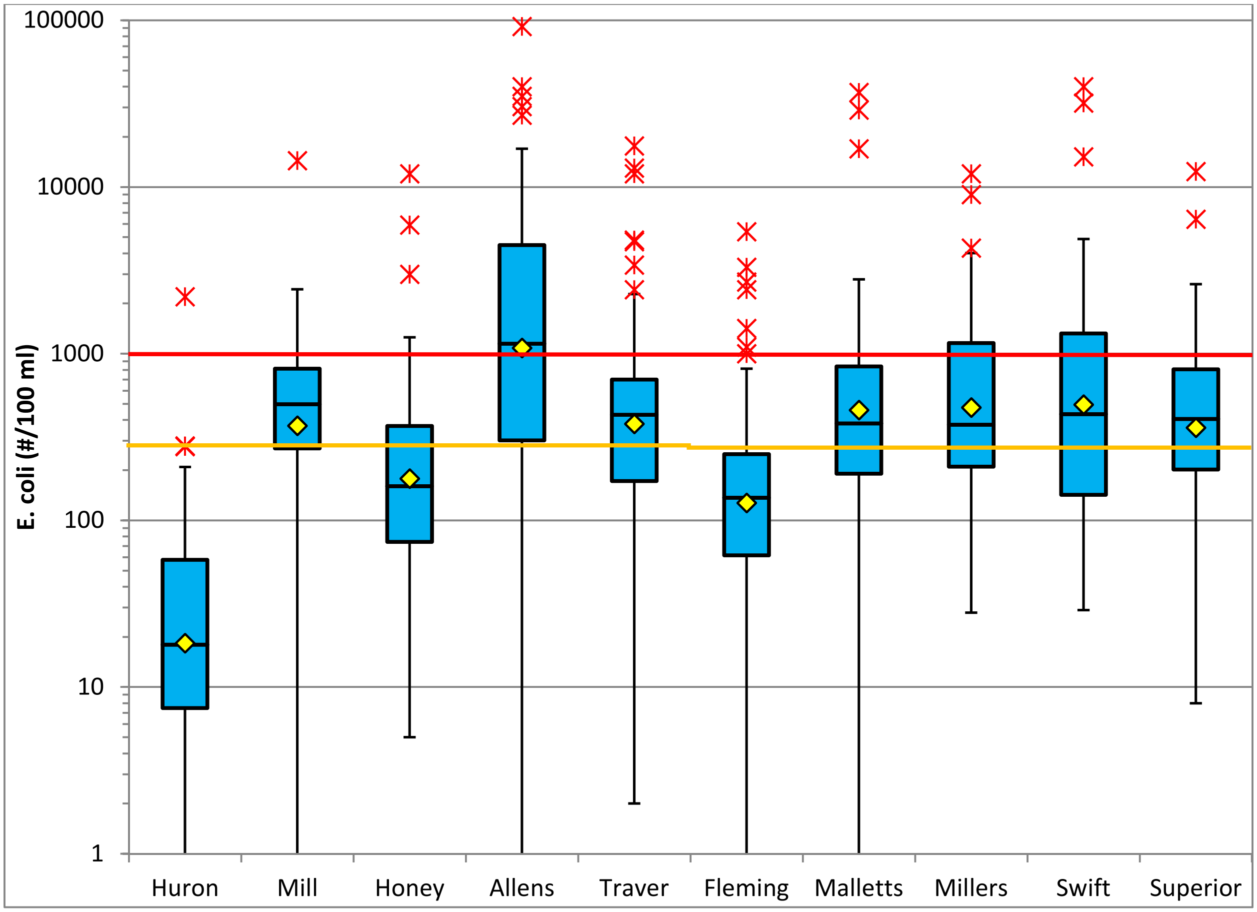


Figure 7. Range of *E. coli* counts in sampling 2003-13 showing median, interquartile range, mean and extremes. Michigan's single-sample standards for full body (orange) and partial body (red) contact are indicated by colored lines.

Stormwater Site Investigations

The monitoring program added an additional component in 2010. Additional monitoring sites were added to the monitoring regime that were located upstream of existing long-term monitoring sites. These new "investigative" sites (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 3. All but three sites had mean concentrations that were above the long-term downstream site. Sites that had a mean TP concentration difference from downstream sites of greater than 33% are highlighted as potential hot spots. None of the differences were statistically significant at the $\alpha<0.05$ level, but the difference at site

Miller01 was significant at the $\alpha<0.10$ level. Subsequent to monitoring Miller01, a second investigative site (Miller02) was established further upstream. Results from Miller02 were not strongly different from the downstream site on Millers Creek. Land use in the watershed above Miller02 is mostly older vintage residential with some mixed commercial properties included. Land use in between the investigative sites is almost entirely facilities under the jurisdiction of the University of Michigan and part of their storm system. This area has been identified in the Millers Creek Watershed Management Plan as a critical area for remediating erosion issues and reconnecting floodplain.

The other potential hot spots also have distinctive land uses. The Allens Creek site (AC01) is one of the few surface water access points in that watershed. It lies at the downstream end of the University of Michigan Golf Course. The Traver Creek site (TC01) is just upstream of a golf course and downstream of low-density residential and agriculture. And Mill Creek (Mill02) is just downstream of a golf course and agriculture as well.

Table 3. Mean total phosphorus results from investigative sites and differences from paired downstream sites.

Creek	Investigative site ID	Mean TP (mg/l)	Mean Difference from downstream (mg/l)	Percent Difference	n (# samples)
Honey	HC01	0.05	-0.04	-47%	13
Allens	AC01	0.14	**0.03**	**34%**	12
Malletts	Mal01	0.06	0.01	31%	10
Mill	Mill02	0.11	**0.06**	**106%**	9
Mill	Mill03	0.06	0.01	15%	9
Millers	Miller01	0.12	**0.06**	**101%**	12
Millers	Miller02	0.11	0.02	21%	7
Swift	SR01	0.18	0.03	17%	6
Swift	SR02	0.13	0.01	10%	7
Fleming	FC01	0.04	0.00	-4%	7
Traver	TC01	0.12	0.04	59%	7
Traver	TC02	0.07	-0.02	-27%	7

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 Ford and Belleville Lakes 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.

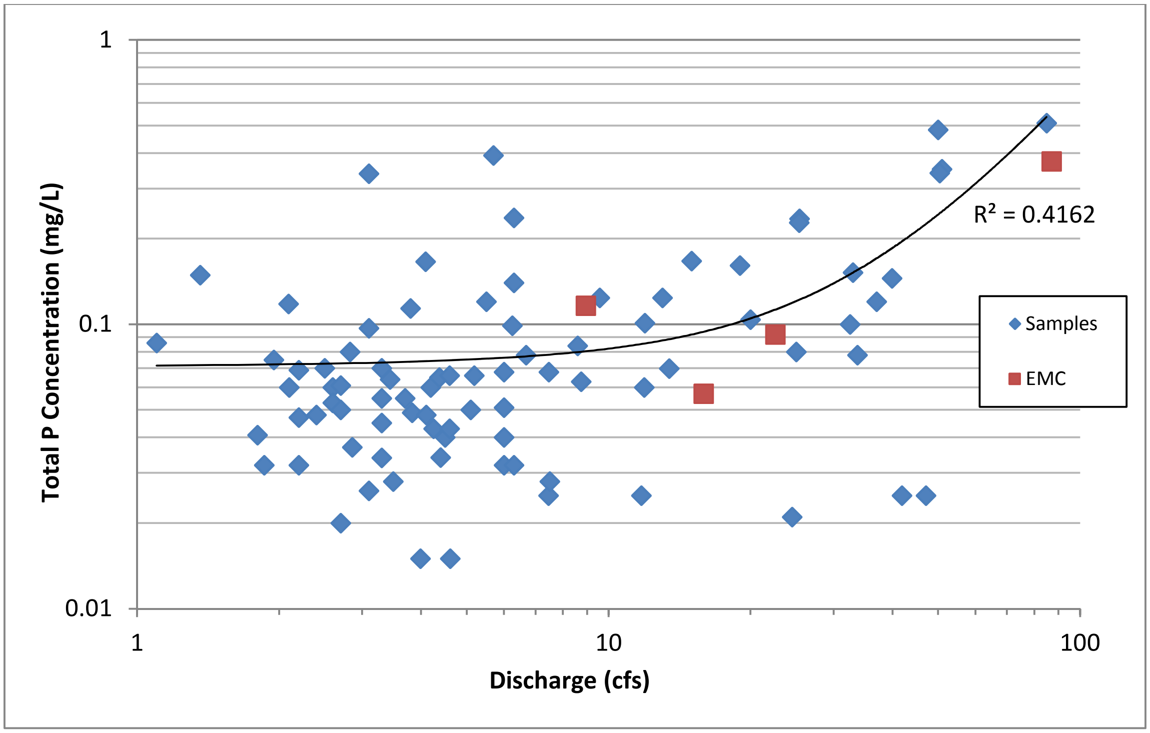


Figure 8. Sampling data from Malletts Creek showing TP concentration and stream discharge along with the best fit curve. Event Mean Concentrations (EMC) from wet weather sampling are also shown.

Some sites exhibit a strong, positive relationship between TP concentration and stream discharge. Figure 8 shows this relationship for Malletts Creek. Discharge can explain 42% of the variability (R^2). With this site, as with others, as the discharge increases, so does the TP concentration. 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 little correlation between concentration and flow, but, at all monitoring sites, the relationship was positive.

Storm samples were collected across 4-6 points in time for 16 wet weather events at five 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. EMCs tended to vary evenly around the best-fit curve estimated from the baseline monitoring samples (see Figure 8). Thus, 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. Stated another way, estimating wet-weather loads from data collected utilizing a regular sampling approach would not be expected to result in underestimations.

Table 4. Loading estimates for Middle Huron streams comparing two different time periods against the most current 2013 data (lbs/day).

Site	TP Mean Daily Load Est. (2003-2006)	TP Mean Daily Load Est. (2007-2013)	TP Mean Daily Load Est. (2013)	% Difference
Huron @ N. Territorial** (upstream)	38.34	77.7	82.31	50.66%
Mill Creek**	25.26	51.01	27.39	50.48%
Honey Creek**	5.07	17.74	11.93	71.42%
Allens Creek	3.41	5.74	4.6	40.59%
Subtotal to Wall St.	72.08	152.19	126.23	52.64%
Other sources/(sinks)	88.3	22.04	44.03	-300.64%
Huron @ Wall St.	160.38	174.23	170.26	7.95%
Traver Creek	0.83	3.42	1.41	75.73%
Fleming Creek**	5.84	11.31	9	48.36%
Millers Creek~	0.28	0.62	0.27	54.84%
Malletts Creek	15.32	16.56	17.11	7.49%
Swift Run	1.2	2.5	2.38	52.00%
Subtotal to Geddes Pond	183.85	208.64	200.43	11.88%
AA WWTP	49.62	52.98	57.97	6.34%
Superior Drain**	0.7	1.34	1.1	47.76%
Subtotal to Ford Lake	234.17	262.96	259.5	10.95%
Other sources/(sinks)	-102.63	-97.08	NA	-5.72%
Huron @ Ford Lake (US-12)#	131.54	165.88	NA	20.70%

**data not available in 2007

~data only available for 2008-2009

data 2003-2010, 2012

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[4]. These results are compiled into a multi-year analysis found in Table 4. The sampling record contains a far greater number of dry-weather samples than wet-weather samples; since sampling is done at regular intervals and rain events are short in duration. While there is variability site to site, TP concentrations are generally much higher during wet-weather events. Flow-weighted average (FWA) concentrations account for this by extrapolating dry and wet-weather events across the entire daily flow record for a given time period. FWA TP concentrations are all quite a bit higher than simple sample means and more accurately allow for site-to-site comparisons. Table 4 shows the loading estimates for all ten middle Huron sites from 2003-2006, 2007-2013, and the most recent 2013 data.

Overall, TP loading estimates have increased at each site since the initial 2003-2006 sampling period; note the dramatic differences in some cases. Many of the sites saw a 40%, or greater, increase in the TP loading since the first time period (2003-2006; Table 4). These increases can be explained by an increase in wet-weather generating events during the 2009-2011 period, in which all of the sites experienced a spike in discharge, and at most sites FWA TP as well (Appendix B). Table 4 breaks the Huron River down into three sections with contributing tributaries: the upper portion starting at Huron River at Hudson Mills (N. Territorial Rd.), the middle portion that travels through Ann Arbor to Geddes Pond, and the lower portion from the Ann Arbor Waste Water Treatment Plant (AAWWTP) to the mouth of Ford Lake in Ypsilanti, at US-12/Michigan Avenue.

Several interesting observations stand out in Table 4. Upstream of the Huron River at Hudson Mills has accounted for at least 50% of what is traveling downstream, with Mill Creek contributing the largest load of the tributaries in this reach, at greater than 30% during each time period (2003-2006 and 2007-2013). While this is not surprising, since Mill Creek is by far the largest tributary, with 92,600 acres in the creekshed, Honey and Allens Creek still load phosphorus at a comparable rate considering that their creeksheds are much smaller. Together, Honey and Allens Creeks, have loaded at most 15% of the total phosphorus accounted for in the "Subtotal to Wall Street". One interesting observation about the upper portion is that much more of the phosphorus load was accounted for in 2007-2013 than in the previous time period. In 2003-2006, 55% of the mean TP load estimated at Huron at Wall Street was unaccounted for as part of an additional source of TP to the system. During 2007-2013, this number decreased to only 13%. This may in part be due to increased sampling efforts, or may actually represent a decrease in unknown point source pollutants in this portion. Either way additional investigation should be added upstream and within this section to locate these sources.

The middle portion of the river contributes to overall TP mean daily load in a much smaller amount than the upper portion, despite Fleming and Malletts Creeks being some of the larger tributaries in the watershed. Malletts Creek loads the largest proportion in this stretch, adding as much as 48% during 2007-2013, with Fleming Creek contributing 33% of the total load in the middle reach. The remaining three tributaries (Traver and Miller Creeks, and Swift Run) each contributed less than 10% of the total load.

Below Geddes Pond, the Ann Arbor Waste Water Treatment Plant (AAWWTP) is the largest phosphorus contributor in the lower section, loading 98% of the total in this section. However, it is important to mention that the AAWWTP and Superior Drain are the only tributaries/contributors this analysis accounted for in the lower portion. Opposed to the upstream portion where phosphorus is being added by additional unknown sources, in the lower portion, more than 50% of the accounted phosphorus (Subtotal to Ford Lake) is being lost in sinks before reaching the sampling site at Huron River at US-12/Michigan Avenue.

These differences can be seen more clearly by examining flow-weighted average (FWA) concentrations across the entire 2003-2013 record when compared to the most recent 2013 loading data (Figure 9). Concentrations at all tributary sites were above the target concentration of 0.05 mg/L, except for Millers Creek in 2013. In addition, a majority of the tributaries FWA TP concentrations were more than twice the target level for both the overall sampling record and 2013. A greater number of the tributaries have declined, in phosphorus concentration, in 2013 than have increased. Several observations stand out in this analysis when comparing the site specific loading figures found in Appendix B to FWA values in Figure 9. Of the five sites that increased in 2013 (Huron River at Hudson Mills, Honey, Allens and Malletts Creeks, and Swift Run), the trend, from the site specific loading figures for the entire record, shows phosphorus increasing at three of those sites (Huron River at Hudson Mills, Honey Creek, and Swift Run). The opposite is true at the two remaining sites (Allens and Malletts Creeks), indicating that phosphorus concentrations are declining, despite their 2013 values being greater than the overall record.

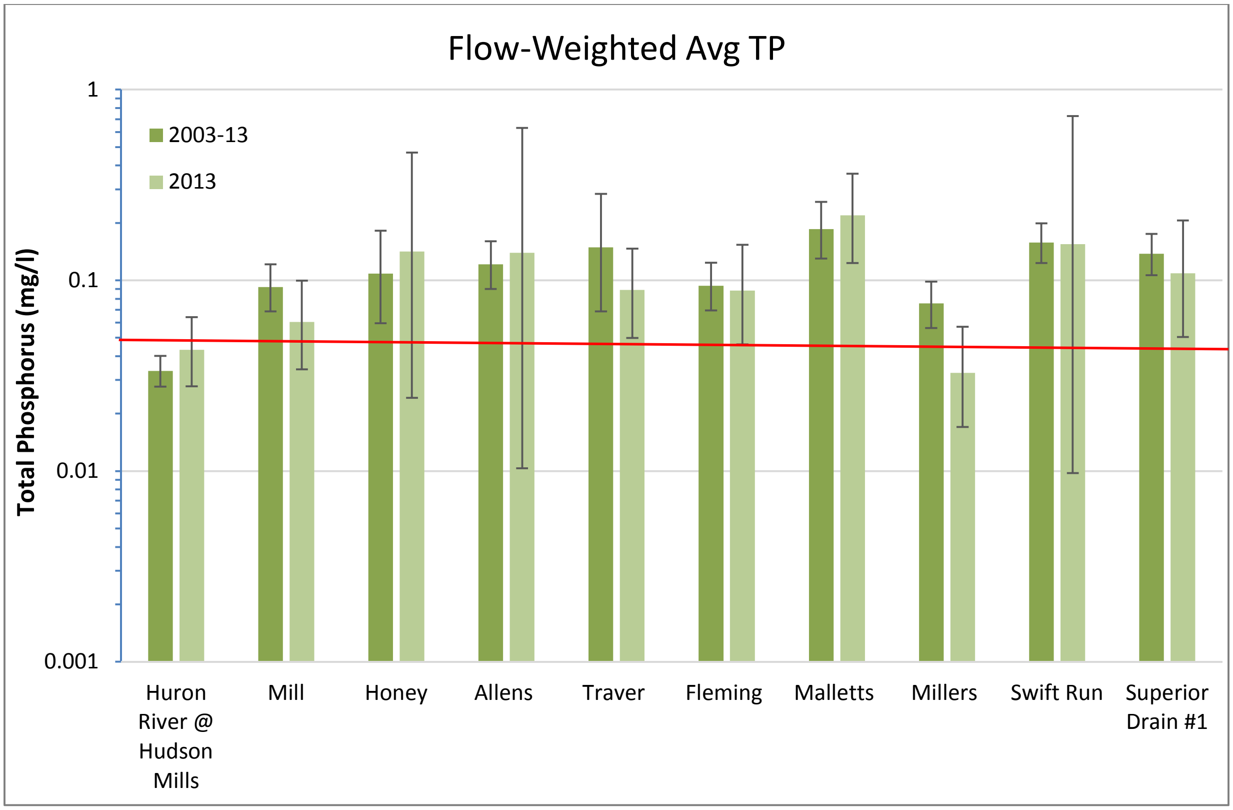
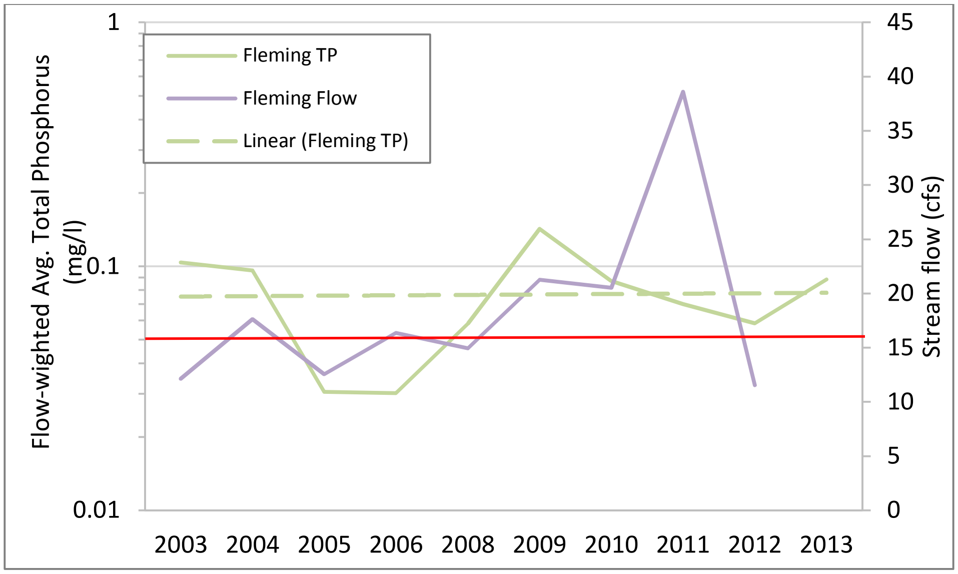


Figure 9. Flow-weighted average TP concentrations along with 95% confidence intervals for each long-term monitoring site over the entire sampling record and 2013. The target concentration threshold of 0.05 mg/l is shown in red.

Looking at individual tributaries, TP trends and runoff relationships can be better determined. Figure 10 shows the FWA TP at Fleming Creek for each year studied, compared to the corresponding TP-TSS relationship for the tributary. TP concentration varies from year-to-year, but this variation is not always consistent with the variation in average stream flow (Figure 10, top). In addition, as average stream flow increased significantly in 2010 and 2011, FWA TP decreased. In streams that exhibit this trend, stormwater plays a greater role in phosphorus dilution instead of addition, as a result of increased flow. This can be explained further by examining the TP-TSS relationship, Figure 10 (bottom). Only 13% (R^2=0.132) of the phosphorus concentration present in the tributary is explained by TSS, indicating that a majority of the phosphorus is traveling in a dissolved form, unbound to sediment, suggesting that streambank erosion during storms plays a small role in phosphorus loading at Fleming Creek.



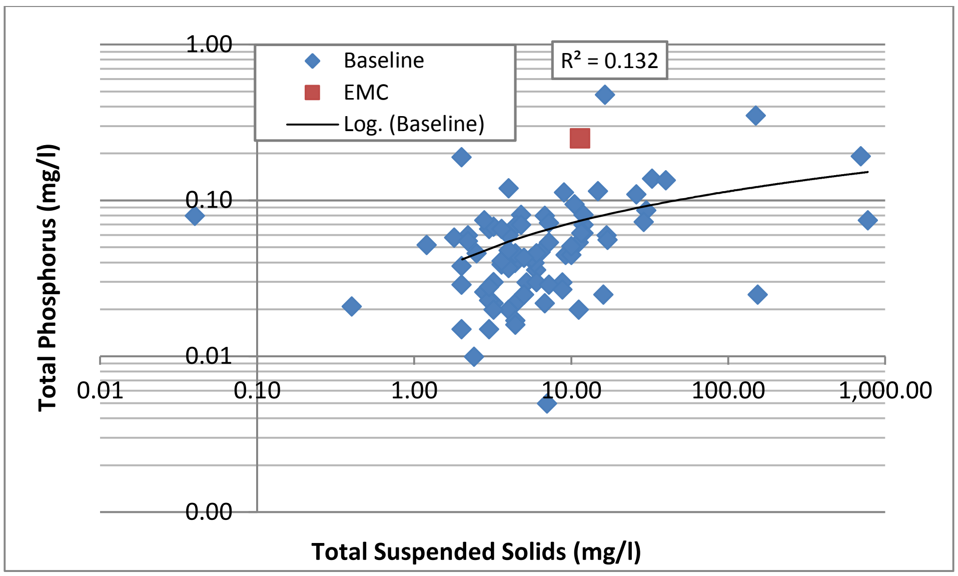


Figure 10. Flow-weighted average TP and average flow at Fleming Creek showing the target TP concentration of 0.05 mg/l is shown in red (top), and the TP-TSS relationship for the entire 2003-2013 record (bottom).

Beyond the impact that hydrology has on nutrient and sediment loading, a stream's flow regime can also impact stream ecology directly. Seven of the ten long-term monitoring sites have been monitored for continuous stream flow for at least one growing season. Using stream flow data, one can compare common measures like peak flow and return to base flow following comparable storm events. However, these statistics vary by contributing drainage (catchment) size. One statistic that is fairly comparable regardless of catchment size is "flashiness.[5]" Flashiness is a unitless index that ranges from 0 to just over 1 that is based on a combination of peak flow and return to base flow.

[5] Fongers, D., K. Manning, J. Rathbun. *Application of the Richards-Baker Flashiness Index to Gaged Michigan Rivers and Streams.* Michigan Department of Environmental Quality, August 3, 2007.

Table 5 presents summary statistics from the gage record, with the period that the gage was active listed. All of the tributaries fall into the highest or most flashy quarter of streams in Michigan, based on the flashiness index and comparisons across the state. The streams are characterized by low base or minimum flows that rise rapidly to very high peak flows following rain events. This pattern of hydrology can increase the likelihood of channel and streambank erosion, and may make it difficult for biota to establish refuge. Further, as illustrated by Figure 11, runoff from storms can lead to dramatically increased pollutant concentrations, like phosphorus, despite the dilution effect from increased water volume.

Table 4. Discharge statistics for gaged streams in the Middle Huron River Watershed

Site	Period Monitored	Drainage Area (sq. mi.)	Median Flow (cfs)	Peak Flow* (cfs) (Event Precip. (in))	Minimum flow* (cfs)	Flashiness (Quartile)†
Mill Creek (full record)	2002-2011	130	62.0	996 (6.10)	18	0.20 (4)
Malletts Creek (full record)	2002-2011	11	4.2	775 (2.58)	0.99	0.75 (4)
Mill Creek	2008-2011	130	75.0	996 (6.10)	21	0.20 (4)
Malletts Creek	2008-2011	11	4.6	775 (2.58)	1.4	0.74 (4)
Honey Creek	May-Nov/2008 May-Oct/2009 May-Oct/2012 May-Nov/2013	23	7.5	407 (2.61)	2.11	0.30 (3)
Allens Creek	Jul-Dec/2007 Jan-Jul/2008 Feb-Jun/2009 Apr-Aug/2010	5	5.3	1,062 (0.96)	-100	0.84 (4)
Traver Creek	Jun-Sep/2007 May-Sep/2011 Apr-Nov/2012	7	1.3	660 (2.73)	0.00	0.53 (4)
Fleming Creek	May-Nov/2009 Apr-Nov/2010 Apr-Oct/2011 May-Oct/2013	31	11.7	1,176 (2.73)	3.9	0.44 (4)
Swift Run	Jun-Sep/2007 May-Nov/2010 Apr-Oct/2011	5	0.65	273 (2.60)	0	0.64 (4)

** Peak flow and minimum flow are extracted from the complete, sub-daily flow record, whereas the other statistics are based on mean daily discharge.*

† The flashiness quartile is the number of the quartile where the flashiness index would place the stream compared to sites across Michigan, where 1=lowest or most natural quartile and 4=highest or most impacted quartile.

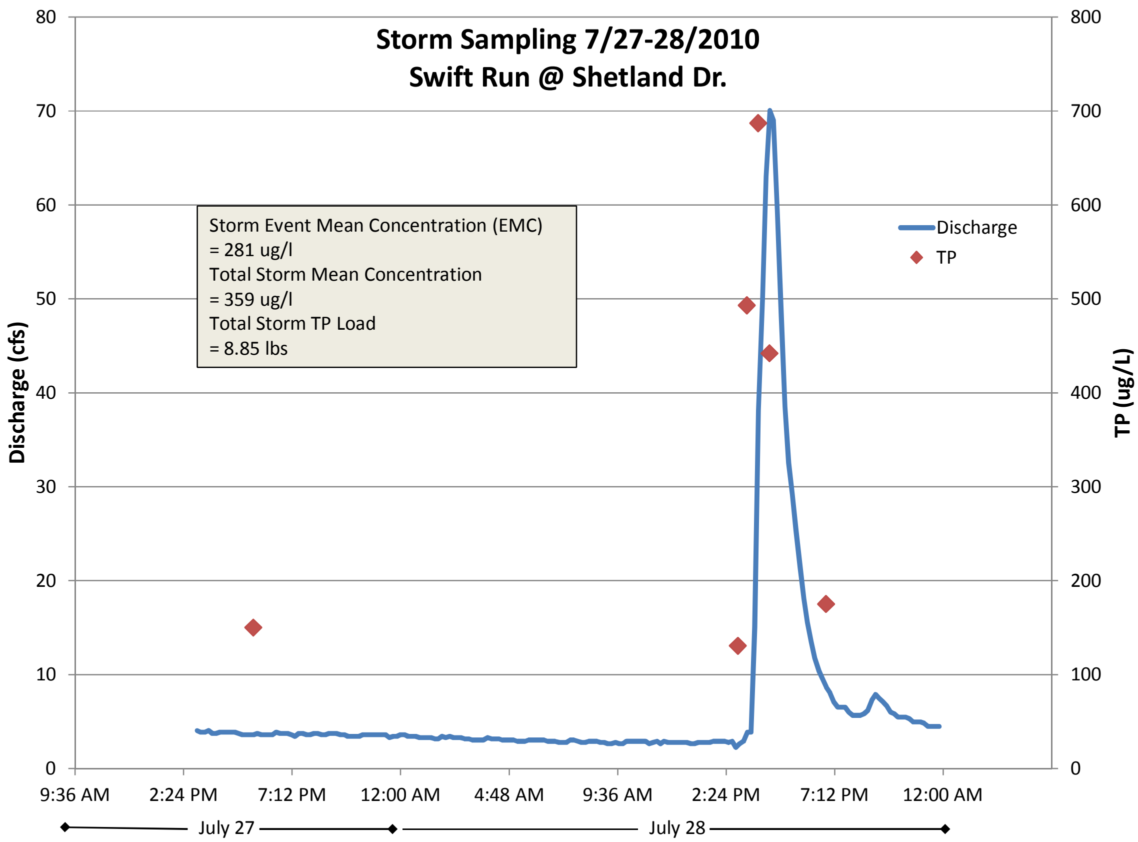


Figure 11. Sampling data illustrating a 0.56 inch (24-hour total) wet-weather event between July 27 and 28, 2010 at Swift Run. Graph illustrates discharge over time with individual TP results from water quality samples on the right axis.

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

Four basic water quality parameters are routinely measured in stream and lake waters and have also been monitored over the course of the Middle Huron Stream Monitoring program: temperature, pH, conductivity and dissolved oxygen (DO). The results presented and discussed in this report are a compilation of all the data collected for each site over the past ten years. The goal in the presentation of these results is to examine the monitoring data comprehensively and gain an understanding of how each tributary is responding through the growing season in comparison to the other tributaries. In this way, we can also begin to look for trends in the data that will tell us about stream conditions and water quality, and also suggest a direction for future monitoring studies. Temperature data was recorded on each field day at every monitoring site, but the data is used for reference purposes only, and not further analyzed. Dissolved oxygen measurements were collected into 2010 until the DO sensor failed. It was not collected beyond 2010.

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 13). Several sites, including those that drain the most urbanized areas, have high conductivity ranges that exceed the recommended conductivity level. For several sites, even the first quartile (lowest 25%) value is above the recommended conductivity level of 800 µS. [6] 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.

[6] 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)

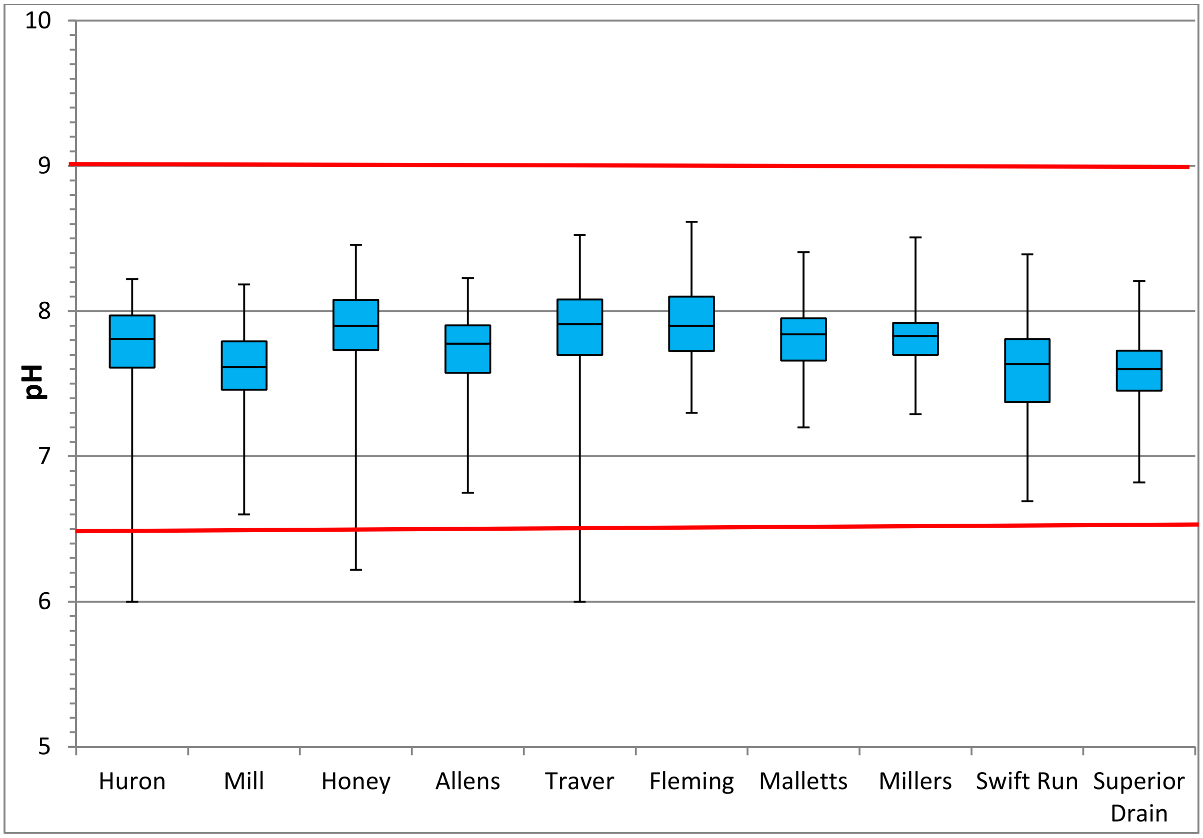


Figure 12. Box plot of the range of pH values for each site, with the box representing 25th to 75th percentiles, whiskers to the minimum and maximum, and centerline representing the median values. Red lines are the minimum and maximum of the water quality standard.

Figure 12 depicts pH values measured during the monitoring seasons from 2002 – 2013 for each of our 10 long-term sites. Median values for all sites ranged between 7.6 and 7.91, with little variability in individual samples. All but three results were within the acceptable range to meet state water quality standards, with the exceptions of one sample in Honey Creek at 6.2, Huron River at 6.0, and Traver Creek at 6.0. These were likely due to a short-lived cause of undetermined origin.

<u>Conductivity</u>

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.

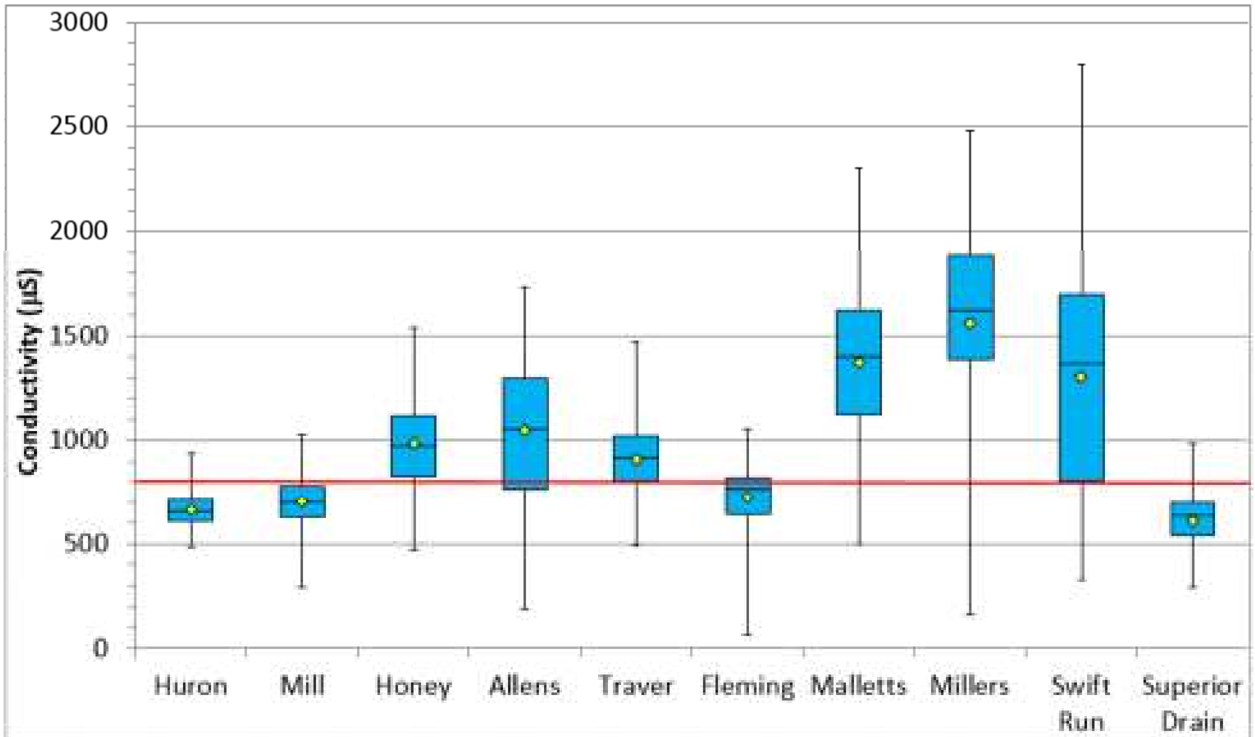


Figure 13. Box plot of the range of conductivity values for each site, with the box representing 25th to 75th percentiles, whiskers to the minimum and maximum, centerline representing the median values, and yellow points for the means. The red line indicates the upper limit of 800 µs for healthy, oligotrophic Michigan waters.

The conductivity results are presented for all sites over the 2002-2013 monitoring seasons in a similar fashion as was done for pH (see Figure 12). The median values for conductivity exceeded the upper limit for healthy waters (800 µS) for 6 of the 10 monitoring sites. In fact, only the Huron River and Superior Drain sites were consistently below that ecological impact value. The sites with the highest mean values are all in more urbanized environments. These sites also have the greatest range of conductivity measurements of all streams studied. It cannot be determined from these results which ions are driving the elevated conductivity values in these streams, so further investigation is warranted to determine the nature and potential sources of dissolved ions.

Dissolved Oxygen (DO)

Most aquatic plants and animals require a certain level of oxygen dissolved in the water for survival. Trout and stoneflies thrive in waters with high dissolved oxygen levels, whereas carp and bloodworms can out-compete other species in waters with low DO. DO levels drop to very low levels in warm, stagnant water, whereas fast-flowing, cooler water generally has high concentrations of DO. Some forms of pollution can also provide conditions that impact DO levels. For example, excess nutrients such as phosphorus and nitrogen can result in reductions in DO levels, which can be detrimental to certain species of aquatic insects.

The normal for DO values in Michigan waters ranges between 5 to 15 mg/L. The statewide minimum water quality standard is 5 mg/L. However, concentrations change throughout the day and night due to air and water temperature changes, photosynthesis, respiration and decomposition.

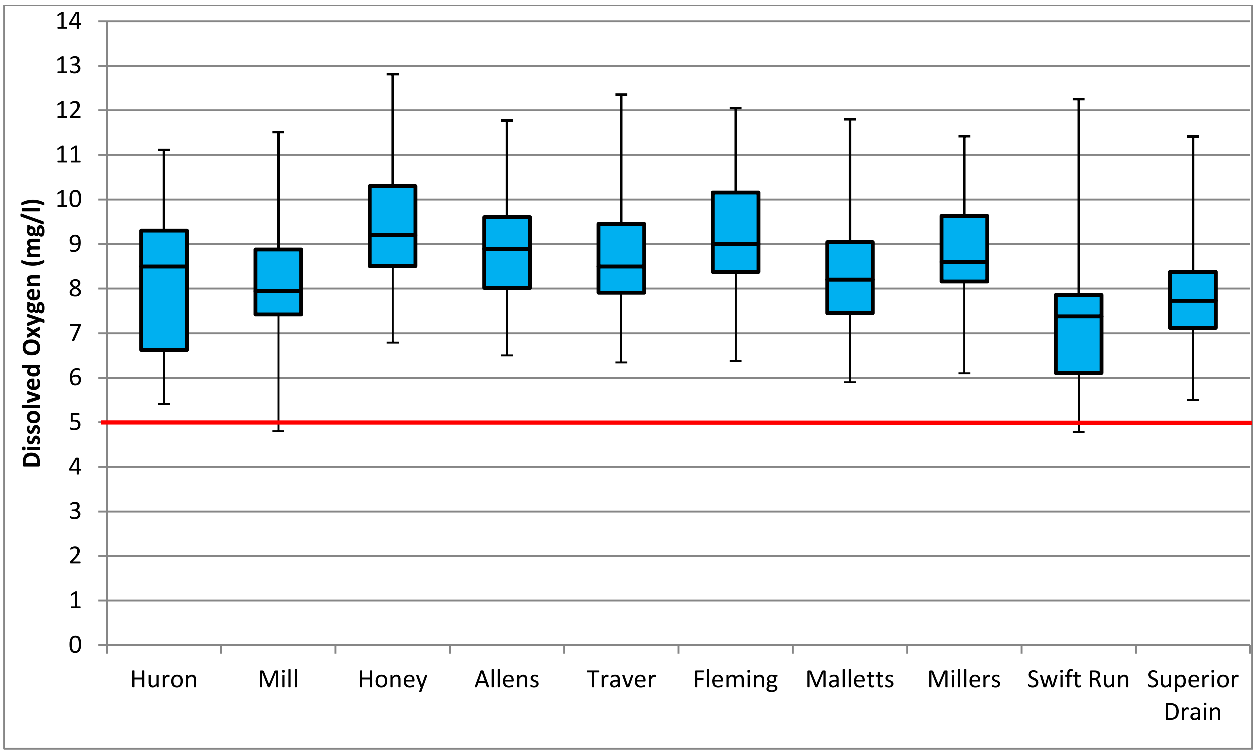


Figure 14. Box plot of the range of dissolved oxygen levels sampled 2002-10, for each site, with the box representing 25th to 75th percentiles, whiskers to the minimum and maximum, and centerline representing the median values. The red line indicates statewide minimum water quality standard of 5 mg/L.

Like conductivity and pH, the DO data was subjected to the same level of basic statistical analysis. As can be seen in Figure 6, over the period when the DO sensor was functional (2002-10), there were only 2 instances where DO levels were measured below the 5 mg/L bio-threshold: once each at Mill Creek and at Swift Run. No cause of those low DO levels was discovered. Median values for all sites ranged between 7.38 mg/L (for Swift Run) and 9.20 mg/L (Honey Creek).

Interestingly, Swift Run also had one of the highest DO measurements at 12.25 mg/L in May of 2006. DO measurements have typically been highest in May of each year, coinciding with the start of the growing season and the increased incidence of storm events and higher water velocities, which may serve to mix greater amounts of oxygen into the water.

Nitrogen

Measurements of Total Nitrogen (TN) yield information comparable to concentrations of Total Phosphorus. However, the laboratory used for the program does not measure TN, so nitrate and nitrite were measured in lieu of TN.

Nitrate

Nitrogen is an essential nutrient. Nitrate (NO_3) occurs naturally in both ground and surface waters, and is the most common form of dissolved nitrogen. Natural levels of nitrate in surface water can come from precipitation and runoff, and is not considered a problem at low levels. Streams and lakes in southeastern Michigan are typically limited by phosphorus levels rather than nitrogen, though the overall productivity of a waterbody (i.e. the amount of plant life at any given time) is controlled by the balance of these nutrients.

A typical value of nitrate for Michigan rivers is 0.5 mg/L, although lower nutrient water has nitrate concentrations ranging from 0.01 to 0.1 mg/L. At high concentrations (at or above 1-2 mg/L), nitrate can contribute to eutrophication that decreases dissolved oxygen levels and threatens aquatic plant and animal organisms. High levels of nitrate in surface waters often are related to human activities. Overfertilization of lawns and crops, failing septic and sewage systems, and animal waste inputs contribute to elevated levels of nitrate.

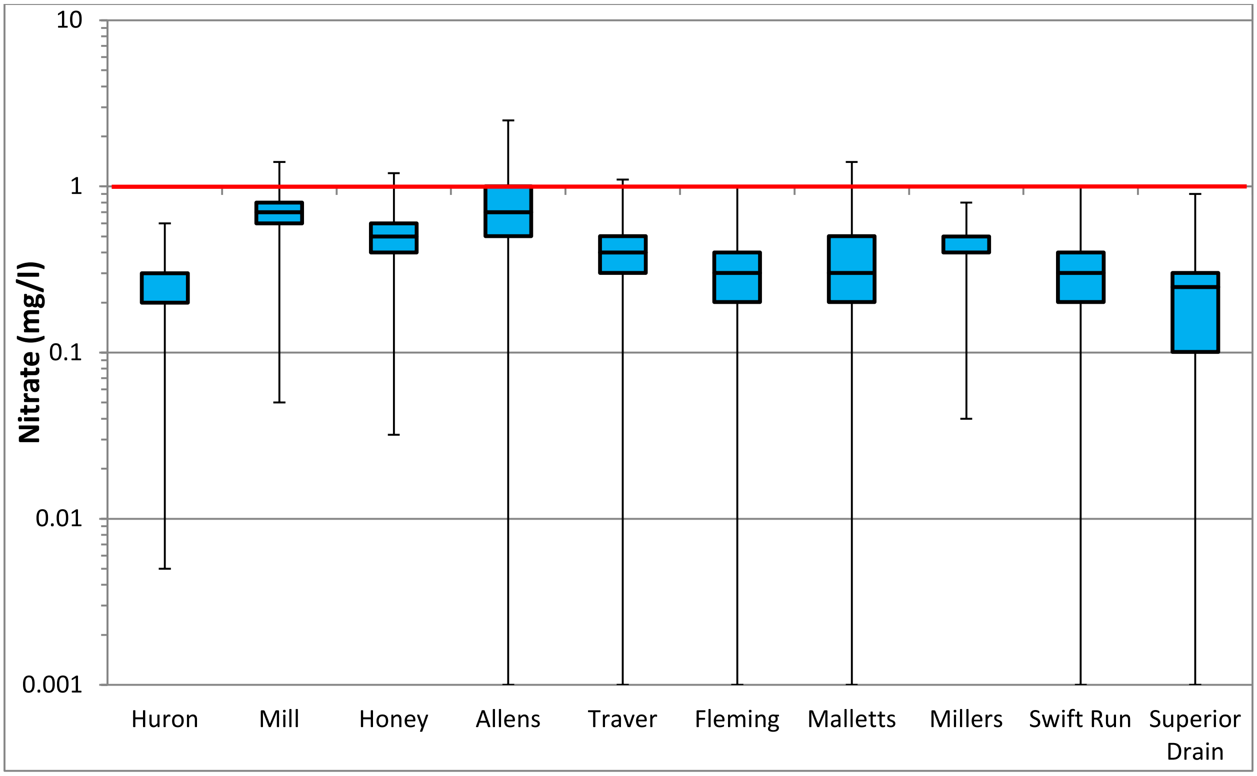


Figure 15. Box plot of the range of nitrate levels for each site, with the box representing 25th to 75th percentiles, whiskers to the minimum and maximum, and centerline representing the median values. Instances of nitrate levels above red line at 1 mg/L indicate high eutrophic concentrations that typically impair water bodies.

An examination of nitrate levels (see Figure 15) show that median concentrations for monitoring sites measured from 2003-2013 ranged from 0.20 mg/L at Huron River to 0.70 at Allens and Mill Creeks. Mean concentrations ranged from 0.26 mg/L at the Superior Drain site to 0.81 mg/L at Mill Creek. Most tributaries were well below 1 mg/L for all samples, and all sites except Allens and Mill Creeks averaged below 0.5 mg/L. Nitrate levels appear to have decreased over time at some sites, but increased at others, notably Fleming and Mill Creeks, and Swift Run. The cause for the trends is uncertain, and may simply be natural variation.

Nitrite

Nitrite (NO_2) is the form of nitrogen that sometimes occurs as a transition compound in the conversion of ammonia (NH_4) to nitrate. Unlike nitrate (NO_3), nitrites are short lived in aqueous systems, so they are often found at very low levels, if at all. However, prolonged exposure to high levels of nitrite can produce a serious condition in fish called “brown blood disease”, as it blocks the blood’s ability to carry oxygen resulting in fish kills.

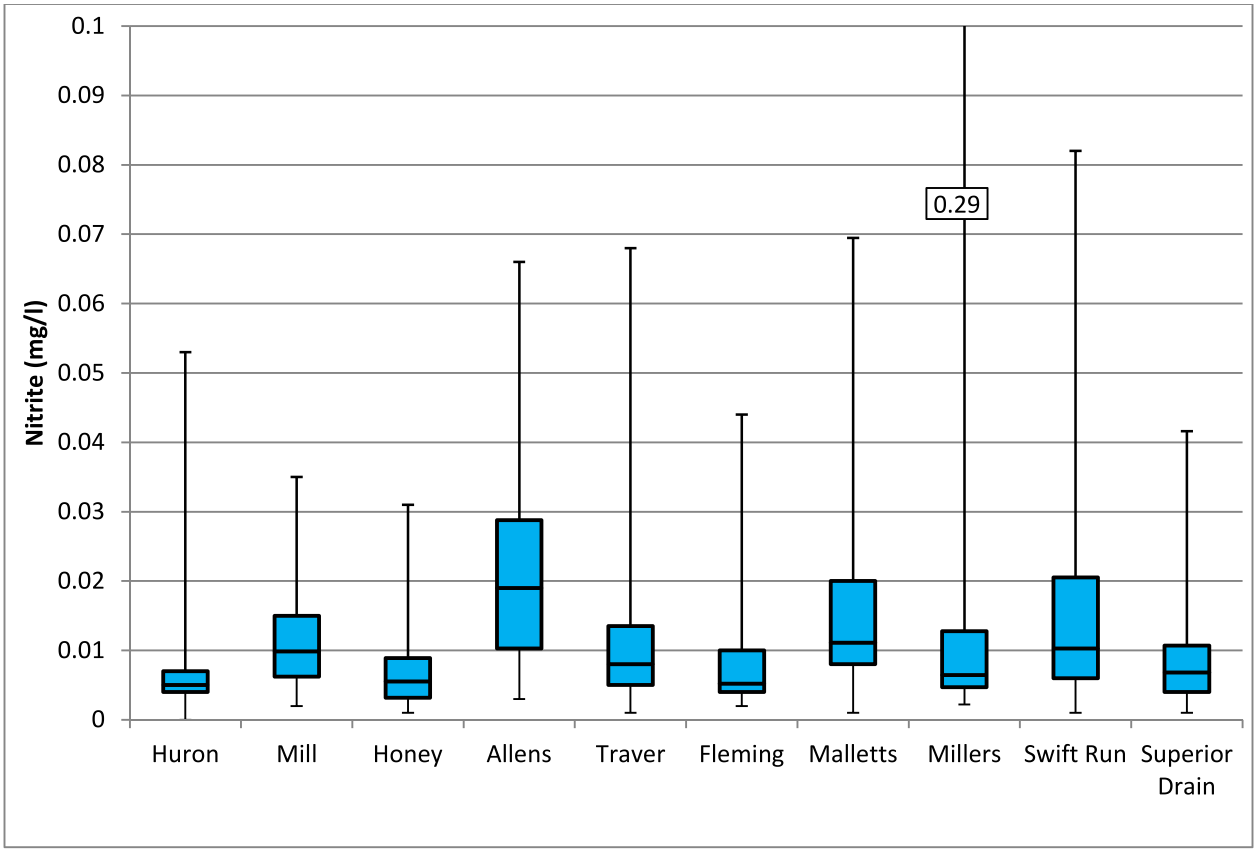


Figure 16. Box plot of the range of nitrite levels for each site, with the box representing 25th to 75th percentiles, whiskers to the minimum and maximum, and centerline representing the median values.

Levels of nitrite that are below laboratory detection are considered low. Normal levels of nitrite concentration range from 0.01 to 0.03 mg/L, while levels higher than 0.03 mg/L should be fairly uncommon since this level is at the threshold for chemical transition from ammonia to nitrate. All monitoring sites in the Middle Huron averaged in this range for nitrite (see Figure 16), however, Allens Creek data ranges close to 0.03 mg/L. While each site has recorded occasional values above 0.03 mg/L, half of the sites had these high levels in 2013 (Allens, Malletts, Millers and Traver Creeks, and Swift Run). There is no discernable trend in nitrite values at any of the monitoring sites.

4. SUMMARY AND CONCLUSIONS

The following general conclusions can be drawn from the analysis of the data collected under the Middle Huron Water Quality Monitoring Program from 2002 through 2013:

Measured values for **Total Phosphorus concentration** varied widely from site to site and from month to month. While concentrations trended down through 2009, that trend has reversed in 2010-13. Flow-weighted average concentrations at most sites project the same trend, as concentrations in 2013 increased above the record average. Still, concentrations overall have decreased in urban tributaries. Ultimately, TP concentrations can vary widely due to many environmental variables.

Total Phosphorus loading also is variable, dropping in some tributaries and rising in others. Some sites, show a tight relationship with stream discharge, such that, large flow events result in a predictably higher load. Other sites, such as Fleming Creek, are much less predictable. Load duration analysis provides evidence that phosphorus loading is more excessive during run-off events.

The data collected on ***E. coli*** thus far indicate that all but the Huron River site regularly exceed state standards. Some sites exceed this standard regularly and greatly. Bacteria levels continue to be an issue of concern in the watershed.

As with the TP results, mean concentrations of **Total Suspended Solids** from the monitoring sites are variable year to year. Some sites show a high correlation between TSS and TP, suggesting that the phosphorus is bound to soil or due to erosive processes. Other sites do not show a strong correlation.

All 10 sites had measured **pH values** that are within the expected range for Michigan surface waters, excepting Honey Creek in September 2005, Traver Creek in September 2012, and Huron River in April 2013 when values were less than 6.5.

Six of the ten sites had average **conductivity** values that exceed the accepted limits. Most of these were the urban sites. This needs investigation to determine the element driving high conductivity levels.

All 10 sites had average values for **Dissolved Oxygen** that are within the normal range for Michigan surface waters. Only two measures at separate sites were below this standard.

Most tributaries were well below 1 mg/L for levels of **Nitrate**. Concentrations of Nitrite were within the normal levels of Michigan surface waters for all sites, on average.

Huron River Watershed Council

Stream Nutrient Monitoring Program

FIELD DATA SHEET: Washtenaw County

Investigators: ____

Stream Name ____________________

SITE #: ____________________

STAFF GAUGE: ____________ (in decimals)

TOTAL PHOSPHORUS, TOTAL SUSPENDED SOLIDS and NITRATE-NITRITE

Collection		Lab Submission	
Date:	Time:	Date:	Time:

QUESTIONS:

What TYPE of GRAB sample measurement was used? Circle one: INSTREAM / BUCKET

Was the bottle rinsed with stream water 3x, and water tossed downstream? Y / N

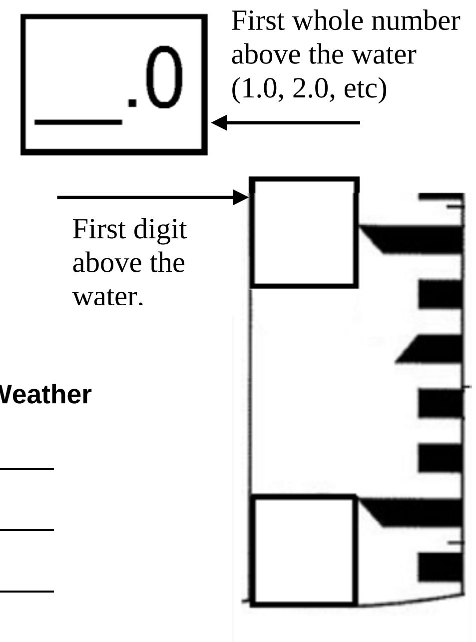
What is the DESCRIPTION for this sample? Circle one: INVESTIGATIVE / BASELINE

Were the TP samples refrigerated overnight? Y / N

If so, location? ____

{ STAFF GAUGE READING }

In boxes and picture below, write numbers and draw water level you see on the staff gauge.



SITE PARAMETERS **(Horiba measurements)**

Water temperature (°C)	
Conductivity (mS)	
pH	
Dissolved oxygen	

Weather - past 24 hours		Current Weather
_____	Storm (heavy rain)	_____
_____	Rain (steady rain)	_____
_____	Showers (intermittent rain)	_____
_____	Overcast	_____
_____	Clear/Sunny	_____

Comments:

For Office Use only

db Visit ID ____________

Initials ____________

Huron River Watershed Council

Stream Nutrient Monitoring Program

For Office Use only
Db Visit ID ________
____
Initials ________

STORM SAMPLE DATA SHEET

Stream name/Site #: ______________________________

Investigators: ______________________________

Comments:

Auto-sampler Deployment		Auto-sampler Retrieval	
Date		**Date**	
Start Time		**Time auto-sampler halted**	
Water Level @ Start (ft)		**Water Level @ Start (ft)**	
Grab Samples Collected (#)		**Grab Samples Collected (#)**	
End Water Level		**End Water Level**	
End Time		**End Time**	

Was a "forced" sample collected @ autosampler? **Y / N** **Time:** __________

Was a forced sample collected @ after halt? **Y / N** **Time:** __________

Was a data logger downloaded and redeployed? **Y / N**

Final sample number ____________________

To be completed @ office:

Number of incomplete samples ____________________

SAMPLES DELIVERED TO LAB:

Bottle #	Date/Time Collected	Sample Label	Parameter(s)

Time samples delivered to lab: ______________________________

Waterproof paper – if this sheet is white.

Flow Datasheet

Site Name: _________________ **on Creek:** _______________ **Team Members:** ____

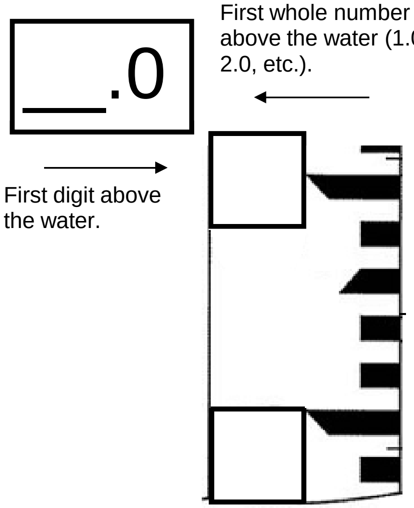
Date: ________________ **Recorder's Name:**____________________________

Distance on tape measure (feet & tenths)	Water's **Depth**	**Velocity** (ft/sec) *(negative is ok)*
Edge of Water:	**0**	**0**
Edge of Water:	**0**	**0**

***Gauge Reading at Start:**

Time:_______ Height:_______

In boxes and picture below, write numbers and draw water level you see on the staff gauge. Draw two lines if gauge changed while you were measuring flow, indicating start and finish levels:



***Gauge Reading at Finish:**

CIRCLE: *same* or *higher* or *lower*

Time:________ Height:_________

REMINDERS

1. Start each flow reading by pressing the ON key.
2. Shorten the distance between readings when the depth changes!
3. Please read the tape from low numbers to high numbers.
4. Don't forget to record edge of water at both sides.

QUESTIONS (circle your answer):

1. Bank at which you began measurements, looking DOWNSTREAM: **Left** **Right**

2. Has it rained in the past 3 days? **Yes** **No**

3. Over how many seconds is the meter averaging readings? **10** **15** (Use 10 ONLY during rapid level change; press arrow keys to change).

4. What watch was used to tell the time? __________

5. Are the readings in ft/sec? **Yes** **No** (if no, press On&Off keys simultaneously to change)

6. Is the meter set on FPA? **Yes** **No** (If no, press both ARROW keys simultaneously to change)

7. Was the rod set for each depth? **Yes** **No**

8. How close was the rod from the person in the stream?________

9. Was the rod vertical, with the sensor pointing into the flow? **Yes** **No**

Waterproof Paper - If this sheet is white!

Phone number: HRWC (734) 769-5123, ext.13

Huron River Watershed Council

Protecting the river since 1965

1100 N. Main Street Suite 210
Ann Arbor, MI 48104
(734) 769-5123
www.hrwc.org

CHAIN OF CUSTODY DOCUMENT

Please send results to:	HRWC 1100 N Main Street Suite 210 Ann Arbor, MI 48104 Attn: Ric Lawson; rlawson@hrwc.org, 734-769-5123 x609
Purchase Order # LABORATORY IN CHARGE OF ANALYSIS: AAWTP TEL: 734.794.6426 CONTACT: Wendy Schultz	Notes: SOURCE OF SAMPLE

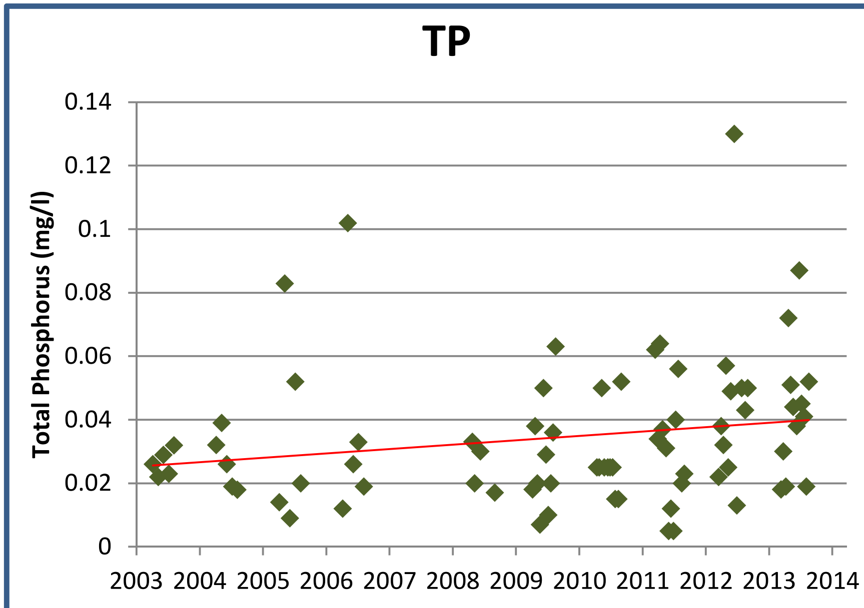
Sample Designation	Collection		Type		Description	No. of containers	PARAMETERS				
	Date	Time	Comp	Grab			Nitrate+Nitrite	TSS	Total Phosphorus	Preservative?	E.coli

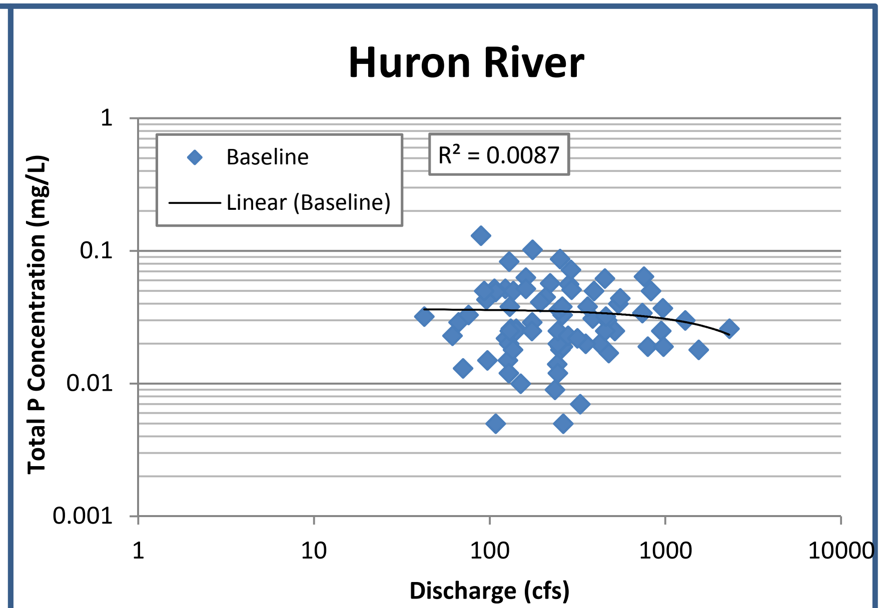
Relinquished by:	Date/Time:	Received by:
Relinquished by:	Date/Time:	Received by:
Relinquished by:	Date/Time:	Received by:
Relinquished by:	Date/Time:	Received by:

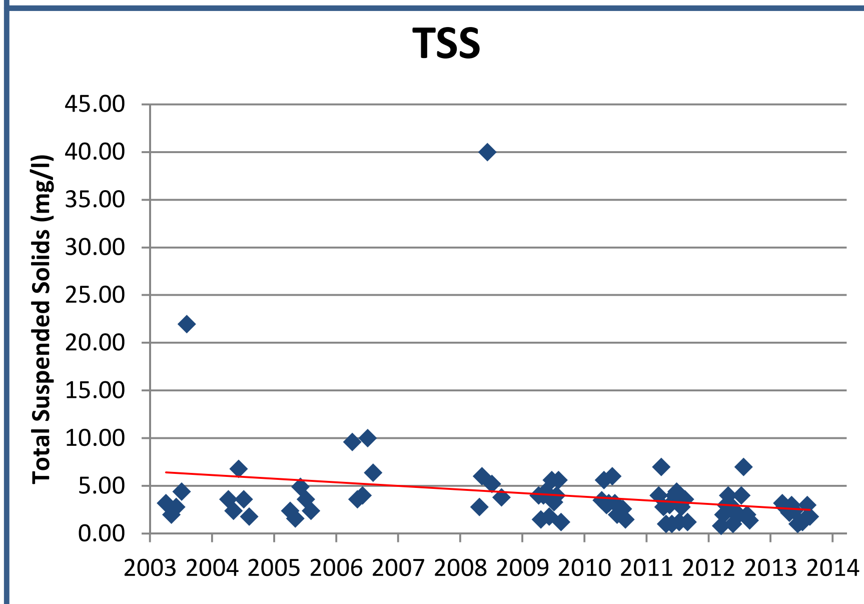
Appendix B.

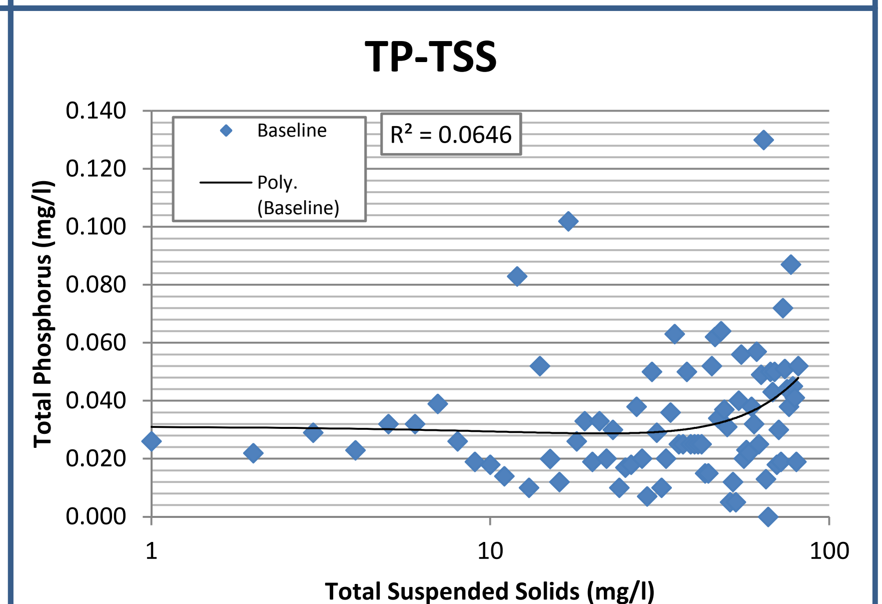
Middle Huron River Watershed Monitoring Results by Site

Huron River – MH01

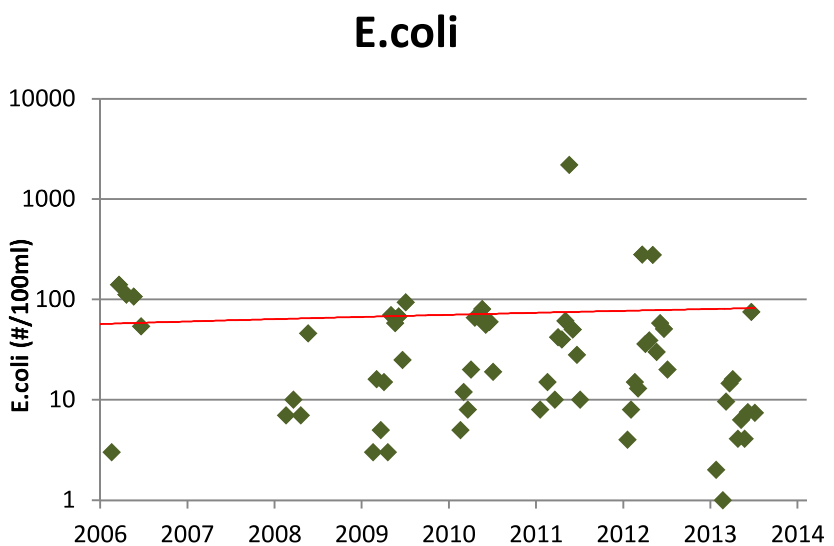


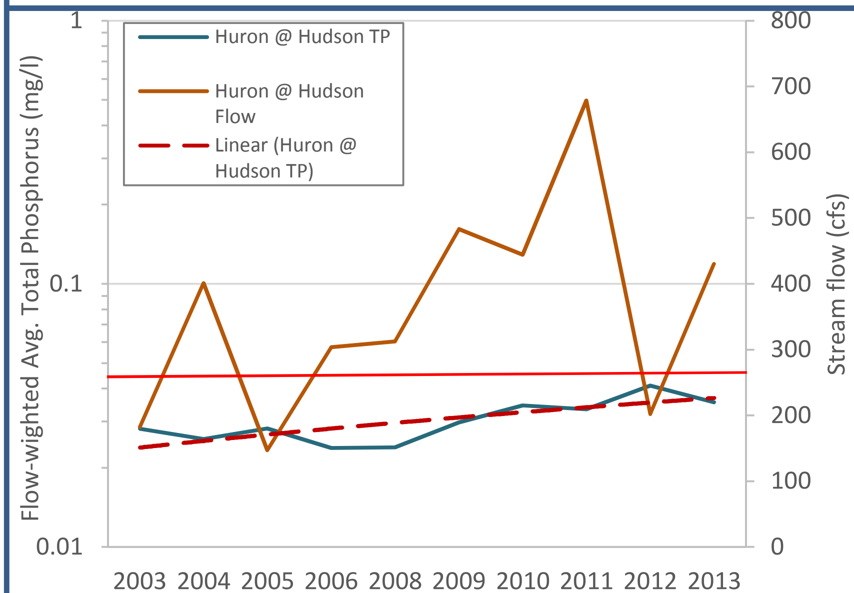




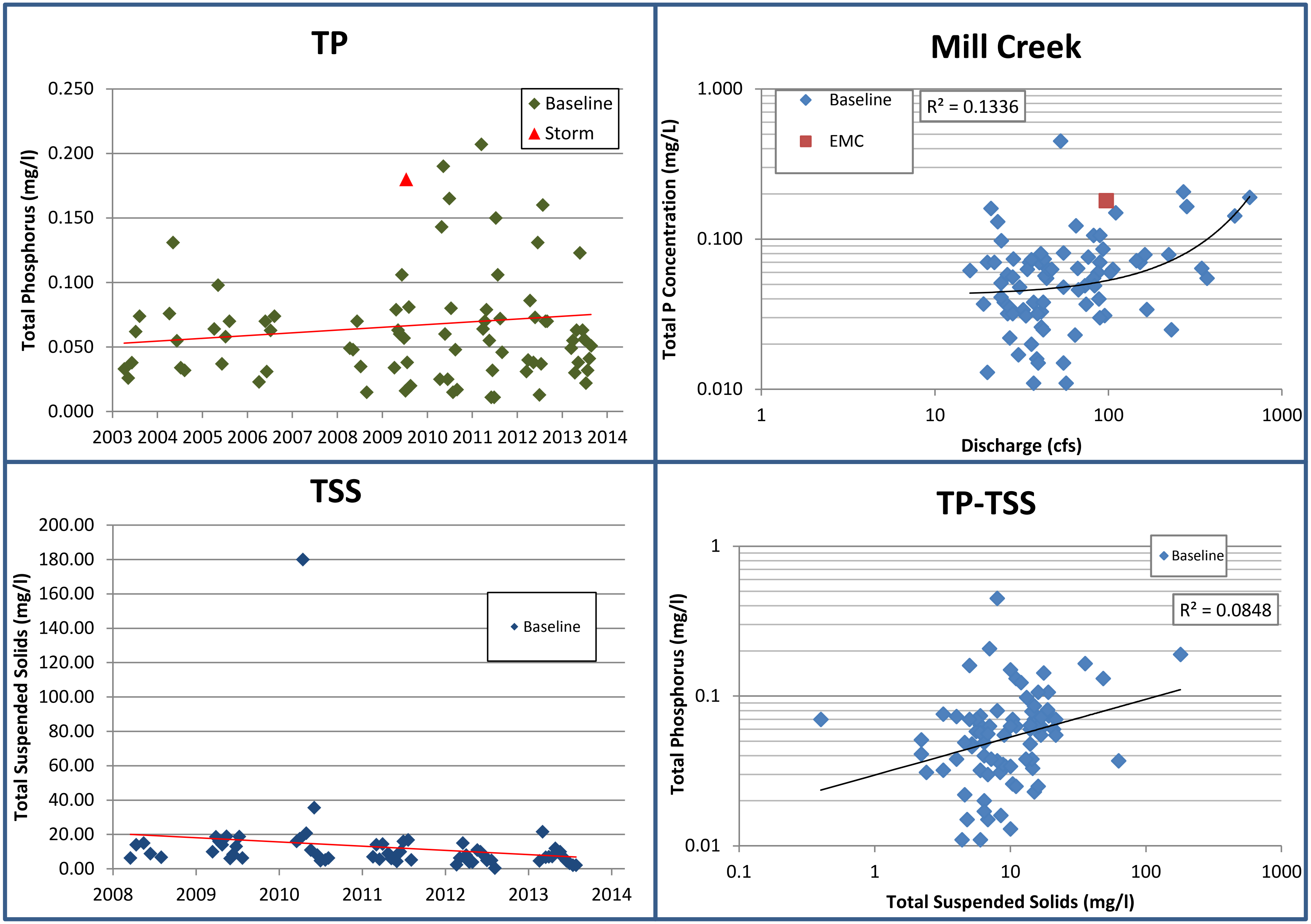


Huron River – MH01

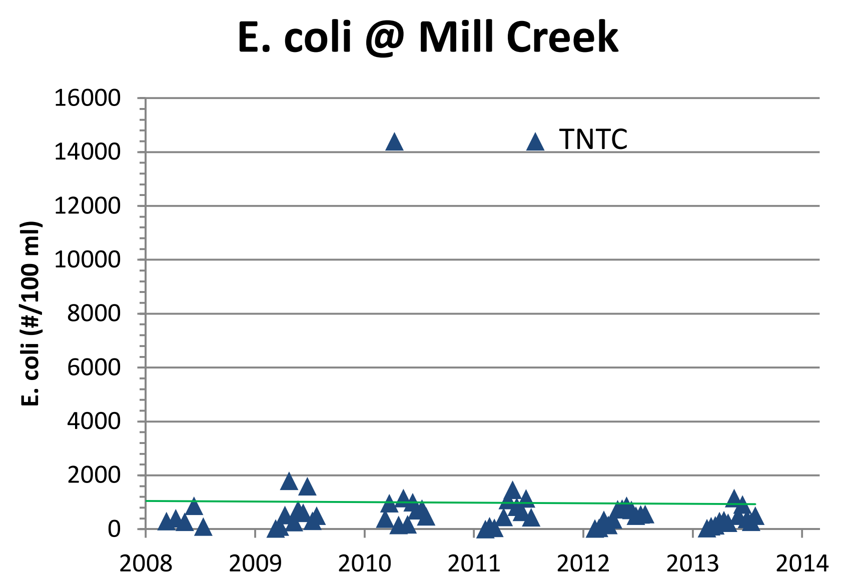


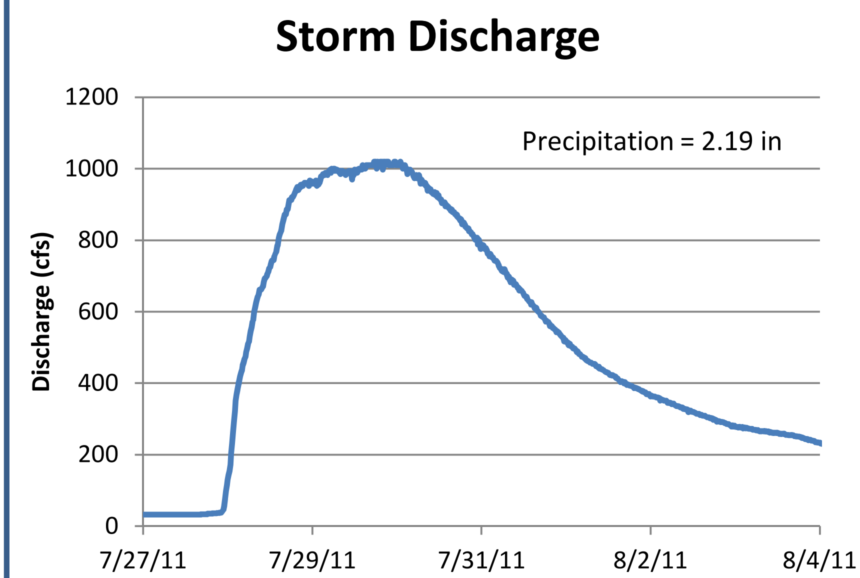


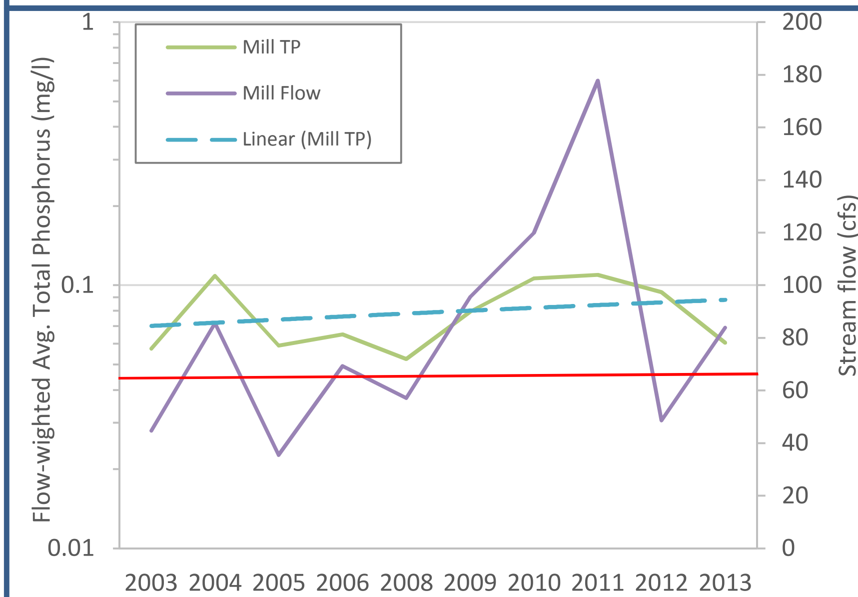
Mill Creek – MH02



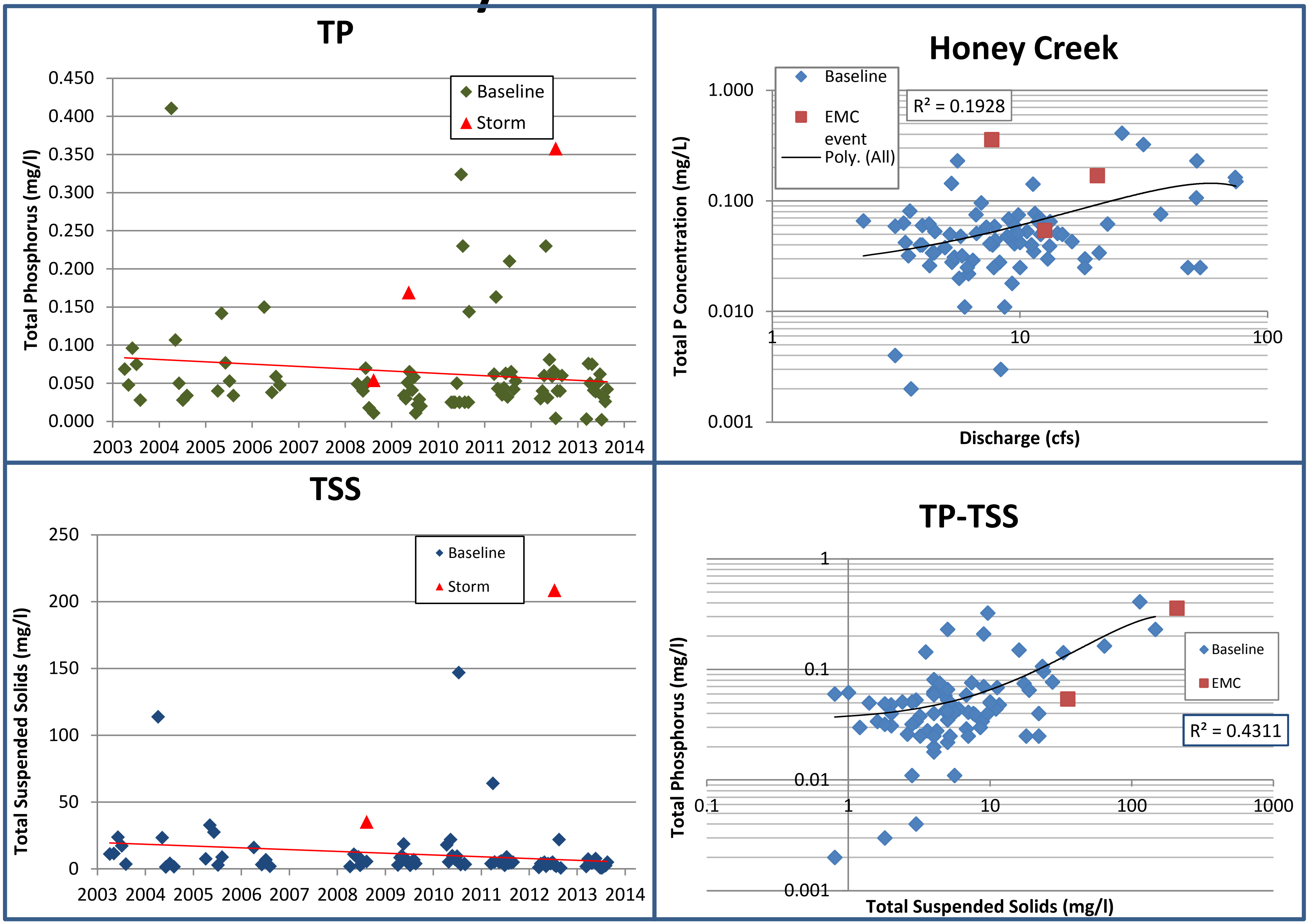
Mill Creek – MH02



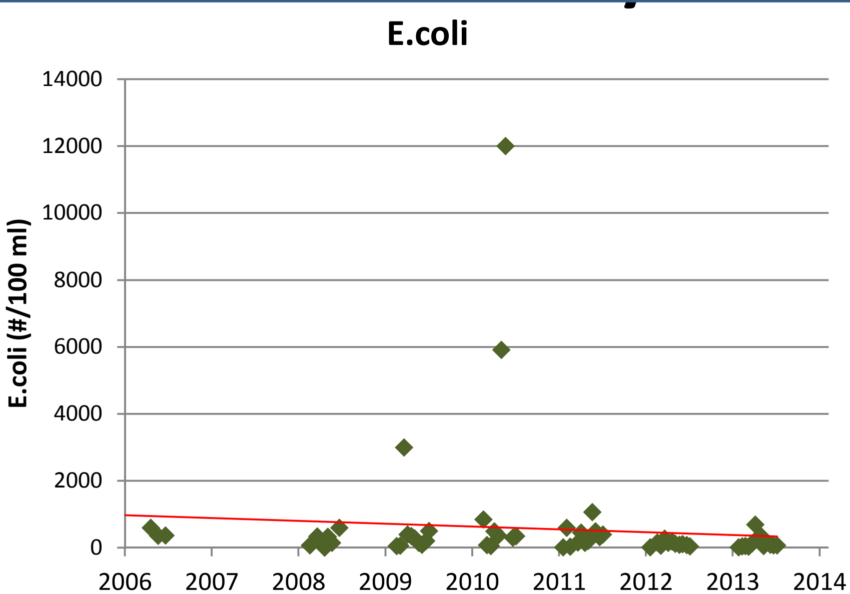


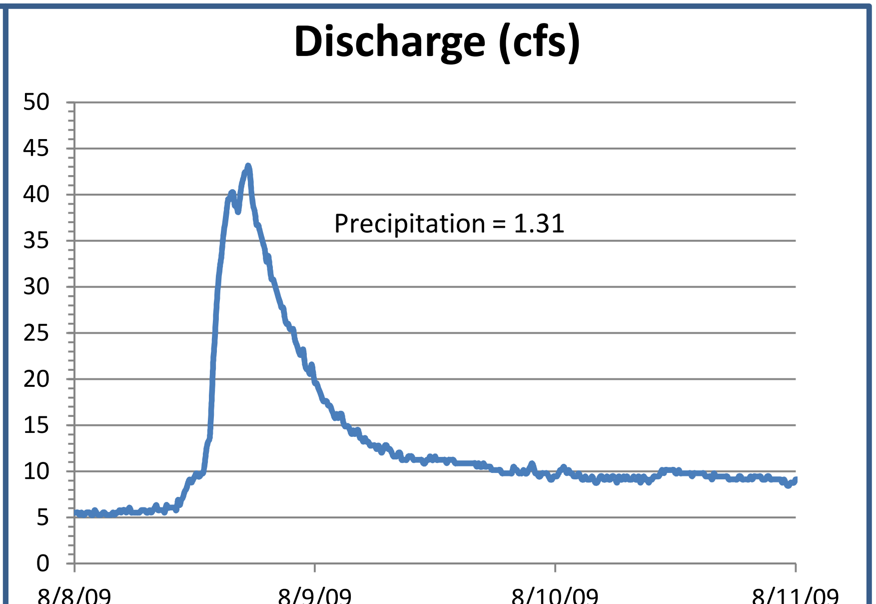


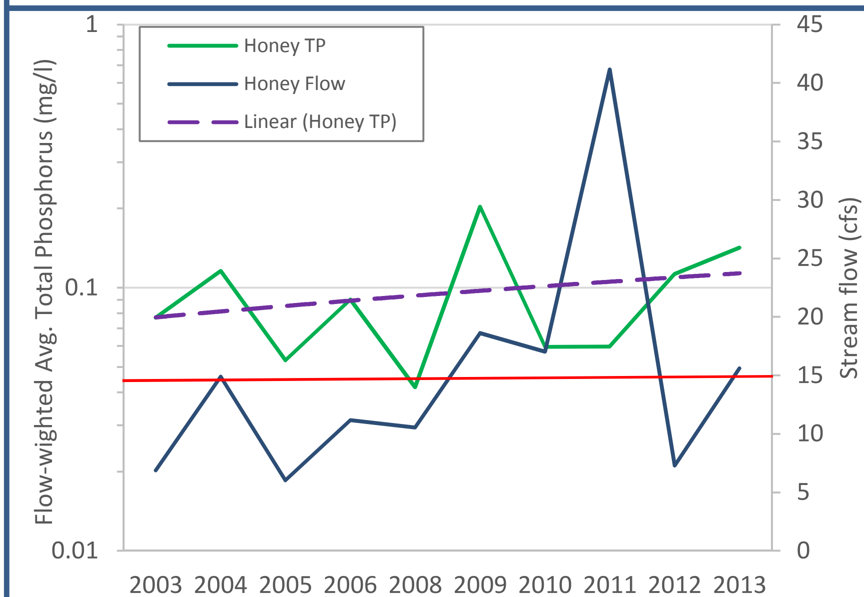
Honey Creek – MH03



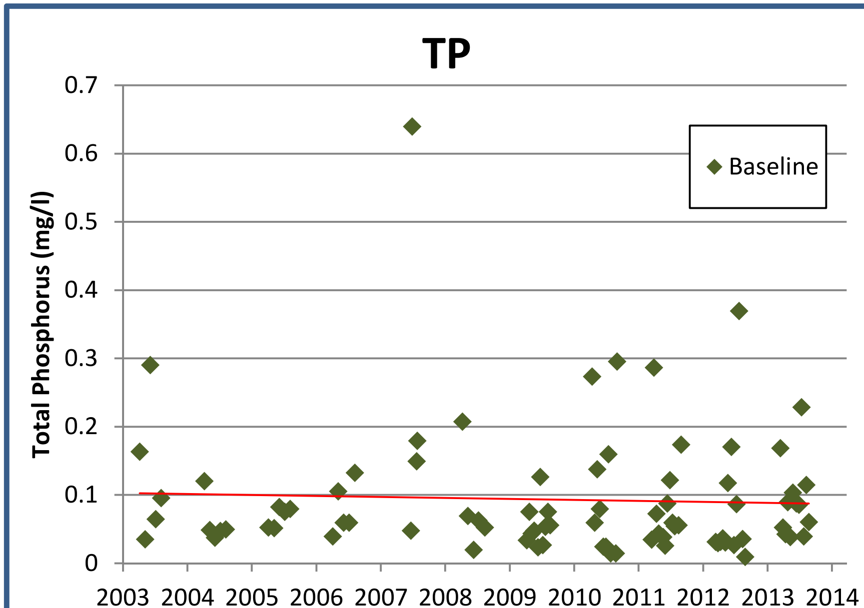
Honey Creek – MH03

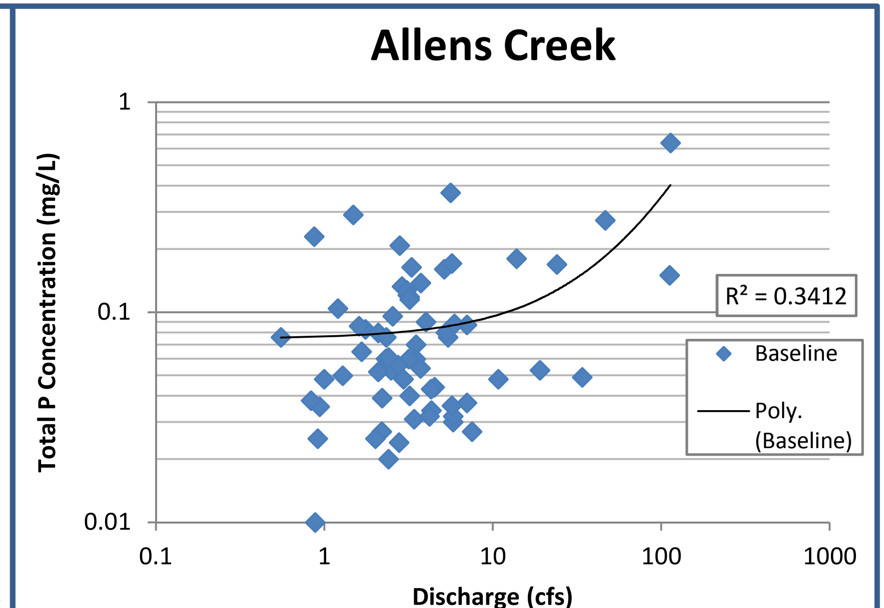


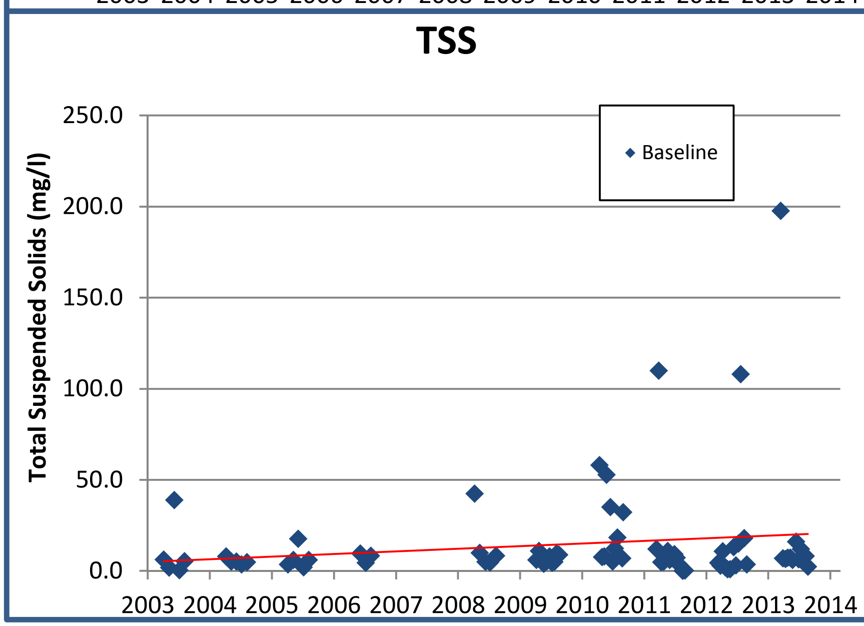


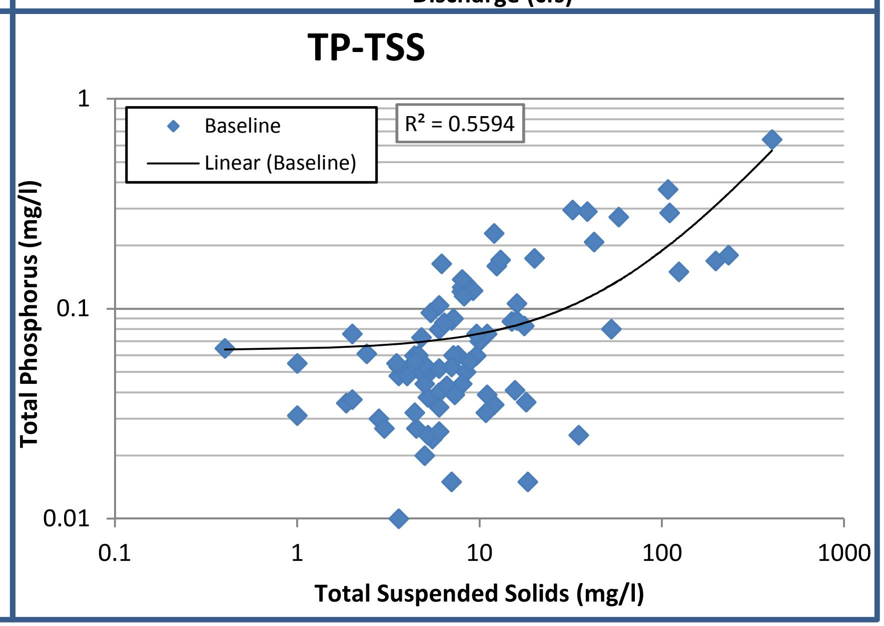


Allens Creek – MH04

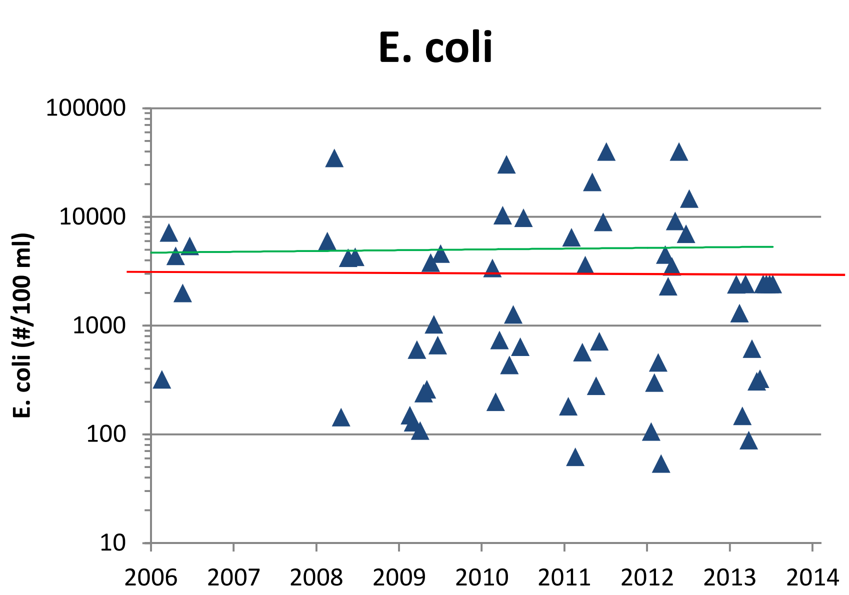


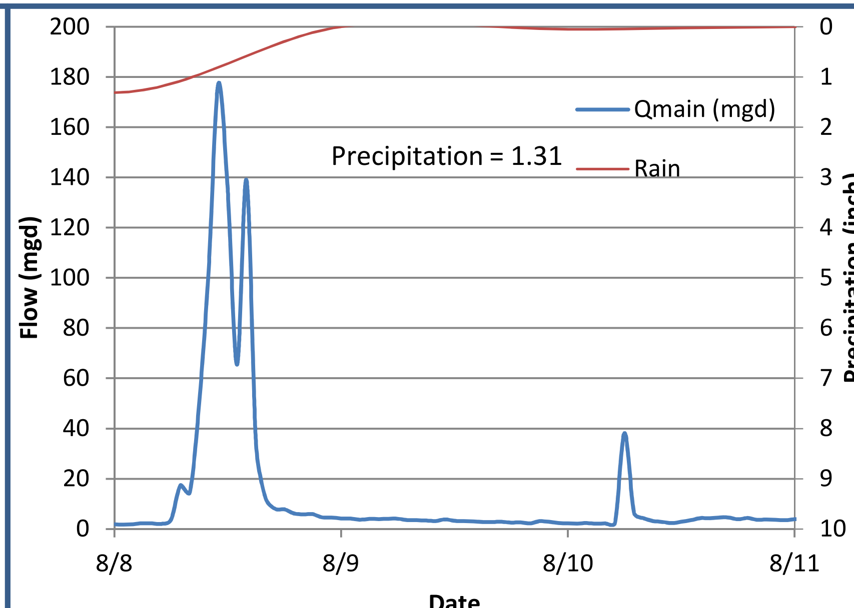


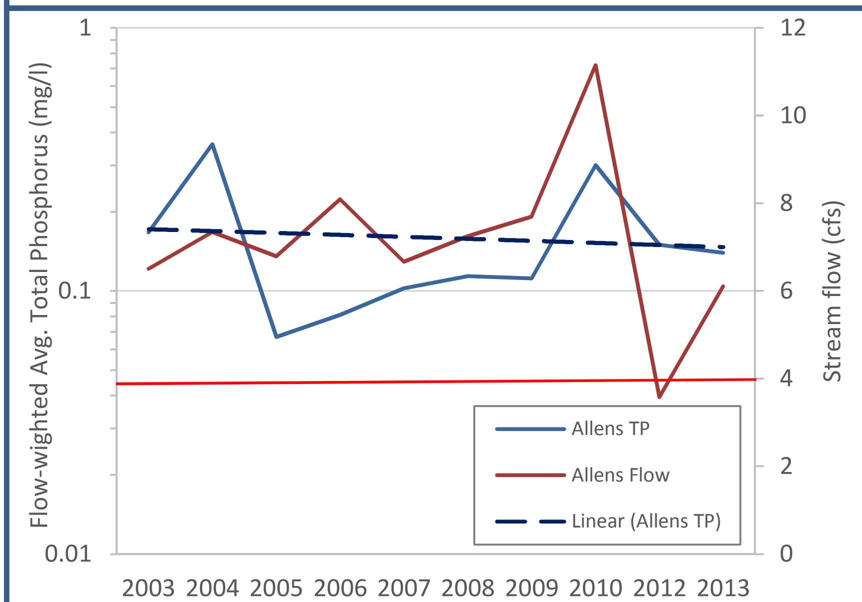




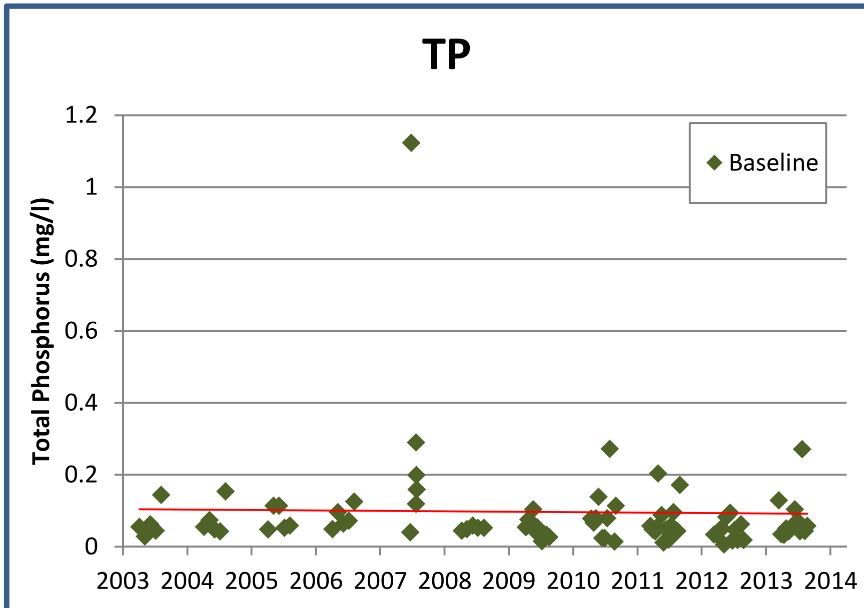
Allens Creek – MH04

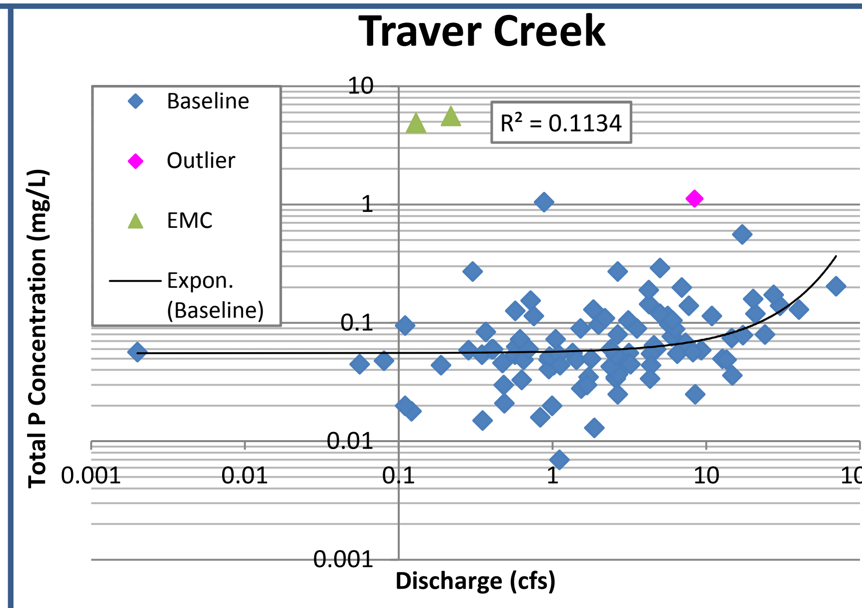


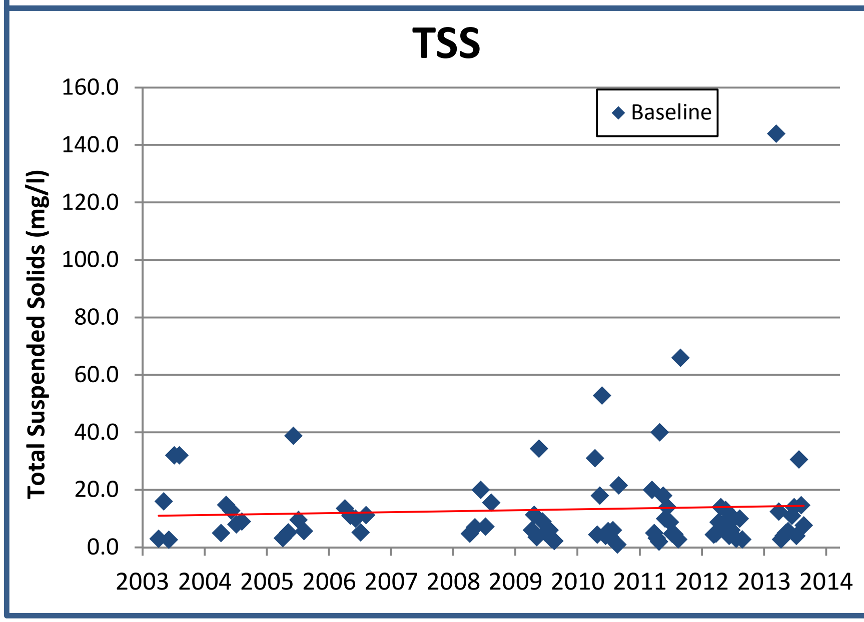


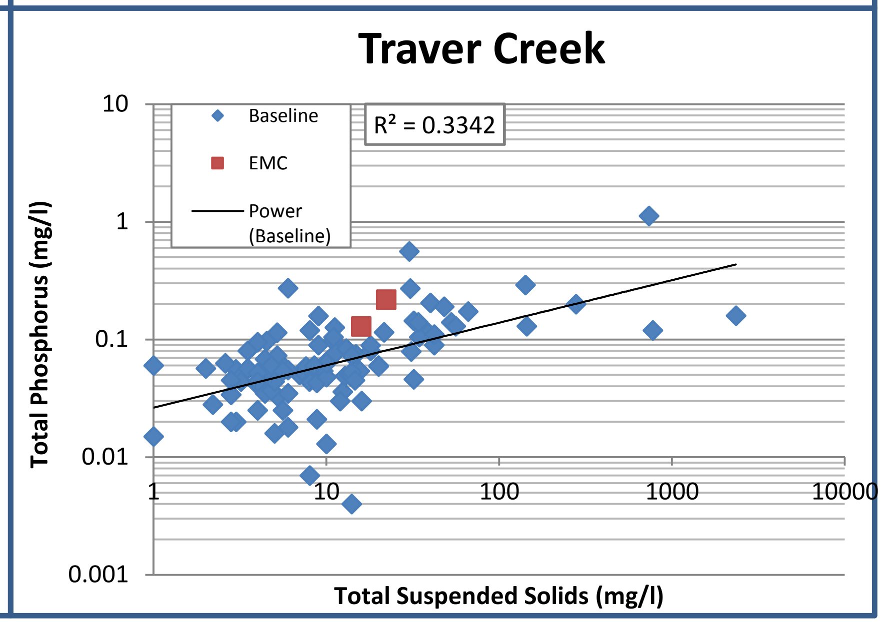


Traver Creek – MH05

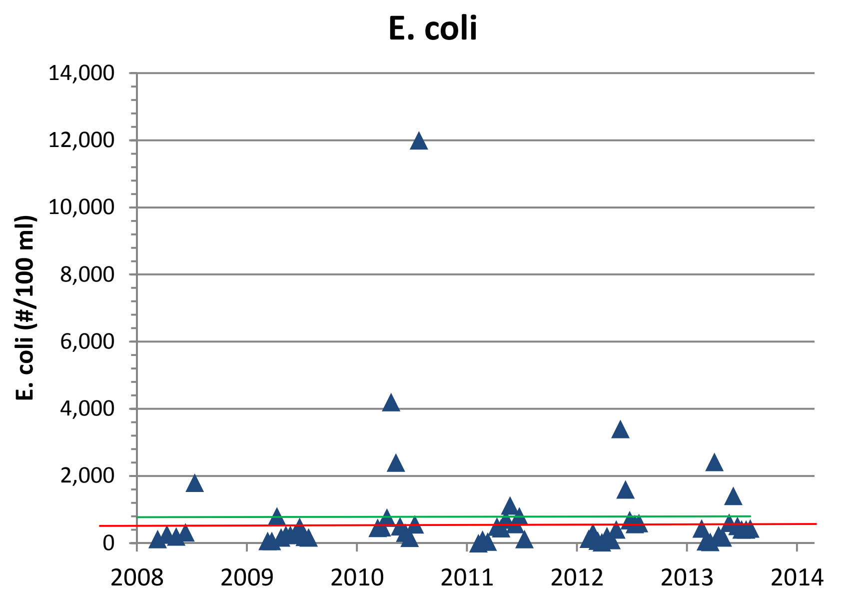


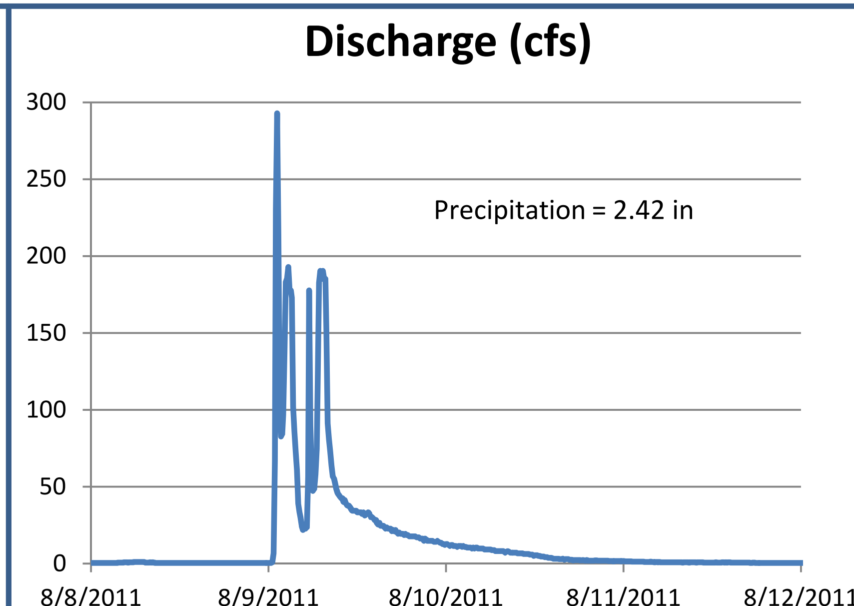


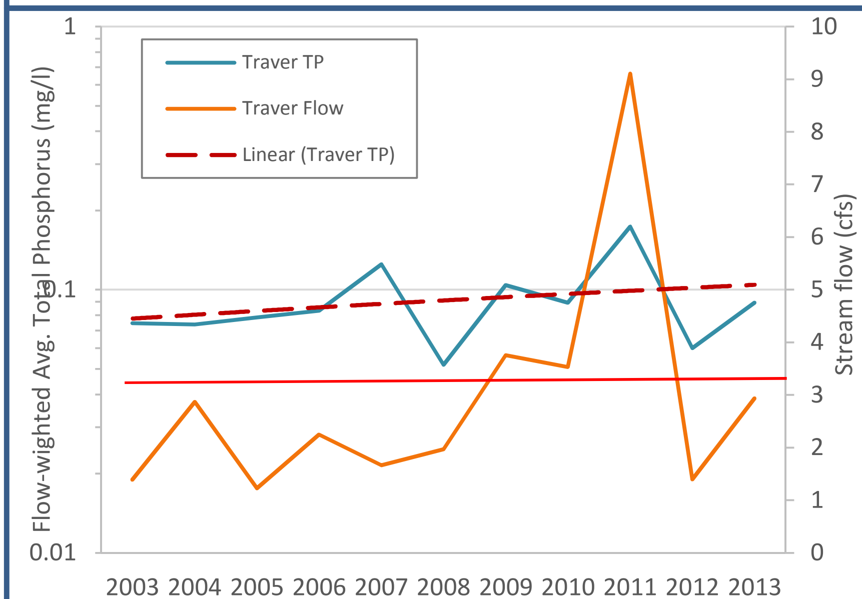




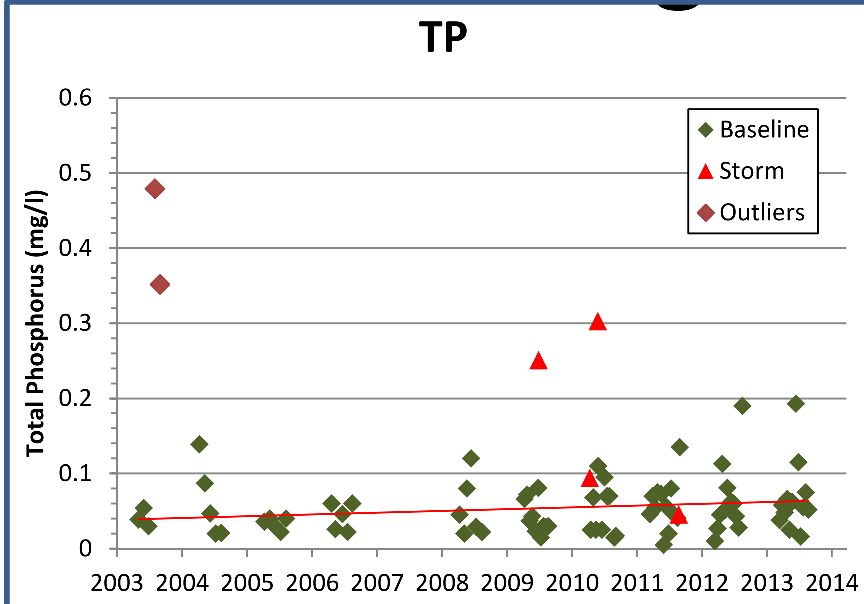
Traver Creek – MH05

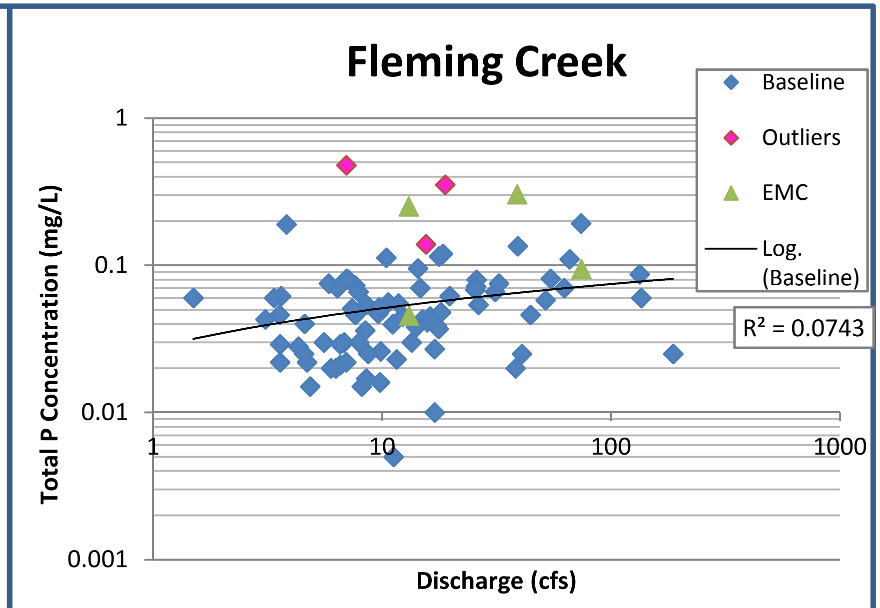


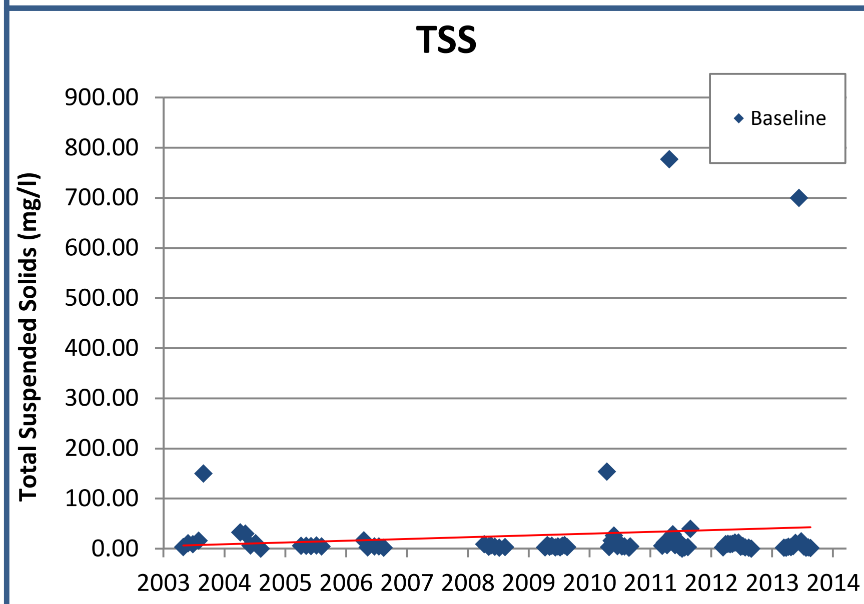


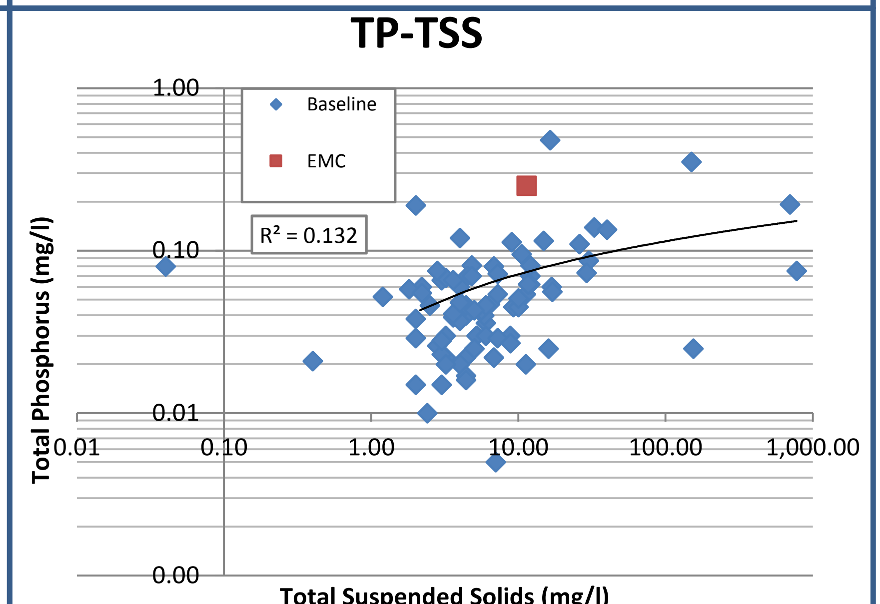


Fleming Creek – MH06

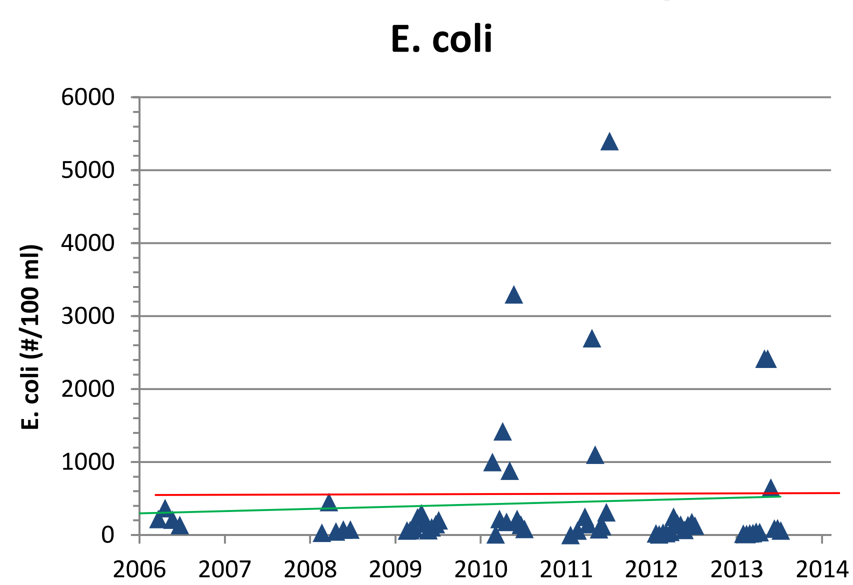


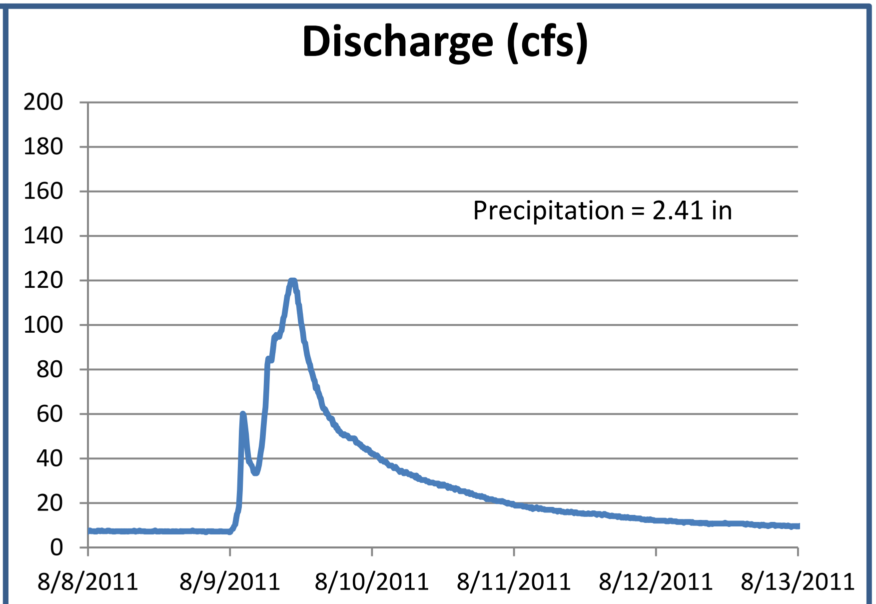


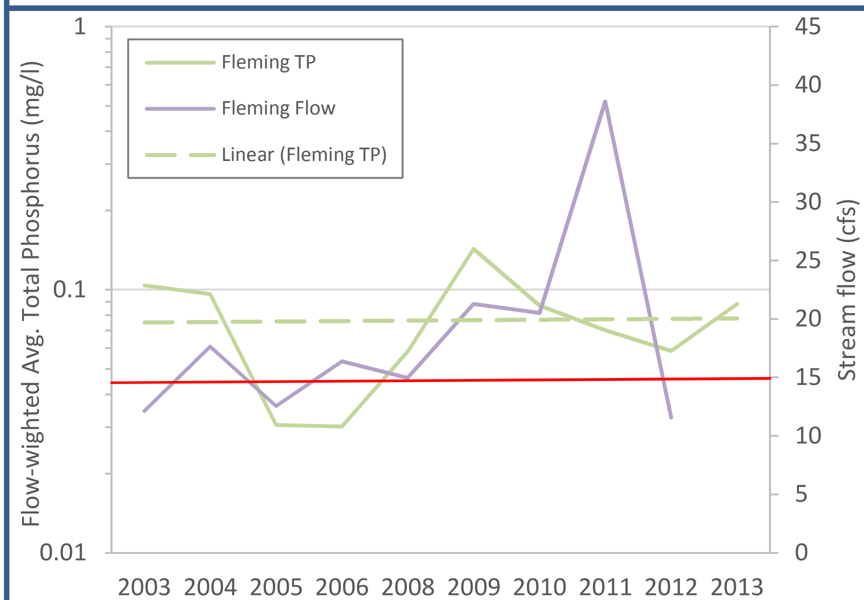




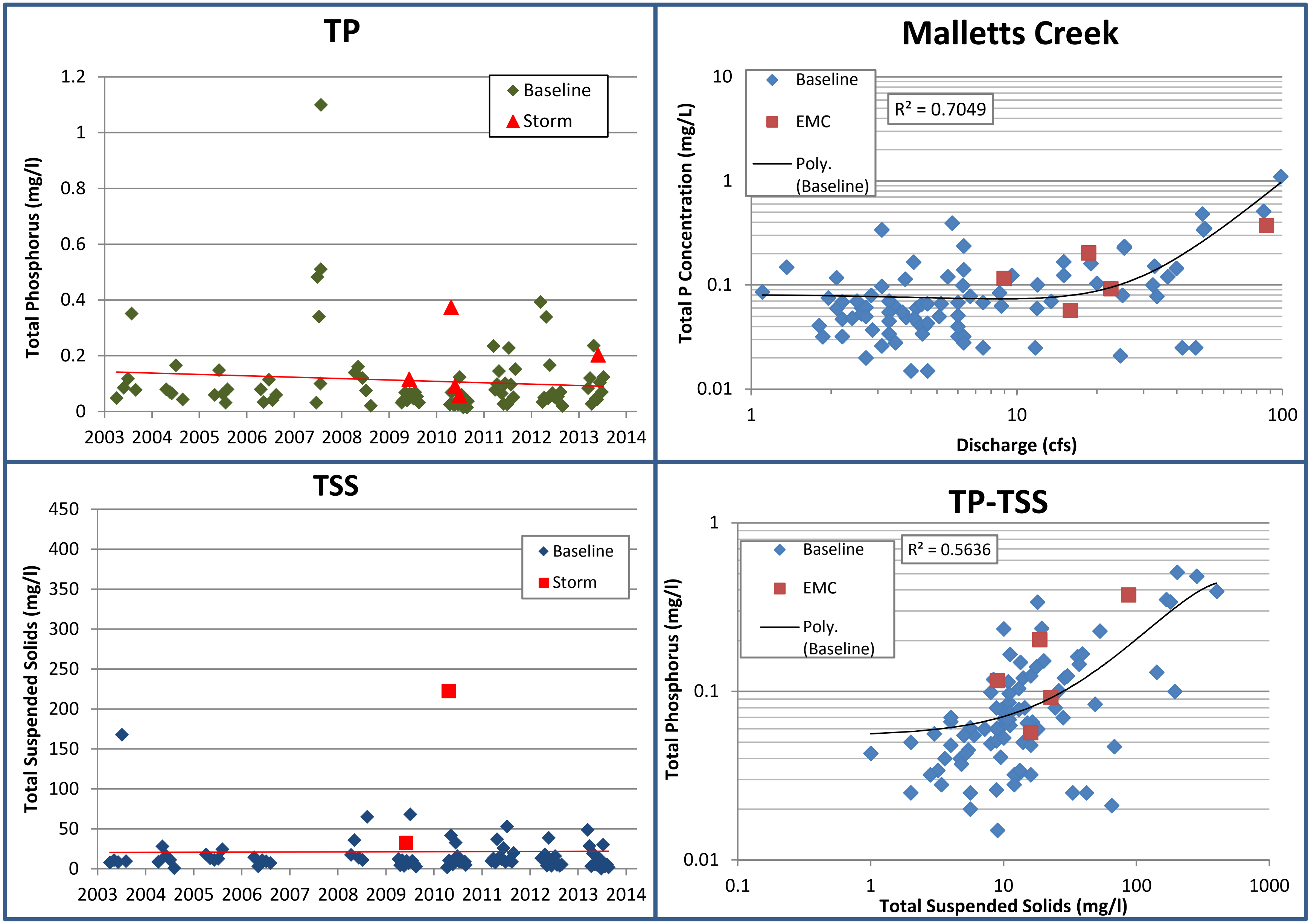
Fleming Creek – MH06



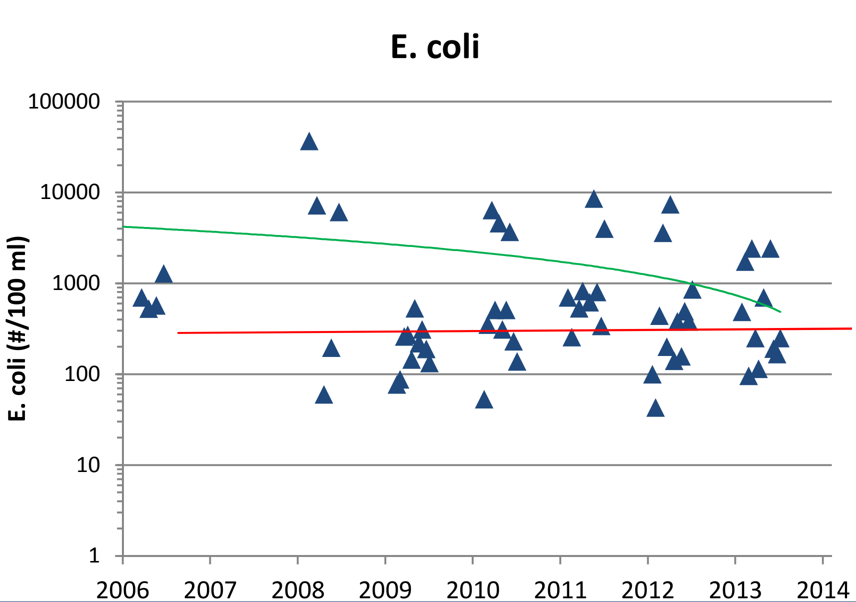


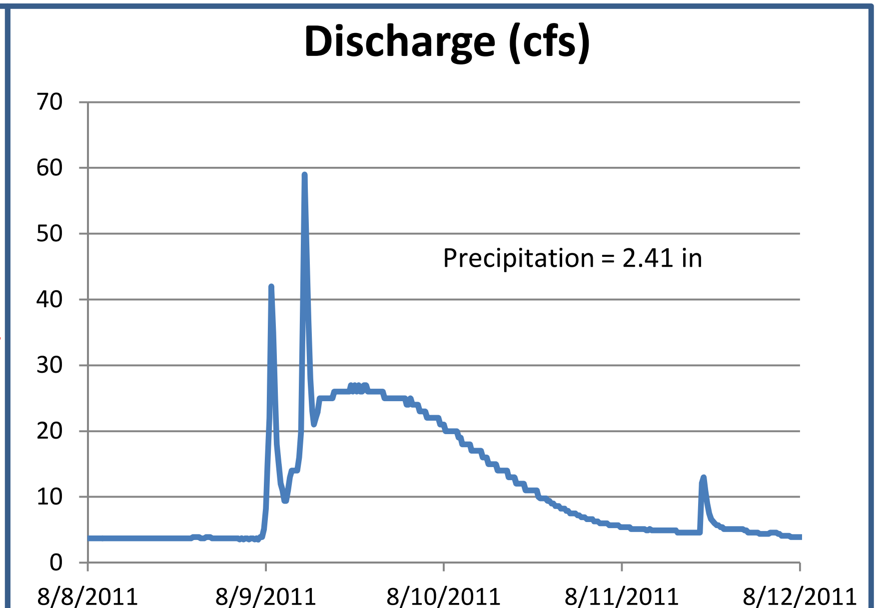


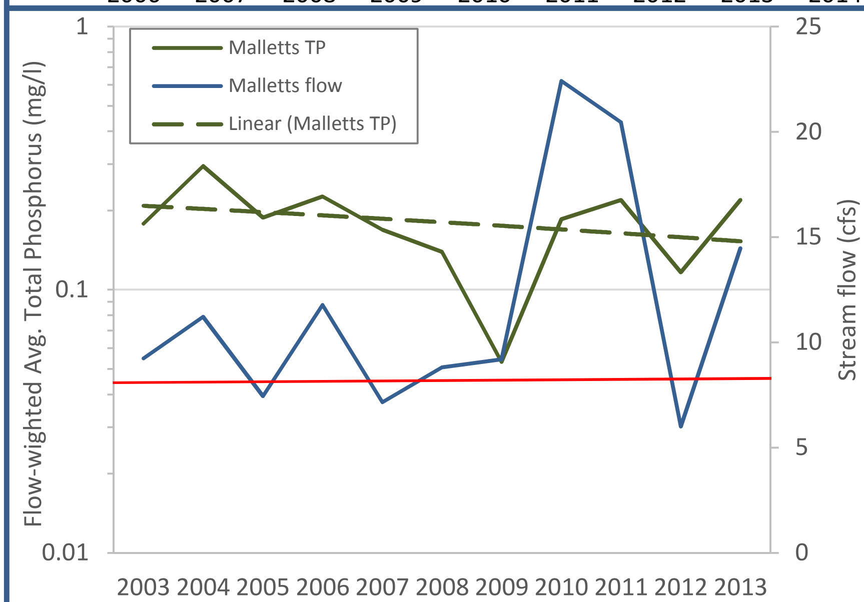
Malletts Creek – MH07



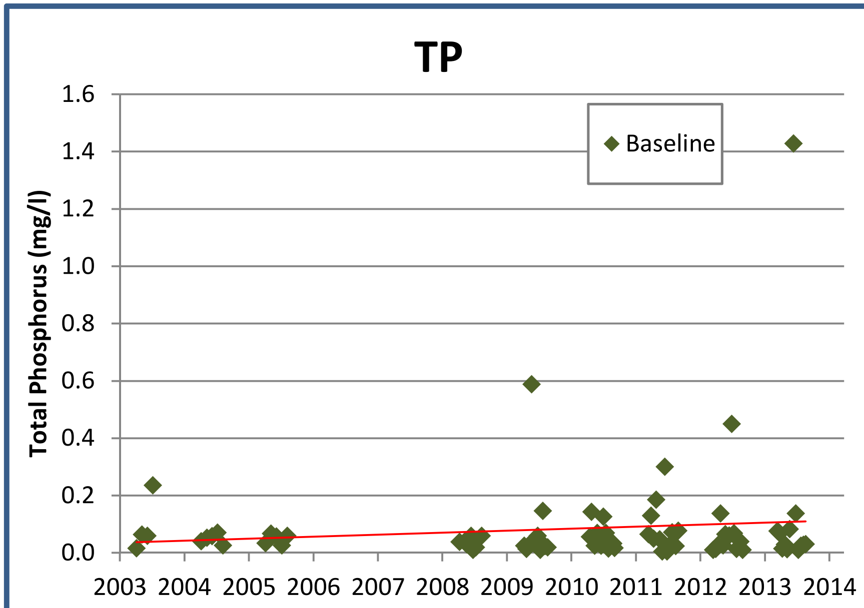
Malletts Creek – MH07

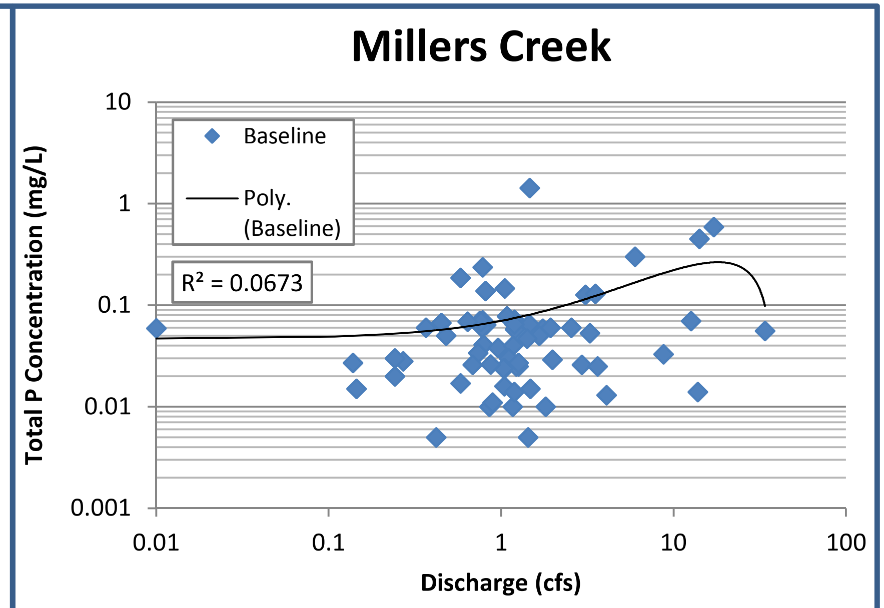


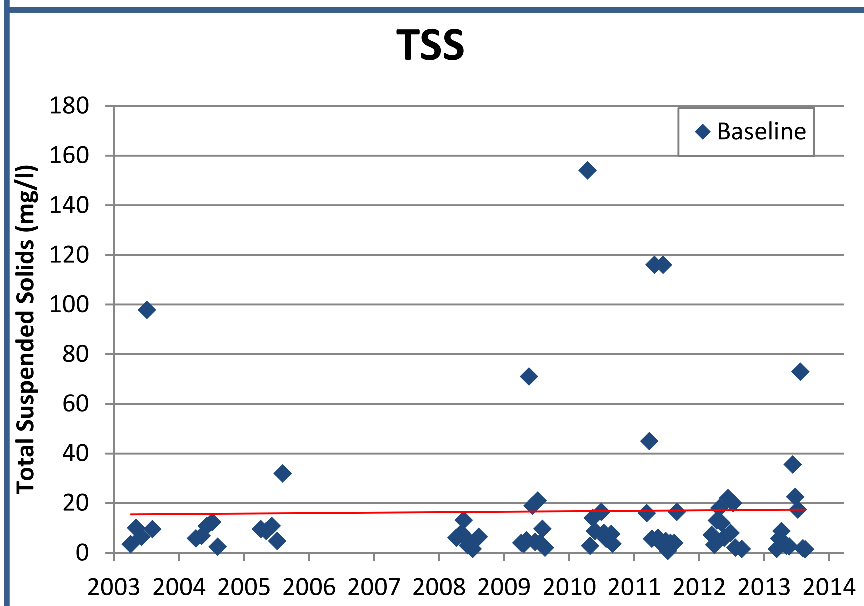


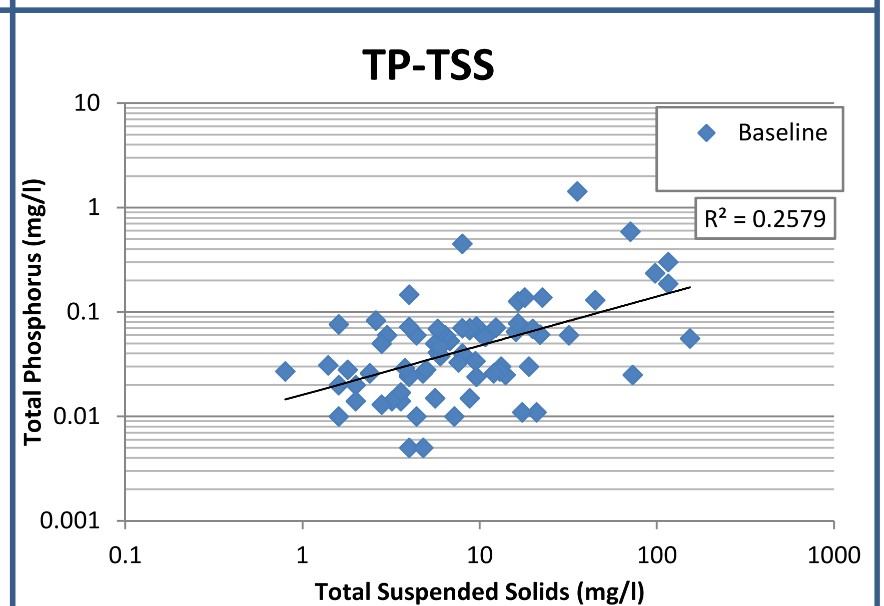


Millers Creek – MH08

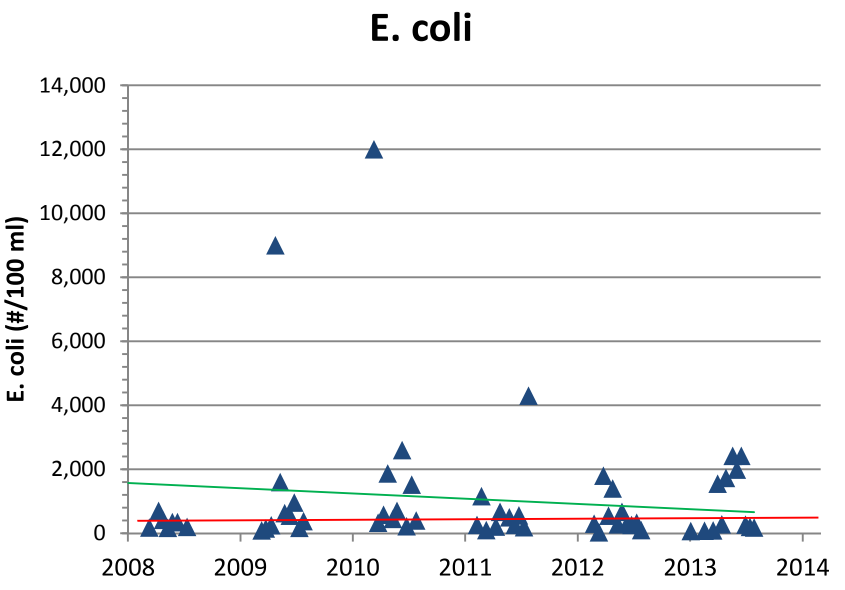


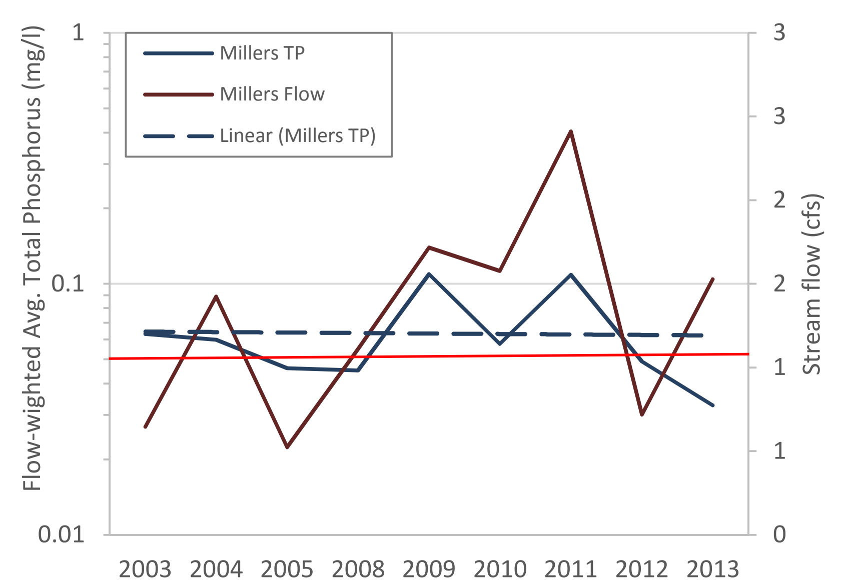




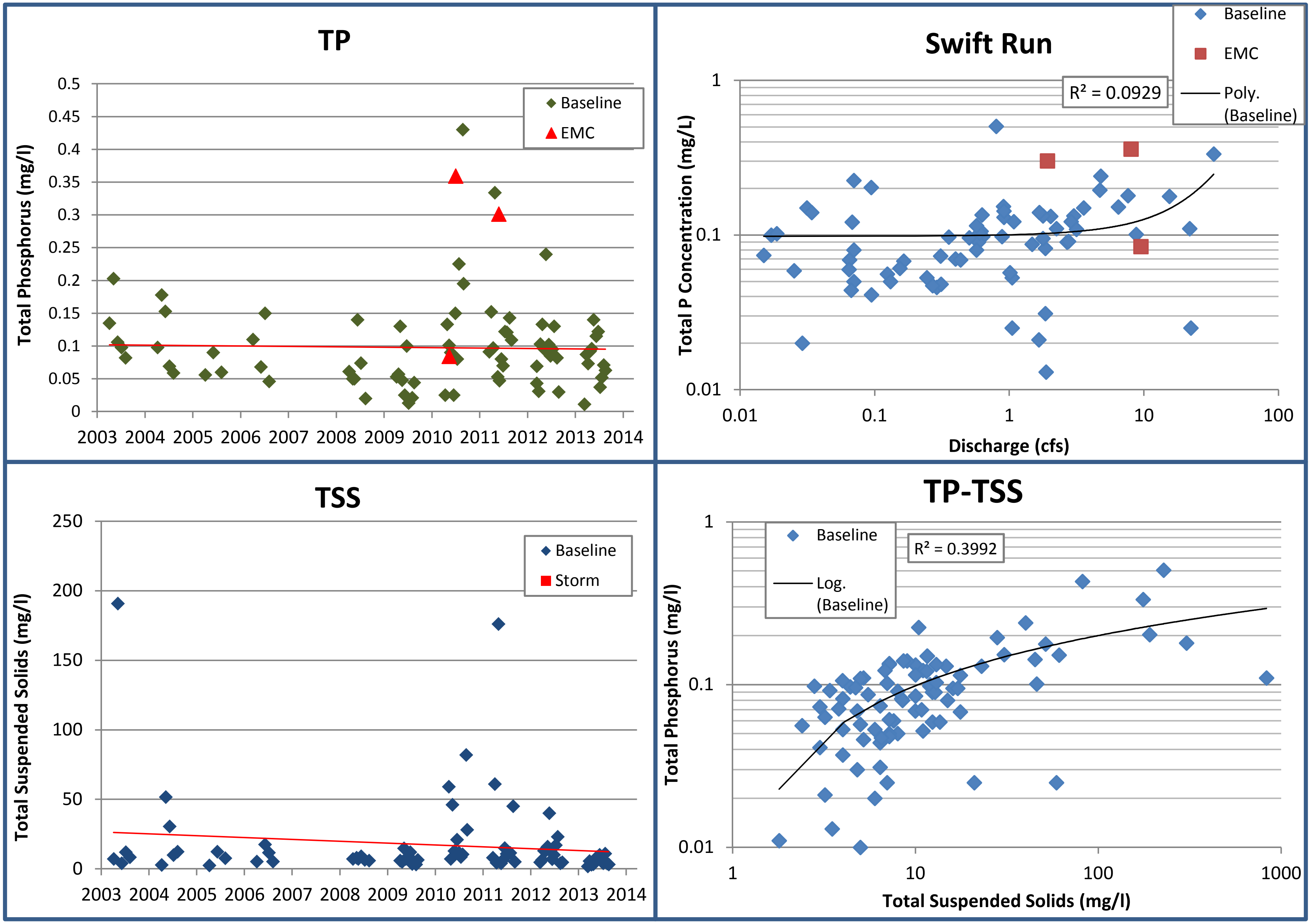


Millers Creek – MH08

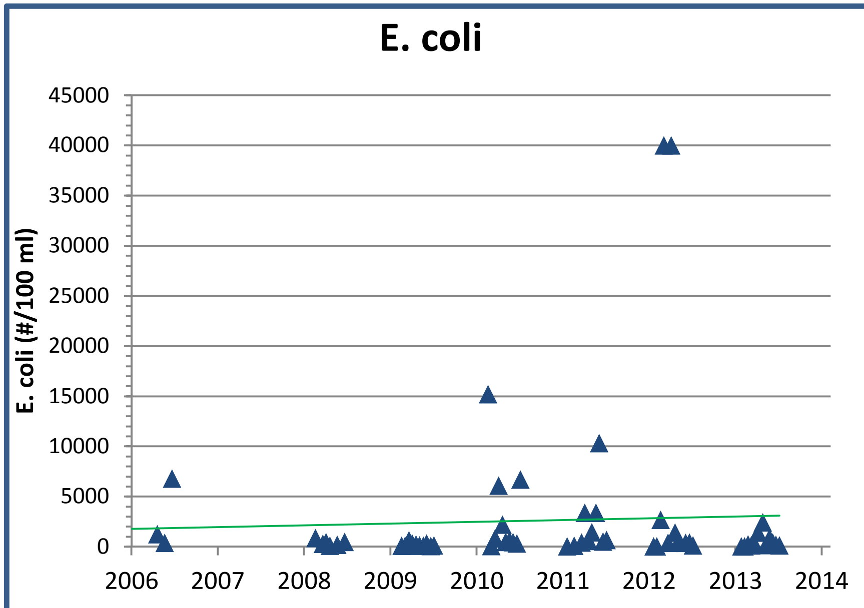


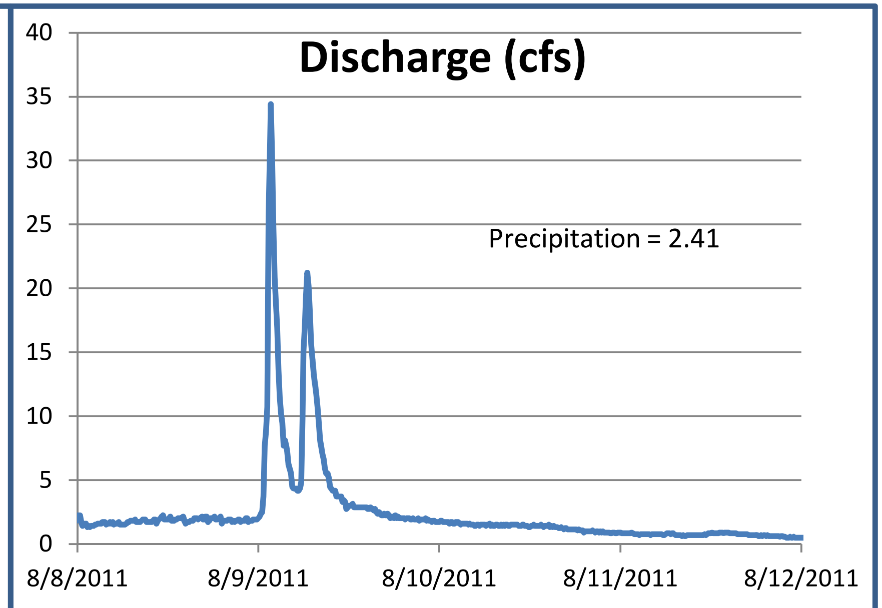


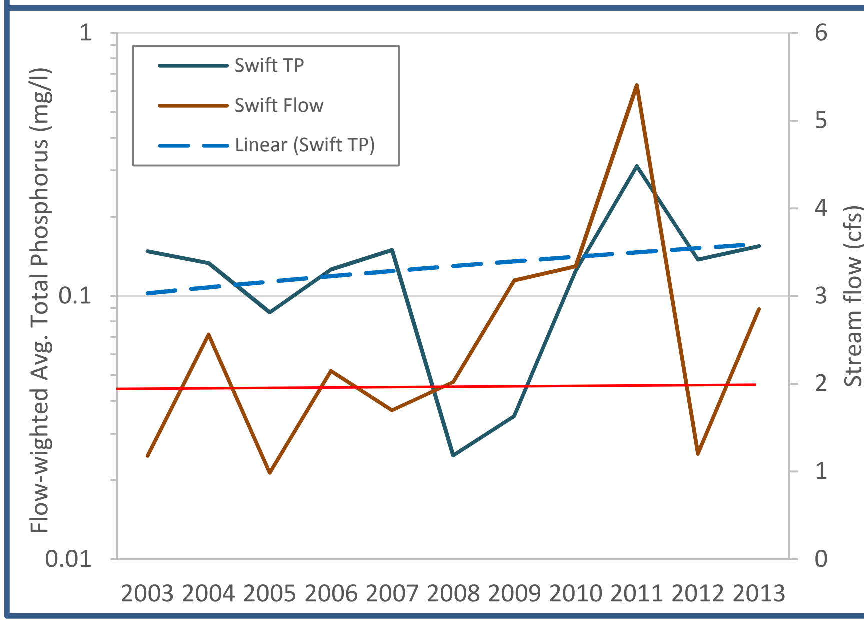
Swift Run – MH09



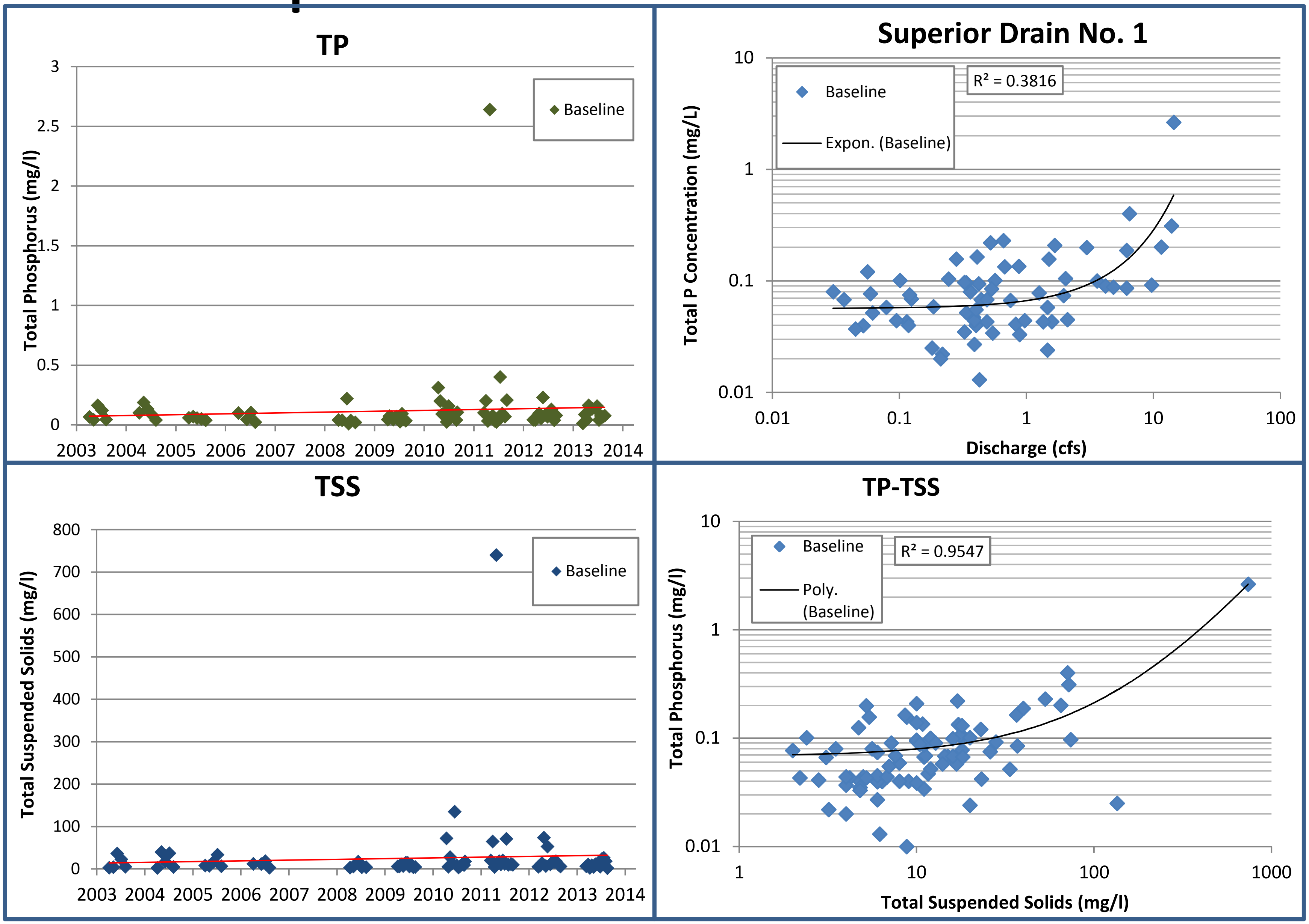
Swift Run – MH09







Superior Drain #1– MH10



Superior Drain #1– MH10