2013-2014 LARGE RIVER ASSESSMENT PROJECT

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ABSTRACT

In 2002, the Susquehanna River Basin Commission (SRBC) realized a need to better understand the dynamic conditions in a large river system and adapted protocols to better understand these systems in the Basin. SRBC monitored the mainstem of the Susquehanna River with varying protocols up until 2007, when SRBC adapted U.S. Environmental Protection Agency (USEPA) protocol as outlined in the manual for the National River and Stream Assessment (NRSA), detailing data collection methods for both wadeable and nonwadeable streams (USEPA, 2008).

SRBC has been monitoring 25 stations on the mainstem of the Susquehanna River at varying intervals dependent upon high flows and droughts occurring over the last nine years. In both 2013 and 2014, SRBC sampled 20 sites on the Chemung, Juniata, West Branch Susquehanna, and Susquehanna Rivers.

Composite benthic macroinvertebrate samples were collected along ten transects at each station. Field and laboratory water quality samples and overall observations also were collected at each site.

Using Rapid Bioassessment Protocol (RBP) macroinvertebrate metrics, two sites were rated as nonimpaired, 17 sites slightly impaired, and 21 sites moderately impaired. Less than 3 percent of the water quality values exceeded respective limits, indicating fairly good water quality in the Susquehanna River.

INTRODUCTION

SRBC has been performing biological assessments throughout the Basin since the late 1970s. When USEPA introduced the first version of the RBP manual (Plafkin and others, 1989), SRBC adopted those methods for use in the interstate stream monitoring program and rotating subbasin surveys. However, neither the previous nor current RBP methods (Barbour and others, 1999) used by SRBC in the aforementioned surveys accurately depicted the biological integrity of the Basin's large rivers: the mainstem Susquehanna, Chemung, West Branch Susquehanna, and Juniata Rivers. Thus, in 2002, SRBC initiated a pilot project to determine proper methods of biologically assessing the large rivers in the Basin. From this pilot project, staff determined that a combination of rock-filled basket samplers and traditional RBP methods was the most effective and consistent collection method for sampling the Susquehanna River (Hoffman, 2003).

In summer 2005, SRBC staff collected biological and water quality data at 25 stations on the mainstem Susquehanna River and at the mouth of major tributaries using the methodology described above. In 2007, staff changed the methodology to mimic the methods drafted by USEPA for NRSA (USEPA, 2008). These methods have been used for the past eight years.

Although the NRSA data collection includes fish, physical habitat, toxicology, and other parameters in addition to benthic macroinvertebrates, SRBC staff chose to focus efforts on benthic macroinvertebrate sampling. Benthic macroinvertebrates were used to assess biological conditions for several reasons. Benthic macroinvertebrates are sensitive to a wide range of stressors, have a wide range of documented pollution tolerances, and are found in a wide variety of habitats throughout lotic systems (Flotemersch and others, 2001a). Additionally, SRBC has background macroinvertebrate data from various sites on the large rivers of the Basin from subbasin surveys and interstate streams monitoring, as well as the previous river assessment studies.

Geography

The Susquehanna River Basin is the largest river basin on the east coast of the United States, draining 27,510 square miles. The Susquehanna River originates at Otsego Lake in Cooperstown, N.Y., and flows 444 miles through New York, Pennsylvania, and Maryland to the Chesapeake Bay at Havre de Grace, Md.

The 2013-2014 Large River Assessment stretched from Mehoopany, Pa., to Columbia, Pa., and encompassed a total of 20 stations over two years: four in the Middle Susquehanna Subbasin, four on the Juniata River, five in the West Branch Susquehanna River Subbasin, and five in the Lower Susquehanna Subbasin. Downstream of Harrisburg, Pa., the river flows through a series of dams and reservoirs, which this protocol is not designed to assess.

METHODS

Data collection

In fall 2013 and fall 2014, SRBC staff collected macroinvertebrate samples using D-frame nets on the mainstem Susquehanna River and largest tributaries. Field chemistry measurements were taken at each site, and chemical water quality samples also were collected for laboratory analysis. Macroinvertebrate samples were labeled with the site number, the date, and the number of bottles used.

In 2012, SRBC reevaluated the Large River site list to expand coverage up the main tributaries, Chemung River, West Branch Susquehanna, and Juniata River, as well (Figure 1; Table 1).

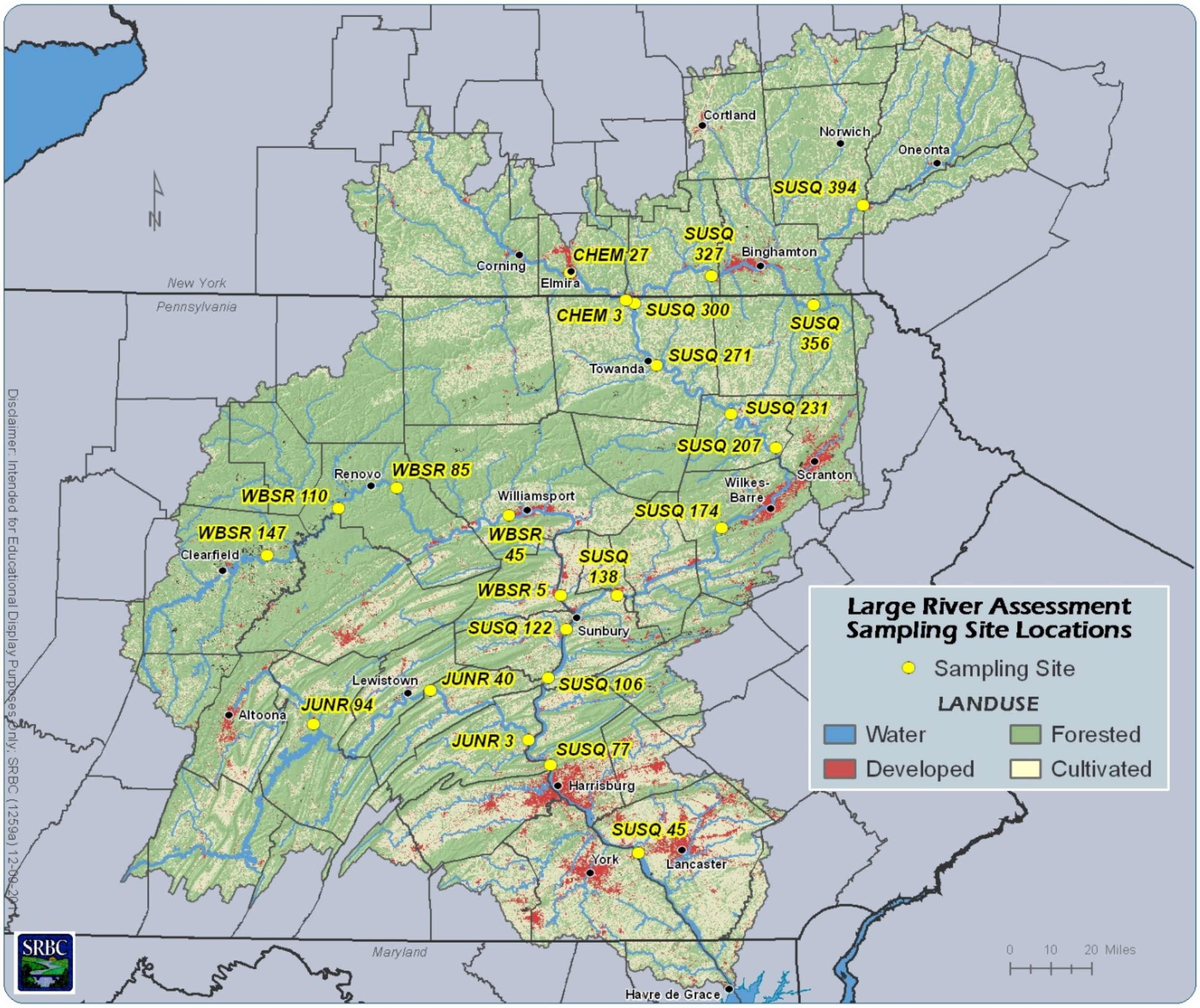

Figure 1. ***Susquehanna River Site Locations***

Table 1. Susquehanna River Station Locations

					Sampled	
Site	**Subbasin**	**Latitude**	**Longitude**	**Description**	2013	2014
SUSQ 394	Upper	42.311206	-75.419517	DS of boat launch, below Unadilla confluence in Sidney, NY	X	X
SUSQ 356	Upper	42.0949	-75.8376	At Kirkwood EWS sonde, Upstream	X	X
SUSQ 327	Upper	42.067736	-76.14445	At Boat access in Apalachin, NY	X	X
SUSQ 300	Upper	41.972661	-76.51175	At Boat access in Sayre, PA	X	X
CHEM 27	Chemung	42.07288	-76.84848	At Elmira EWS Sonde, Downstream	X	X
CHEM 3	Chemung	41.985644	-76.553325	At Boat access in Sayre, PA	X	X
SUSQ 271	Middle	41.753428	-76.410614	At Boat access in Towanda, PA	X	X
SUSQ 231	Middle	41.578472	-76.059225	US of Bridge and Mehoopany Creek, PA	X	X
SUSQ 207	Middle	41.4594	-75.8524	At Boat access in West Falls, PA	X	X
SUSQ 174	Middle	41.1774	-76.1085	At Boat access US of Shickshinny, PA	X	X
SUSQ 138	Middle	40.942139	-76.601114	At Boat access near Danville, PA	X	X
WBSR 85	West Branch	41.319686	-77.632478	DS of Boat access near Hyner, PA	X	
WBSR45	West Branch	41.225772	-77.107367	US of Boat access near Linden, PA	X	X
WBSR 5	West Branch	40.941419	-76.865306	At Boat Access near Lewisburg, PA	X	X
SUSQ 122	Lower	40.822753	-76.839139	At Boat access near Hummels Wharf, PA		X
SUSQ 106	Lower	40.651619	-76.9226	DS of Boat access near McKees Half Falls, PA	X	X
SUSQ 77	Lower	40.3435	-76.911739	At Boat access at Fort Hunter, PA	X	X
JUNR 94	Juniata	40.385933	-77.872994	At Boat access in Mt Union, PA	X	X
JUNR 40	Juniata	40.60686	-77.470225	At Boat access in Lewistown Narrows, PA	X	X
JUNR 3	Juniata	40.430831	-77.013247	At Boat access near Amity Hall, PA	X	X
SUSQ45	Lower	40.030408	-76.509408	At Boat access DS of bridges in Columbia, PA	X	X

Chemical water quality

Water samples were collected at each sampling site with a depth-integrated sampler to measure nutrient and metal concentrations in the river. Field water quality measurements included water temperature, dissolved oxygen, conductivity, and pH. All field measurements were collected instream with a YSI 6820-V2 meter that was calibrated every day.

A list of laboratory parameters is located in Table 2. Samples were iced and sent for analysis to ALS Environmental, Middletown, Pa.

Table 2. Parameters for Laboratory Analysis

Parameters	
Alkalinity (mg/l)	Nitrite-N T (mg/l)
Aluminum (ug/l)	Nitrogen TOT (mg/l)
Bromide (ug/l)	Orthophosphate (mg/l)
Calcium T (mg/l)	Phosphorus (mg/l)
Chloride (mg/l)	Sodium (mg/l)
Hardness T (mg/l)	Sulfate (mg/l)
Hot Acidity (mg/l)	T Org Carbon (mg/l)
Iron (ug/l)	TDS (mg//)
Magnesium (mg/l)	Total Kjeldahl Nitrogen (mg/l)
Manganese (mg/l)	TSS (mg/l)
Nitrate-N (mg/l)	Turbidity (NTU)

[a] mg/l = milligrams per liter [b] µg/l = micrograms per liter
[c] nephelometric turbidity units

Macroinvertebrates

Ten equidistant transects were established along a one-kilometer sampling reach at each of the sites. Each transect was located along alternating banks; for example, transects two, four, six, eight, and ten were located on the right bank, while transects one, three, five, seven, and nine were located on the left bank. To collect benthic macroinvertebrates (organisms that live on the stream bottom, including aquatic insects, crayfish, clams, snails, and worms), staff used a D-frame net with 500-µm mesh to collect three samples within a 10-meter area surrounding each transect, to a depth of 0.5 meters. Samples were taken from multiple habitats, including bottom substrate, woody debris, undercut banks, and macrophytes. A total of 30 samples were then composited into a single sample, which was preserved in the field in 95-percent denatured ethyl alcohol. After sampling was completed at a given site, all equipment that came in contact with the sample was examined carefully, picked free of algae or debris, rinsed thoroughly, and sprayed with 10-percent bleach solution before sampling at the next site. Additional organisms that were found on examination were placed into the sample containers.

Subsampling and sorting procedures were based on the 1999 RBP document (Barbour and others, 1999). In the laboratory, composite samples were sorted into 300-organism subsamples, when possible, using a gridded pan and a random numbers table. The organisms contained in the subsamples were identified to genus (except Chironomidae and Oligochaeta) when possible and enumerated.

Continuous Instream Monitoring

In 2003, SRBC established the Early Warning System (EWS) program for public water suppliers in Pennsylvania with intakes in the Susquehanna River and expanded the system in the New York portion of the Basin in 2006. Currently, nine EWS stations monitor a minimum of pH, temperature, and turbidity at critical locations along the Susquehanna River using online analyzers that transmit the data in real-time to water treatment plants and SRBC. The EWS project provides water suppliers not only notice of possible contamination events but also current conditions of the rivers. Because of this, SRBC aligned six of the Large River sites very near six of the EWS sites. Sites CHEM27, SUSQ45, SUSQ77, SUSQ138, SUSQ356, and WBSR5 all have real-time field water quality data to show conditions around the sampling date.

DATA ANALYSIS

Chemical water quality

Chemical water quality was assessed by examining field and laboratory parameters. Limit values are listed for each parameter based on current state and federal regulations or references for aquatic life tolerances (Table 3; Buda, 2008).

Table 3. Water Quality Standards

Parameters	Limits	Reference Code	Reference
Based on state water quality standards:			
Temperature	≤ 30.5 ºC	a	a. http://www.pacode.com/secure/data/025/chapter93/s93.7.html
Dissolved Oxygen	≥ 4 mg/l	a	b. http://www.pacode.com/secure/data/025/chapter93/s93.8c.html
pH	≥ 6.0 and ≤ 9.0	a	c. http://www.dec.ny.gov/regs/4590.html#16132
Alkalinity	≥ 20 mg/l	a	d. http://www.dsd.state.md.us/comar/comarhtml/26/26.08.02.03-3.htm
Total Chloride	≤ 250 mg/l	a	
Total Dissolved Solids	≤ 500 mg/l	c	
Total Sulfate	≤ 250 mg/l	a	
Total Iron	≤ 1.5 mg/l	a	
Total Manganese	≤ 1.0 mg/l	a	
Total Aluminum	≤ 0.75 mg/l	b	
Total Magnesium	≤ 35 mg/l	c	
Total Sodium	≤ 20 mg/l	c	
Total Suspended Solids	≤ 25 mg/l	a	
Turbidity	≤ 50 NTU	d	
Based on background levels, aquatic life tolerances, or recommendations:			
Conductivity	≤ 800 µmhos/cm	e	e. http://www.uky.edu/WaterResources/Watershed/KRB_AR/wq_standards.htm
Total Nitrogen	≤ 1 mg/l	f	f. http://water.usgs.gov/pubs/circ/circ1225/images/table.html
Nitrate-N	≤ 0.6 mg/l	f	g. http://www.uky.edu/WaterResources/Watershed/KRB_AR/krww_parameters.htm
Total Nitrite	≤ 1 mg/l	c	h. Hem (1970)
Total Phosphorus	≤ 0.1 mg/l	g	i. Based on archived data at SRBC
Total Orthophosphate	≤ 0.02 mg/l	f	
Total Organic Carbon	≤ 10 mg/l	h	
Total Hardness	≤ 300 mg/l	g	
Acidity	≤ 20 mg/l	i	
Calcium	≤ 100 mg/l	i	

Macroinvertebrate Analysis

A series of macroinvertebrate metrics was calculated for each sample, and assessments of the sites were performed. Benthic macroinvertebrate samples were assessed using procedures described by Barbour and others (1999), Klemm and others (1990), and Plafkin and others (1989). Using these methods, staff calculated a series of biological indexes for each station. The metrics used in this survey are summarized in Table 4. Metric 2 (Shannon-Wiener Diversity Index) followed the methods described in Klemm and others (1990), and all other metrics were derived from Barbour and others (1999).

Table 4. Summary of Metrics Used to Evaluate the Overall Biological Integrity of River Benthic Macroinvertebrate Communities

Metric	Description
1. Taxonomic Richness (a)	The total number of taxa present in the 300-organism subsample. Number decreases with increasing disturbance or stress.
2. Shannon-Wiener Diversity Index (b)	A measure of biological community complexity based on number of equally or nearly equally abundant taxa in the community. Index value decreases with increasing stress.
3. Hilsenhoff Biotic Index (a)	A measure of the organic pollution tolerance of a benthic macroinvertebrate community. Index value increases with increasing stress.
4. EPT Index (a)	The total number of Ephemeroptera (mayfly), Plecoptera (stonefly), and Trichoptera (caddisfly) taxa present in the 300-organism subsample. The index decreases with increasing stress.
5. Percent Ephemeroptera (a)	The percentage of Ephemeroptera in a 300-organism subsample. Percentage decreases with increasing stress.
6. Percent Dominant Taxa (a)	A measure of community balance at the lowest positive taxonomic level. Percentage increases with increasing stress.
7. Percent Chironomidae (a)	The percentage of Chironomidae in a 300-organism subsample. Percentage increases with increasing stress.

Sources: (a) Barbour and others, 1999
(b) Klemm and others, 1990

A reference condition approach was used to determine impairment levels for each site. One reference site was chosen from the sites sampled on the basis of macroinvertebrate metrics and water quality to represent the best combination of conditions. This Large River data report looks at the past eight years (2007-14) as a whole and uses the reference conditions for that time period, further highlighting changes at sites between years due to natural variance of conditions. The 300-organism subsample data were used to generate scores for each of the seven metrics at each site. Scores for metrics 1-4 were converted to a biological condition score, based on the percent similarity of the site's metric score relative to the metric score at the chosen reference site. Scores for metrics 5-7 were based on set scoring criteria developed for the percentages (Plafkin and others, 1989; Ohio Environmental Protection Agency, 1987). The sum of the biological condition scores constituted the total biological score for the sample, and total biological scores were used to assign each sample to a biological condition category (Table 5).

Table 5. Summary of Criteria Used to Classify the Biological Conditions of Sample Sites

SAMPLING AND ANALYSIS

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TOTAL BIOLOGICAL SCORE DETERMINATION

Metric	**Biological Condition Scoring Criteria**			
	6	**4**	**2**	**0**
1. Taxonomic Richness (a)	> 80%	79-60%	59-40%	<40%
2. Shannon Diversity Index (a)	> 75%	74-50%	49-25%	<25%
3. Hilsenhoff Biotic Index (b)	> 85%	84-70%	69-50%	<50%
4. EPT Index (a)	> 90%	89-80%	79-70%	< 70%
5. Percent Ephemeroptera (c)	> 25%	10-25%	1-9%	< 1%
6. Percent Dominant Taxa (c)	< 20%	20-30%	31-40%	>40%
7. Percent Chironomidae (c)	< 5%	5-20%	21-35%	>35%
Total Biological Score (d)				

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BIOASSESSMENT

Percent Comparability of Study and Reference Condition Total Biological Scores (e)	**Biological Condition Category**
>83%	Nonimpaired
79-54	Slightly Impaired
50-21	Moderately Impaired
<17%	Severely Impaired

(a) Score is study site value/reference site value X 100
(b) Score is reference site value/study site value X 100
(c) Scoring Criteria evaluate actual percentage contribution, not percent comparability to the reference station
(d) Total Biological Score = the sum of Biological Condition Scores assigned to each metric
(e) Values obtained that are intermediate to the indicated ranges will require subjective judgment as to the correct placement into a biological condition category

RESULTS

Water Quality

In both 2013 and 2014, the water quality at most of the sampling sites met the water quality standards. Only 2.6 percent (23 of 880) of water quality values exceeded their respective limits. The majority of the exceedances were for nitrate. Exceedances are summarized in Table 6.

Table 6. Number of Exceedances per Parameter

Parameter	Limit	Number of Exceedances
Alkalinity	<20 mg/L	1
Nitrate	>1.0 mg/L	6
Sodium	>20 mg/L	6
Orthophosphate	>0.05 mg/L	4
Phosphorus	>0.1 mg/L	5
Total Suspended Sediment	>25 mg/L	1

Biological Conditions

In 2013 and 2014, staff collected macroinvertebrates at 40 sites. Two of the sites (SUSQ 327 in 2014 and SUSQ 138 in 2013) were found to be nonimpaired. Slightly impaired conditions were found at 17 sites (43 percent), and moderately impaired conditions were found at 17 sites (43 percent). No sites sampled in 2013 or 2014 were found to be severely impaired. Figure 2 shows how the 2013-14 sampling years compare to all sites sampled dating back to 2007. Figures 3 and 4 show individual and median macroinvertebrate conditions, respectively, for sites from 2007 through 2014.

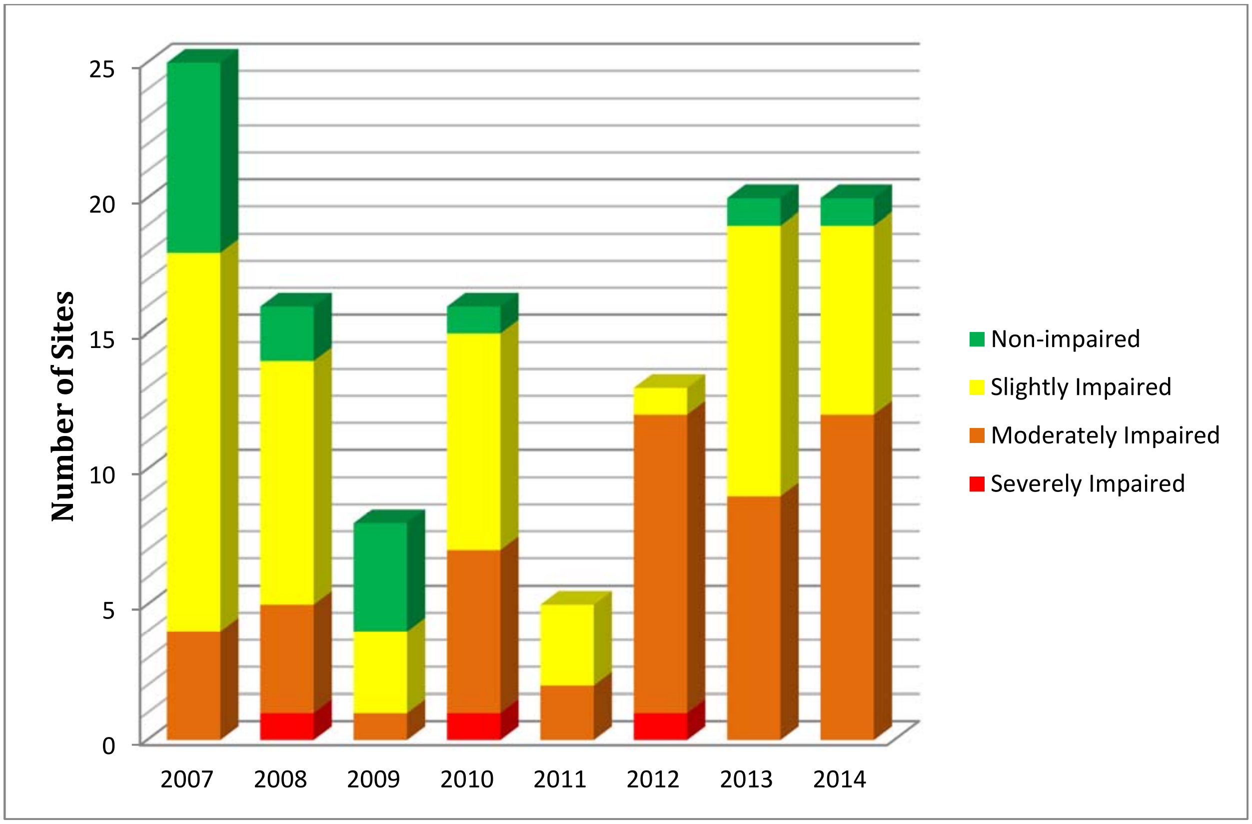

Figure 2. Macroinvertebrate Biological Condition Categories from 2007 through 2014

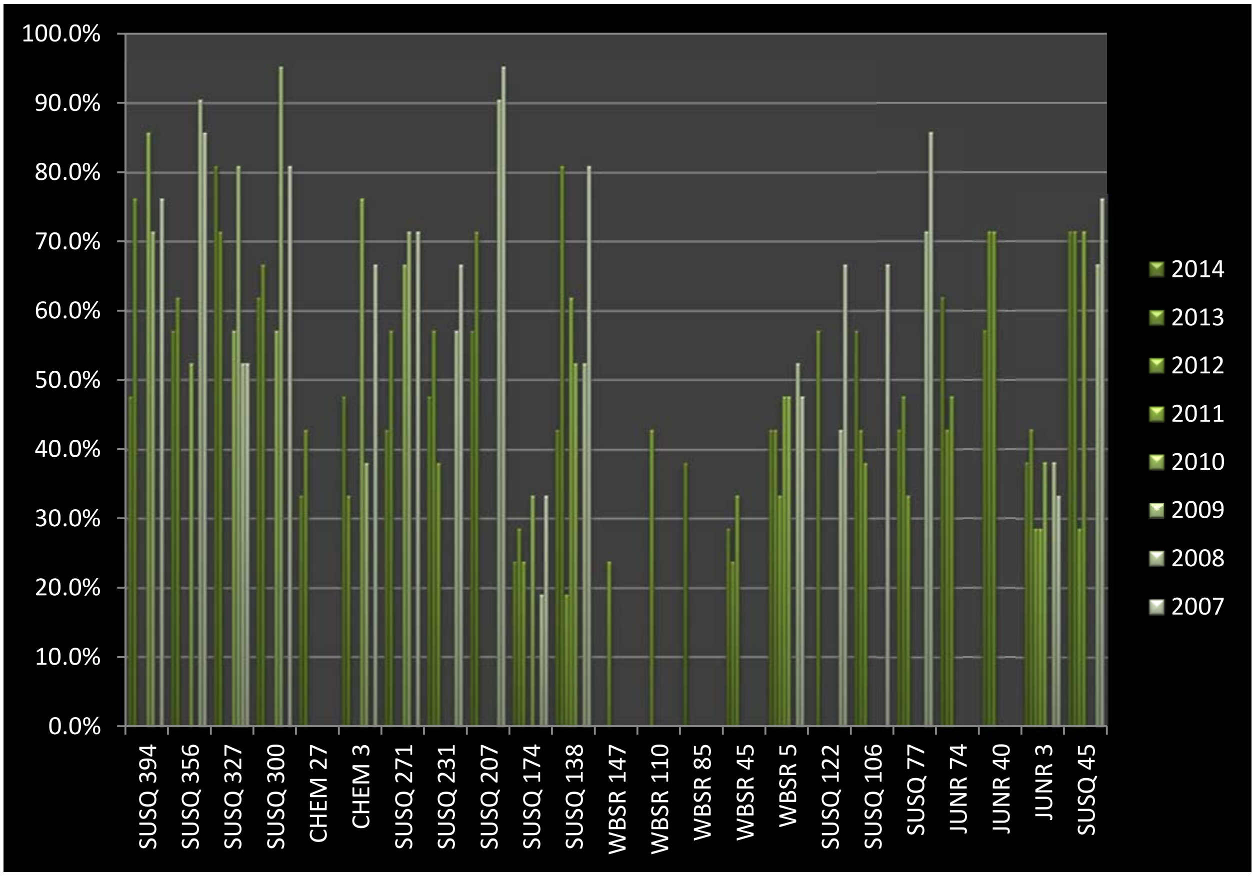

Figure 3. Macroinvertebrate Biological Conditions from 2007 through 2014

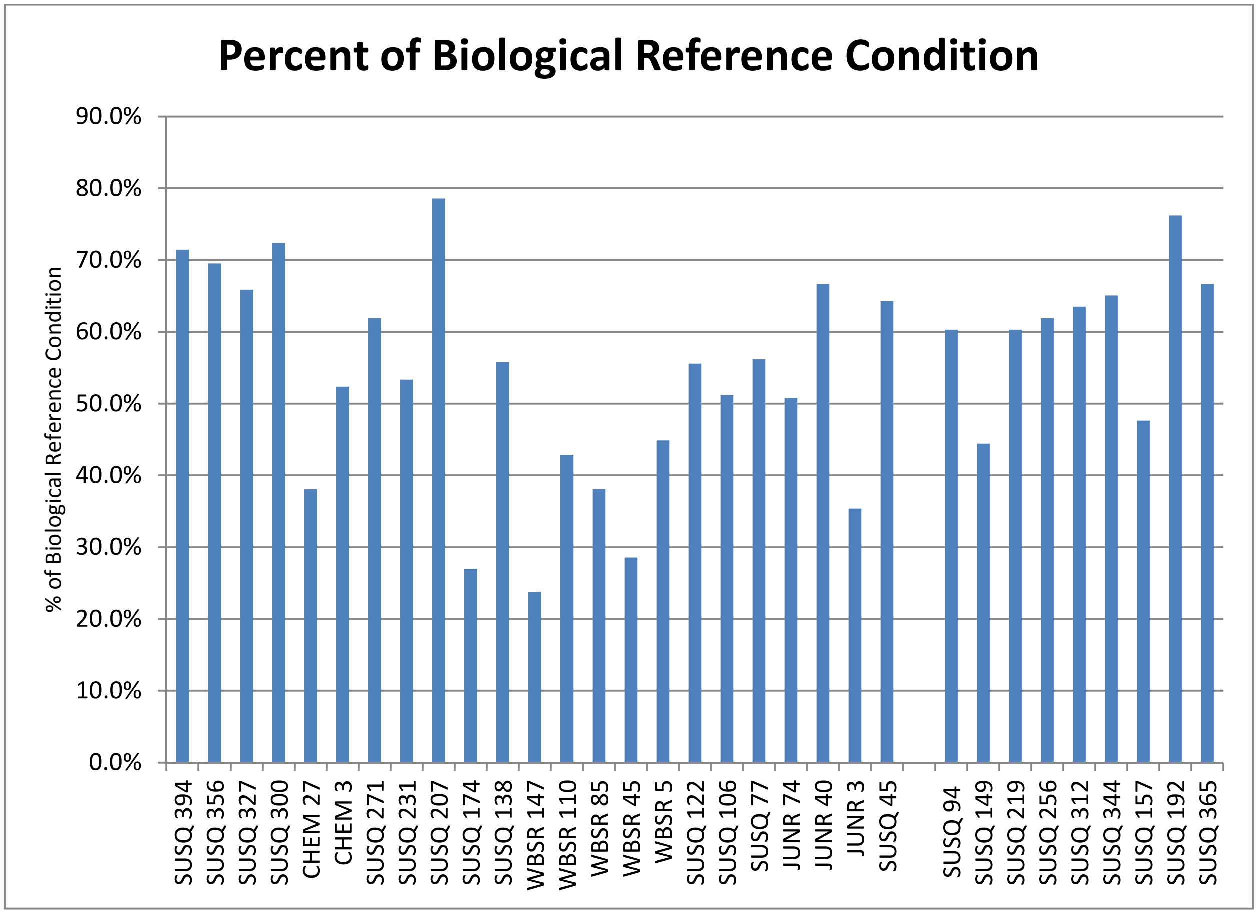

Figure 4. Median Macroinvertebrate Biological Conditions from 2007 through 2014

<u>Continuous Instream Monitoring</u>

Water quality data was compiled for each of the six Large River sites that overlap with the EWS sites. Appendix A shows water quality conditions leading up to the 2013 and 2014 sampling period.

<u>Flow Conditions</u>

Figure 5 below shows the flow conditions leading up to the sampling period near SUSQ45 to broadly cover conditions throughout the river.

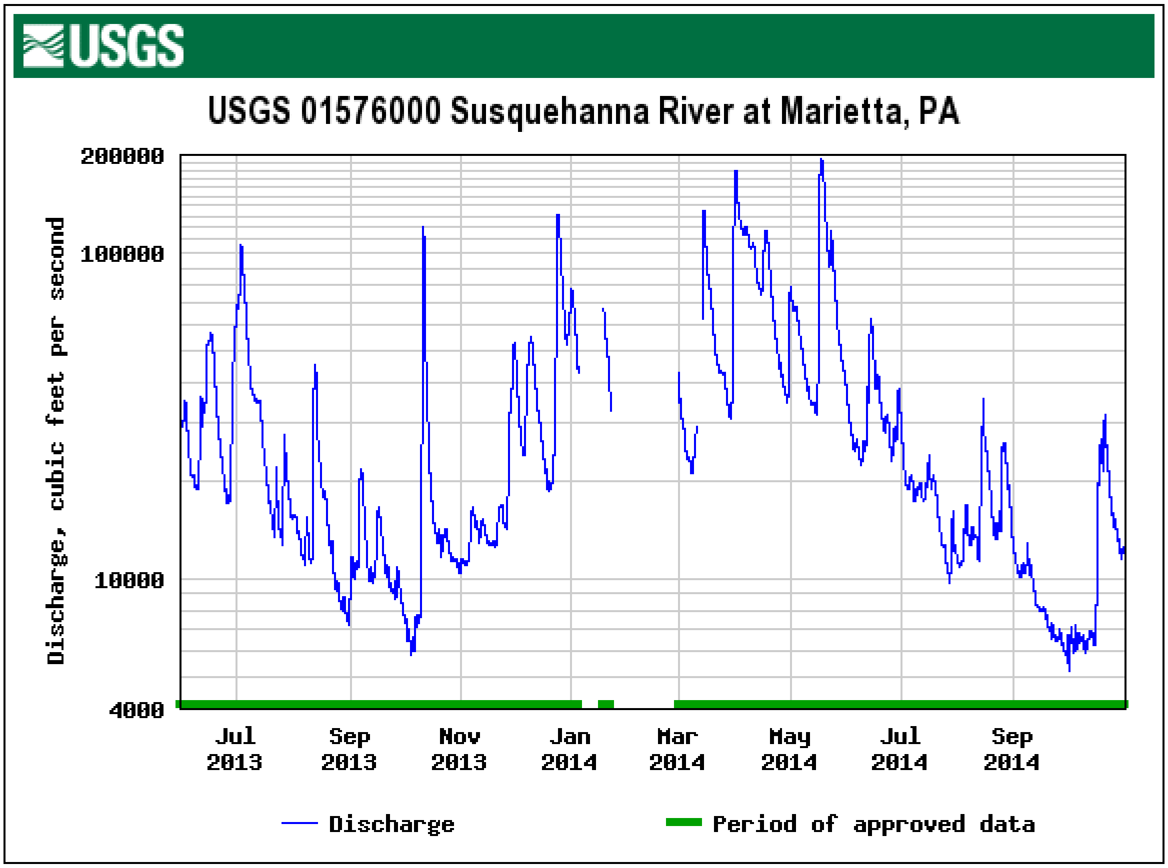

Figure 5. ***Hydrograph of Susquehanna River near SUSQ45, June 2013–October 2014***

DISCUSSION/CONCLUSIONS

Water Quality

The assessments conducted during the 2013-14 Large River Project, when compared to the results of the 2011-12 Large River Assessment (Shenk, 2013), 2010 Large River Assessment Project (Shenk, 2011), 2009 Large River Assessment Project (Shenk, 2010), 2008 Large River Assessment Project (Shenk, 2009), and 2007 Large River Assessment Project (Hoffman, 2008), show that most of the water quality parameters in the mainstem of the Susquehanna River and the mouths of most the larger tributaries are below established water quality standards or recommended life tolerances. Even with 23 values (2.6 percent) exceeding respective recommended aquatic life tolerances, the data analysis shows that the mainstem of the Susquehanna River has fairly good water quality.

Biological Conditions

As shown in Figure 2, the overall biological conditions for sampling years 2013 and 2014 were relatively similar when compared to years past. This could be attributed to many factors such as similar flow conditions, similar site list, timing of collections, etc.

Mainstem Susquehanna

The most upstream sites on the mainstem of the Susquehanna River that were sampled, sites SUSQ394, SUSQ356, SUSQ327, and SUSQ300, are located in the Upper Susquehanna subbasin, which encompasses the stretch of the Susquehanna River from the headwaters in Cooperstown, N.Y., to the confluence with the Chemung River, in Athens, Pa. The Upper Susquehanna subbasin drains approximately 4,950 square miles with main land uses of forested and agricultural areas. Site SUSQ394 is located near Sidney, N.Y., and was rated as slightly impaired in 2013 but moderately impaired in 2014. SUSQ356 near Kirkwood, N.Y., SUSQ327 near Apalachin, N.Y., and SUSQ300 near Sayre, Pa., were all found to be slightly impaired, due to low rating in percent EPT taxa (Ephemeroptera (mayfly), Plecoptera (stonefly), and Trichoptera (caddisfly)) and percent dominant taxa in 2013; however, SUSQ327 was nonimpaired in 2014 while SUSQ356 and SUSQ300 remained slightly impaired with similar scoring.

The next five downstream sites are all located in the Middle Susquehanna subbasin, which encompasses the stretch of the Susquehanna River from the confluence with the Chemung River, in Athens, Pa., to the confluence with the West Branch of the Susquehanna River, in Sunbury, Pa. The Middle Susquehanna subbasin drains approximately 3,700 square miles with main land uses of forested, agricultural, urban, and abandoned mine drainage (AMD) areas. SUSQ271 near Towanda, Pa., and SUSQ231 near Mehoopany Creek, Pa., were both found to be slightly impaired in 2013 and moderately impaired in 2014 due to low ratings in percent dominant taxa and EPT taxa. SUSQ207 near West Falls, Pa., was slightly impaired in both 2013 and 2014 with very similar scoring. SUSQ174 near Shickshinny, Pa., was found to be moderately impaired due to very low ratings in percent Ephemeroptera individuals, EPT taxa, low taxa richness, and percent Chironomids in both 2013 and 2014. SUSQ138 near Danville, Pa., was found to be nonimpaired in 2013; however, it was found to be moderately impaired in 2014 mostly due to percent Chironomids and lack of diversity, which could be from a slight change in localized habitat sampled.

The four remaining sites sampled on the mainstem of the Susquehanna River are located in the Lower Susquehanna subbasin. The lower Susquehanna River flows from the confluence with the West Branch and mainstem in Sunbury, Pa., to where the river meets the Chesapeake Bay in Havre de Grace, Md. This portion of the watershed has a significant amount of agricultural land uses combined with a few densely developed areas, including Harrisburg, Pa., which lies adjacent to the river. The most downstream site is located 45 miles upstream from the Chesapeake Bay because hydroelectric dams on the last stretch of the Susquehanna turn the river into a series of pooled reservoirs, not suitable for monitoring under these protocols. SUSQ122 located near Hummels Wharf, Pa., was found to be slightly impaired due to low EPT taxa and only sampled in 2013. SUSQ106 near McKees Half Falls, Pa., and SUSQ77 near Fort Hunter, Pa., were both found to be moderately impaired due to very low ratings in percent dominant taxa and EPT taxa in 2013. In 2014, SUSQ106 was found to be only slightly impaired with an increase in diversity, while SUSQ77 was very similar to 2013 and moderately impaired. SUSQ45 near Columbia, Pa., was found to be slightly impaired with near identical scoring in both 2013 and 2014.

Chemung River

Two sites were sampled on the Chemung River in both 2013 and 2014. The Chemung River subbasin is an interstate watershed that drains approximately 2,604 square miles of south-central New York and north-central Pennsylvania. The land use is a combination of agriculture and forested. CHEM27 located near Elmira, N.Y., and CHEM3 near Sayre, Pa., were both found to be moderately impaired due to low ratings in percent Ephemeroptera individuals, percent dominant taxa, EPT taxa, and percent Chironomids in both 2013 and similarly in 2014.

West Branch Susquehanna River

The West Branch Susquehanna drains approximately 6,982 square miles from Carrolltown to Northumberland, Pa. Agricultural lands are most abundant near the mouth in the southeastern area, and the few urban areas are mostly small in size. Resource extraction is prominent in the subbasin with many streams severely impacted by mine drainage. In 2013, two sites were sampled, WBSR45 near Linden, Pa., and WBSR5 near Lewisburg, Pa. Both sites were found to be moderately impaired, with two of the lowest ratings across all sites in 2013, particularly in dominant taxa, EPT taxa, and taxa richness. In 2014, both WBSR45 and WBSR5 had nearly identical scores (both moderately impaired). In 2014 WBSR85 near Hyner, Pa., was sampled as well and was also found to be moderately impaired.

Juniata River

The Juniata River is the last large tributary to the Susquehanna River. The Juniata subbasin drains approximately 3,400 square miles from west of Bedford to Duncannon, Pa. The mixed land use in the Juniata River subbasin primarily includes forested areas concentrated on the ridges, with agricultural and urban areas in the valleys. Three sites were sampled on the Juniata River in 2013 and 2014. JUNR74, located near Mt. Union, Pa., was found to be moderately impaired due to low rating in percent dominant taxa and EPT taxa; however, in 2014 it was only slightly impaired mostly due to an increase in diversity. JUNR40 located in the Lewistown Narrows was found to be slightly impaired in both 2013 and 2014, while JUNR3 located near Amity Hall, Pa., was found to be moderately impaired with low-moderate ratings across all categories in both 2013 and 2014.

Future Directions

In 2015, staff plans to reevaluate the Large River Program with emphasis in fish assessments at selected stations as one of the main focus areas. Moving forward, staff plans to incorporate the lower 45 miles for the Susquehanna that is heavily influenced by major impoundment areas into one Large Waters protocol and report that would best summarize current conditions of the Susquehanna and larger tributaries.

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APPENDIX A
CONTINUOUS INSTREAM MONITORING DATA FOR 2013-2014 SAMPLING PERIOD

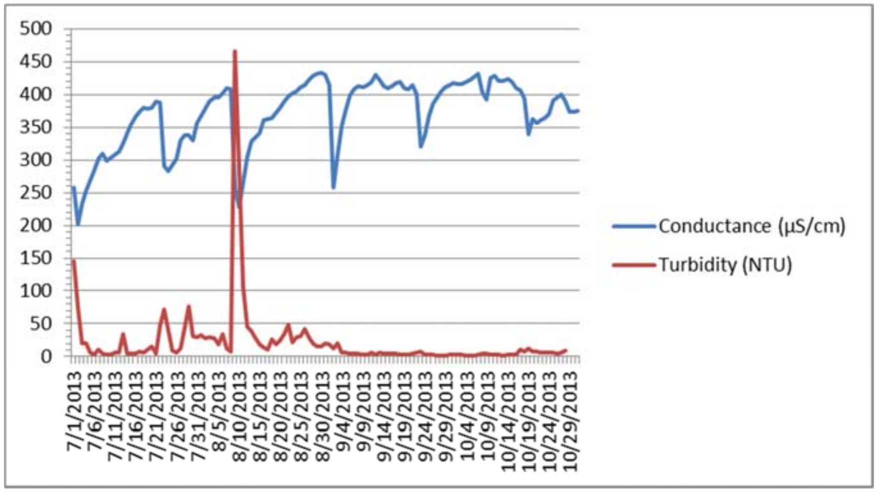

Figure A1a. 2013 Continuous Turbidity and Conductance Data near Chem27

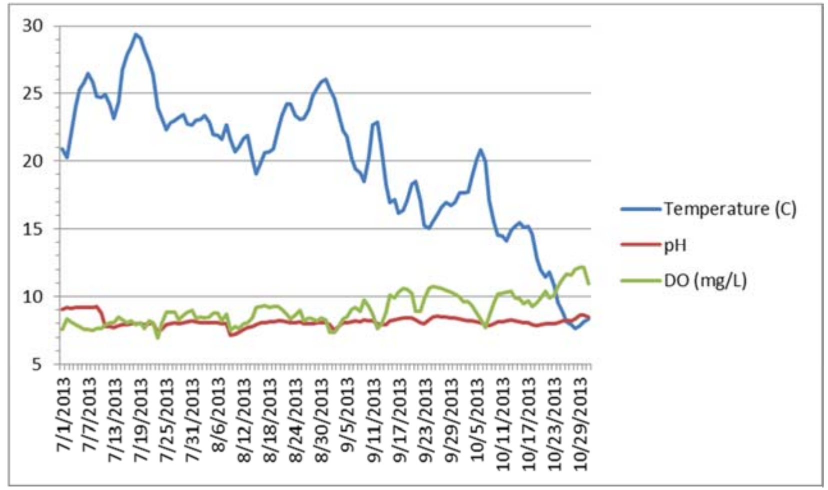

Figure A1b. 2013 Continuous Temperature, pH, and Dissolved Oxygen (DO) Data near CHEM27

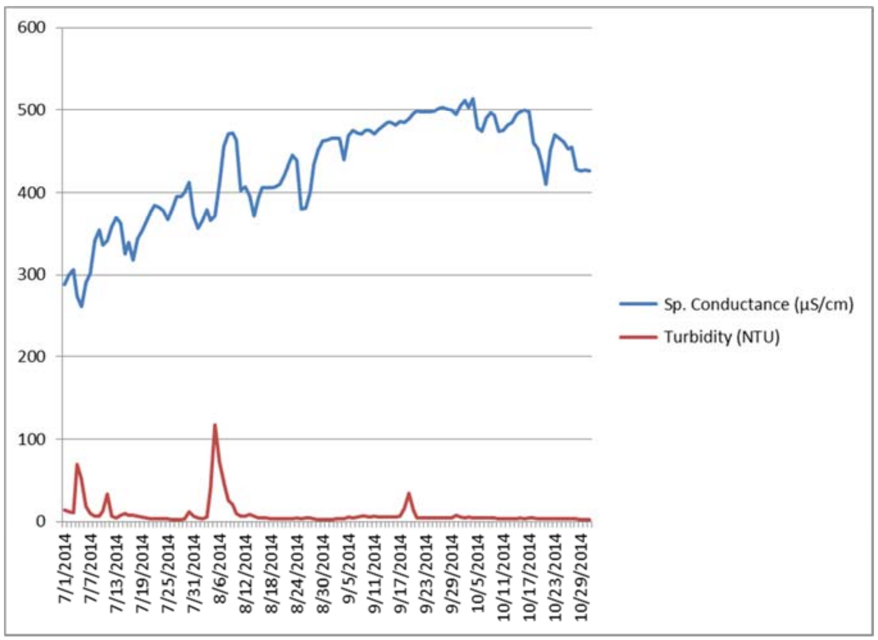

Figure A1c. 2014 Continuous Turbidity and Conductance Data near CHEM27

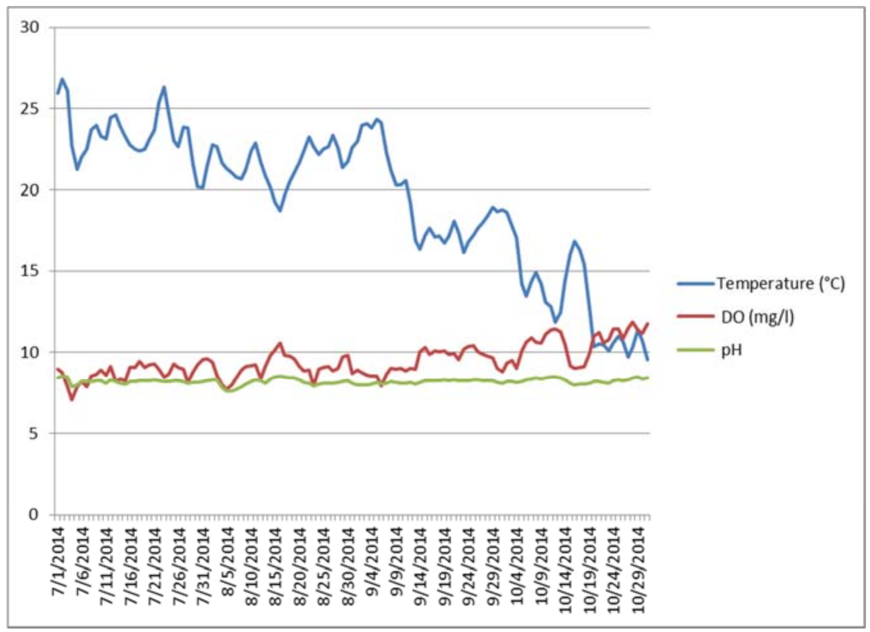

Figure A1d. 2014 Continuous Temperature, pH, and Dissolved Oxygen (DO) Data near CHEM27

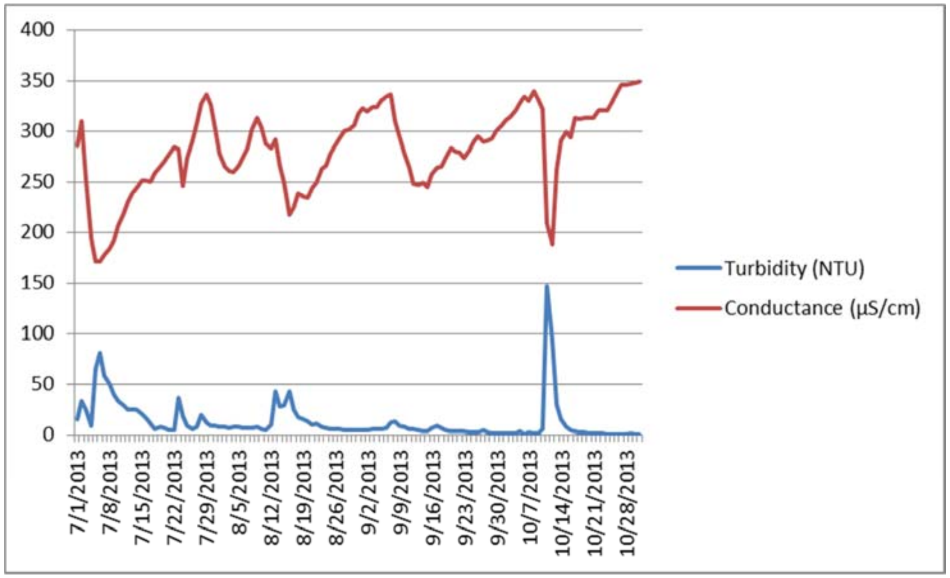

Figure A2a. 2013 Continuous Turbidity and Conductance Data near SUSQ45

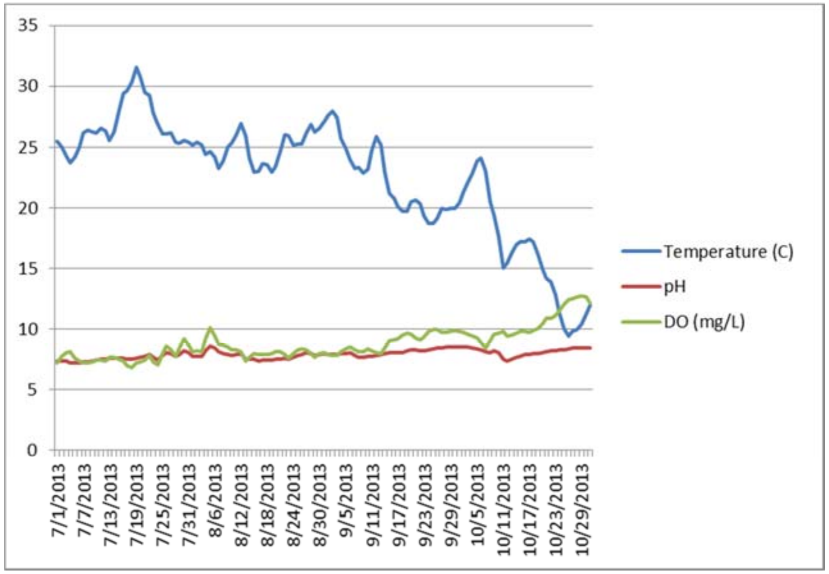

Figure A2b. 2013 Continuous Temperature, pH, and Dissolved Oxygen (DO) Data near SUSQ45

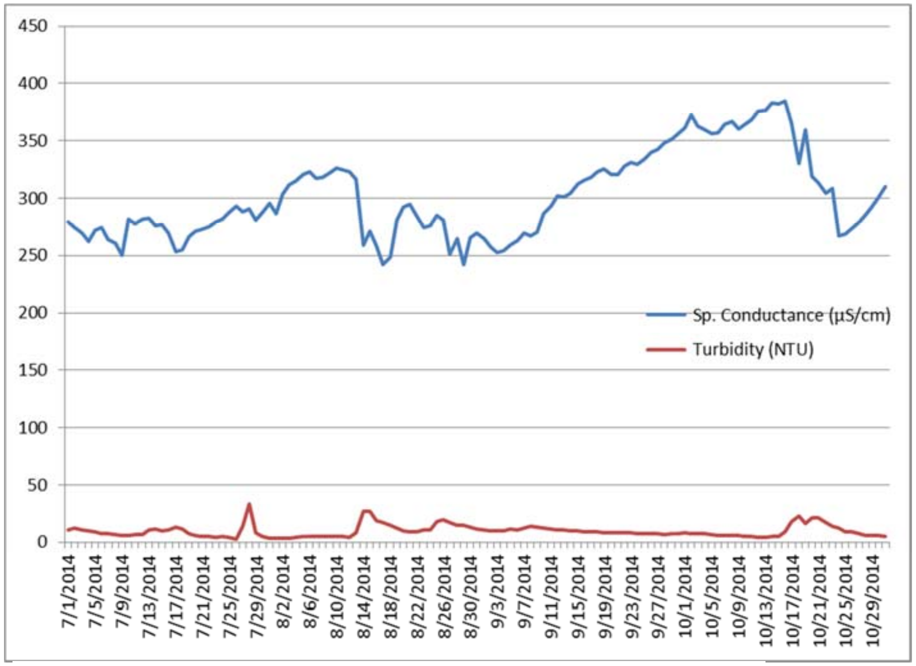

Figure A2c. 2014 Continuous Turbidity and Conductance Data near SUSQ45

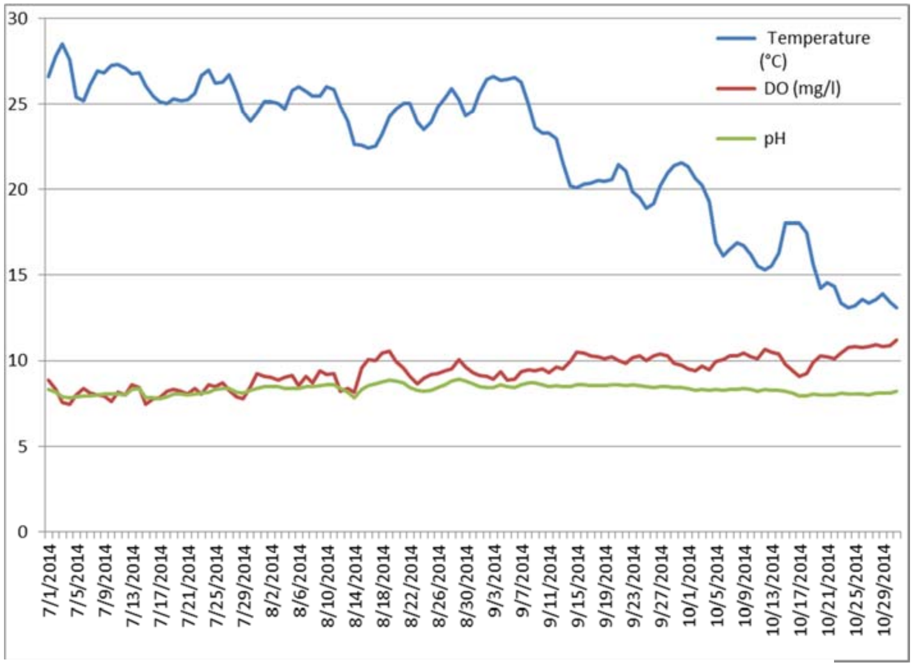

Figure A2d. 2014 Continuous Temperature, pH, and Dissolved Oxygen (DO) Data near SUSQ45

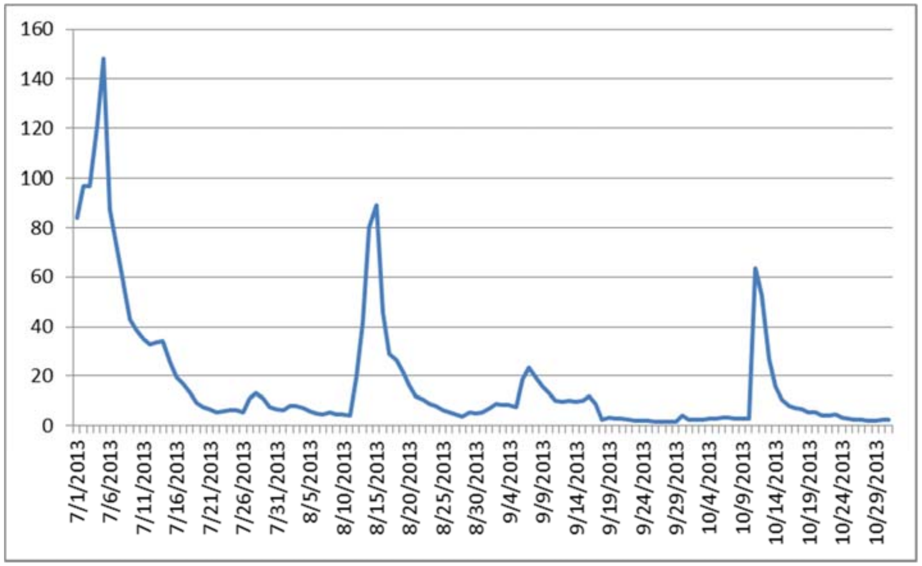

Figure A3a. 2013 Continuous Turbidity Data near SUS77

Figure A3b. 2013 Continuous Temperature, pH, and Dissolved Oxygen (DO) Data near SUSQ77

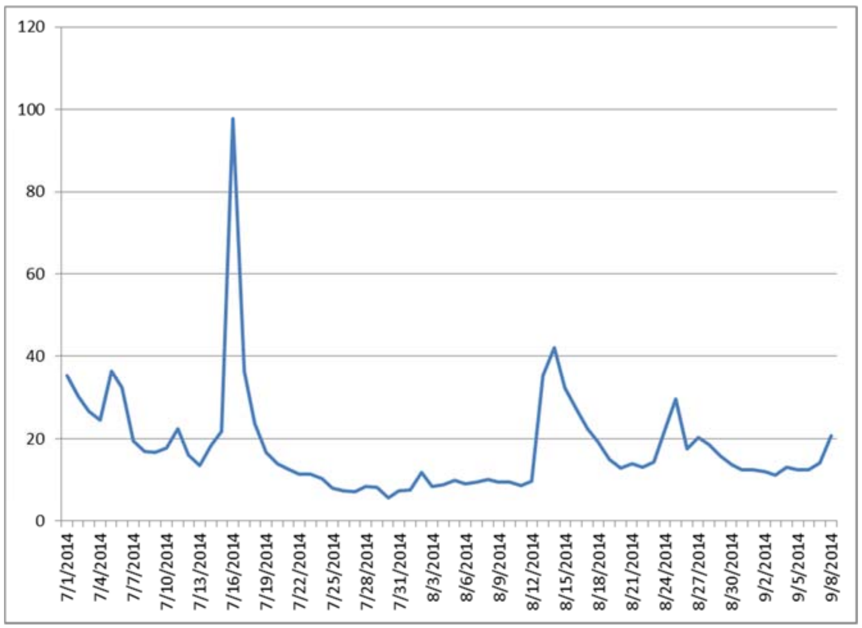

Figure A3c. 2014 Continuous Temperature, pH, and Dissolved Oxygen (DO) Data near SUSQ77

Figure A3d. 2014 Continuous Turbidity Data near SUSQ77

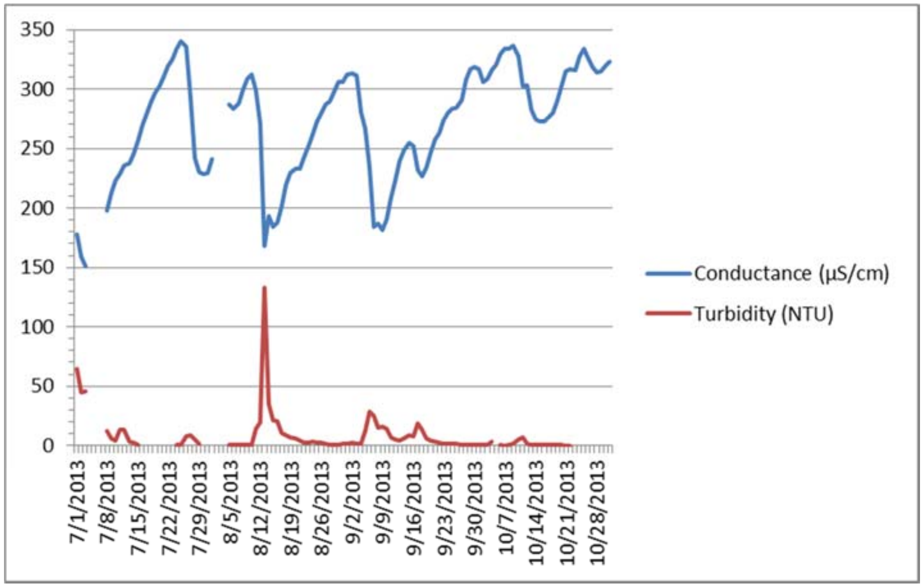

Figure A4a. 2013 Continuous Turbidity and Conductance Data near SUSQ138

Figure A4b. 2013 Continuous Temperature, pH, and Dissolved Oxygen (DO) Data near SUSQ138

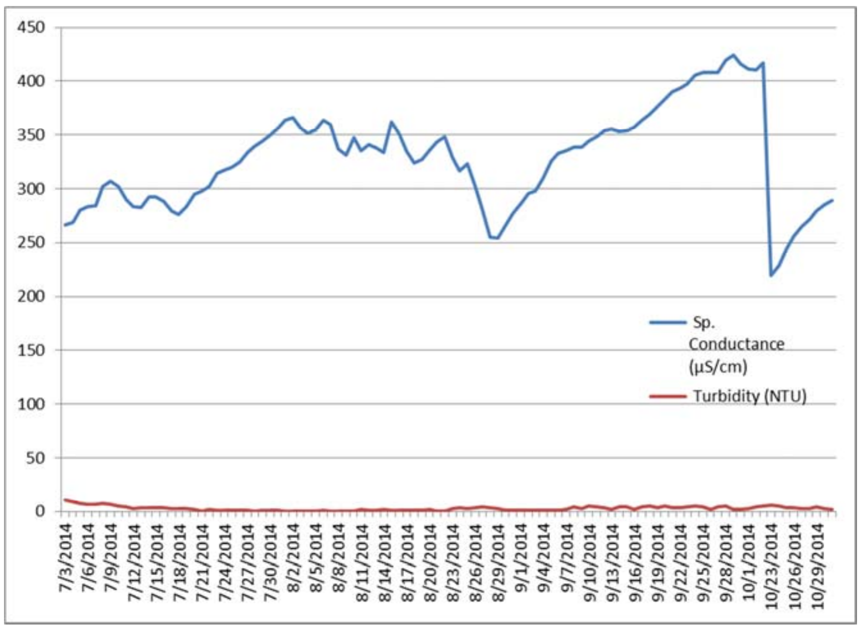

Figure A4c. 2014 Continuous Turbidity and Conductance Data near SUSQ138

Figure A4d. 2014 Continuous Temperature, pH, and Dissolved Oxygen (DO) Data near SUSQ138

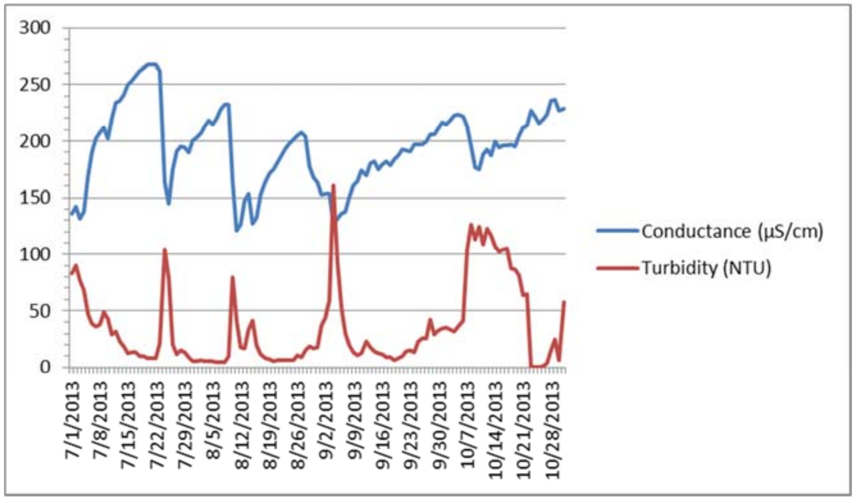

Figure A5a. 2013 Continuous Turbidity and Conductance Data near SUSQ356

Figure A5b. 2013 Continuous Temperature, pH, and Dissolved Oxygen (DO) Data near SUSQ356

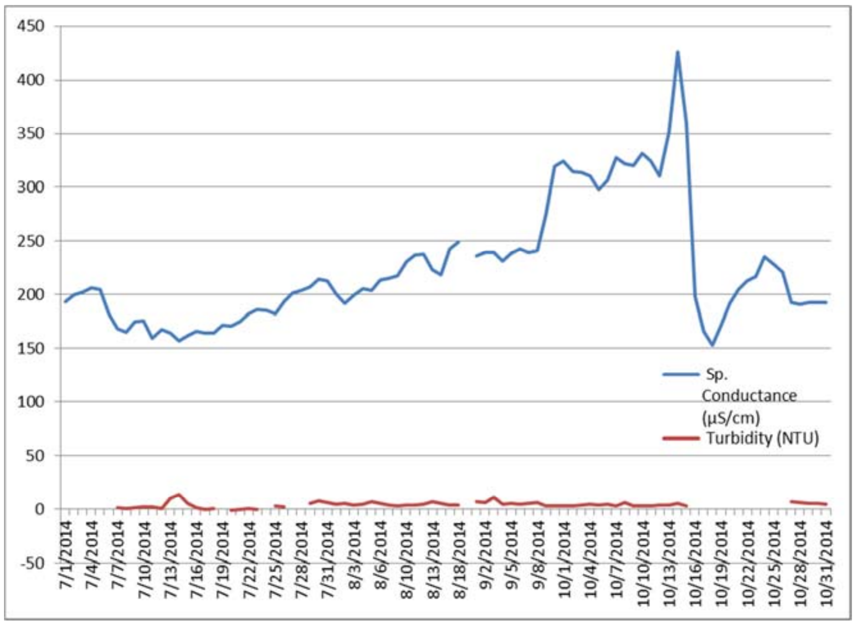

Figure A5c. 2014 Continuous Temperature, pH, and Dissolved Oxygen (DO) Data near SUSQ356

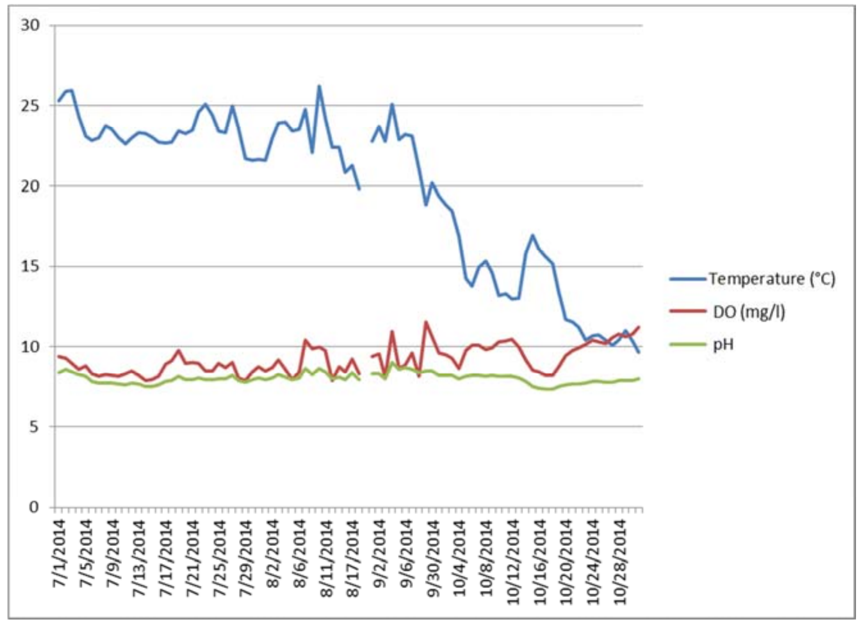

Figure A5d. 2014 Continuous Turbidity and Conductance Data near SUSQ356

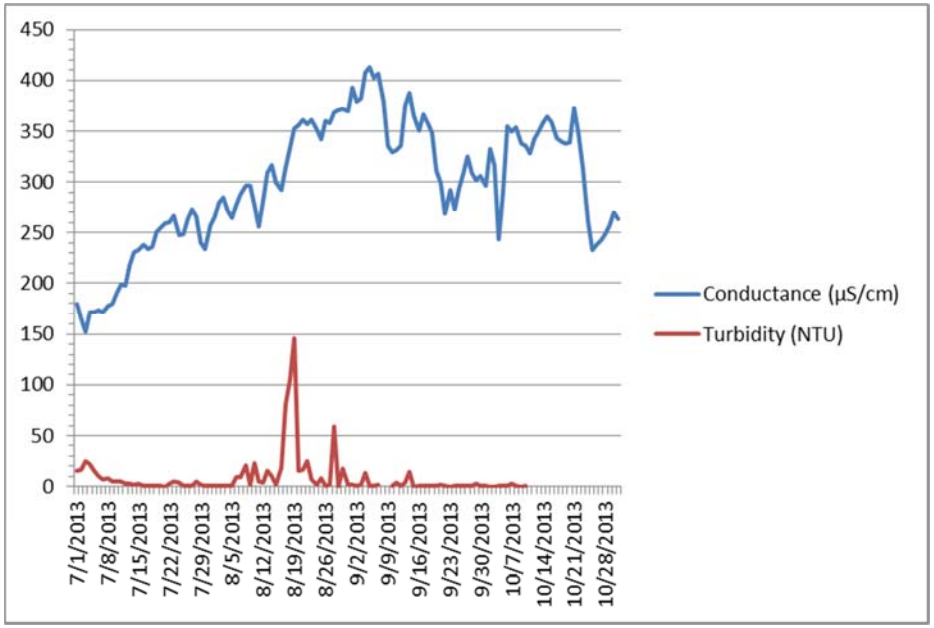

Figure A7a. 2013 Continuous Turbidity and Conductance Data near WBSR5

Figure A7b. 2013 Continuous Temperature, pH, and Dissolved Oxygen (DO) Data near WBSR5

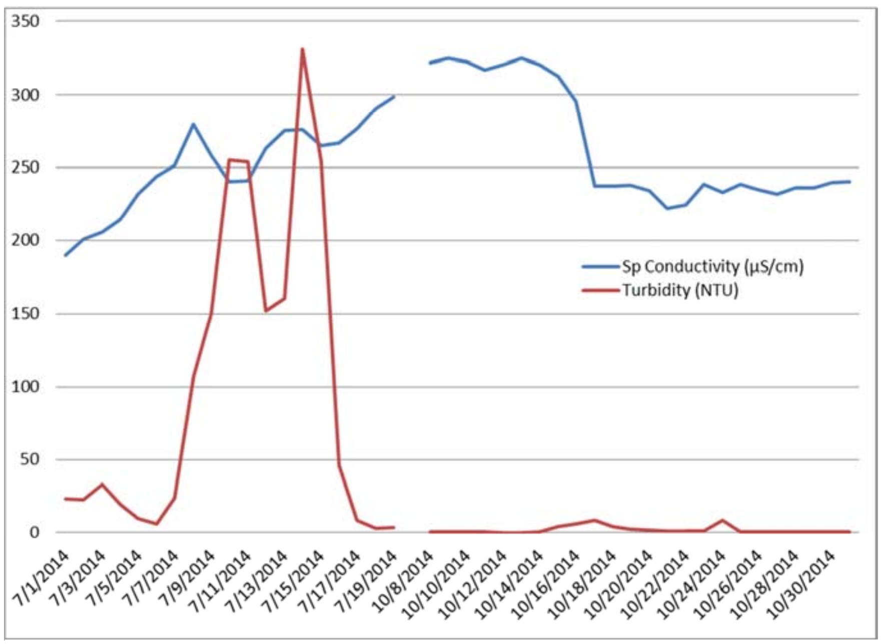

Figure A7c. 2014 Continuous Turbidity and Conductance Data near WBSR5

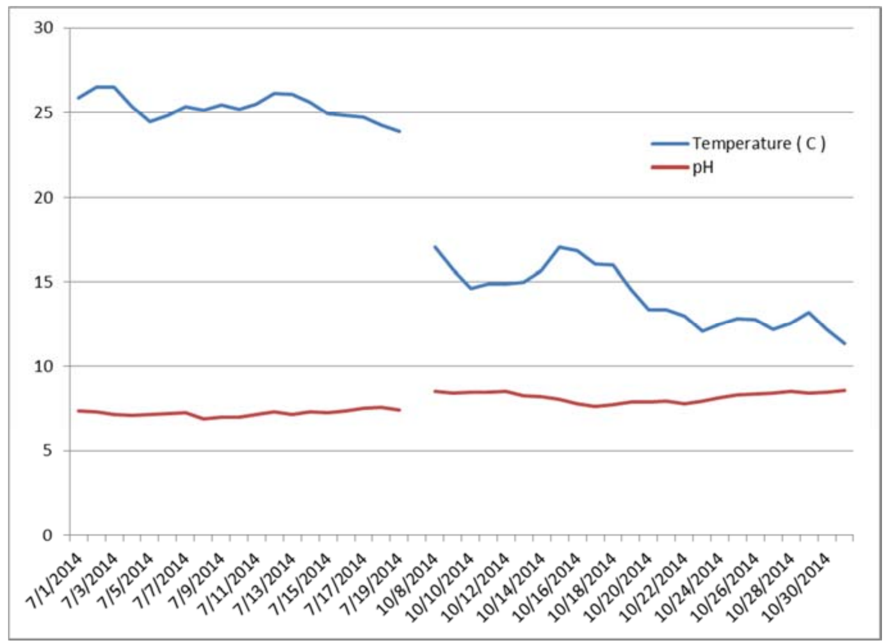

Figure A7d. 2014 Continuous Temperature and pH Data near WBSR5