



pennsylvania

DEPARTMENT OF ENVIRONMENTAL PROTECTION
BUREAU OF CLEAN WATER

Susquehanna River at Marietta, 2013 to 2016 Continuous Instream Monitoring Report

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WATERBODY AND SITE DESCRIPTIONS

Stream Code: 06685

Stream Name: Susquehanna River

HUC: 02050306 – Lower Susquehanna

West Site Description

Site Code: 57465333-001

Site Name: Susquehanna River at Marietta (West)

Latitude: 40.02800

Longitude: -76.5225

Off an abandoned bridge pier island, 80 meters (m) upstream of the State Route 462 bridge and 390 m from the right descending bank

East Site Description

Site Code: 57465333-002

Site Name: Susquehanna River at Marietta (East)

Latitude: 40.03093

Longitude: -76.51265

Off an abandoned bridge pier island, 70 m upstream of the State Route 462 bridge and 225 m from the left descending bank

County: Lancaster

Drainage Area: 67,314 km²

Strahler Stream Order: 8

Designated Use: Warm Water Fishes

BACKGROUND AND HISTORY

The Susquehanna River is the largest tributary to the Chesapeake Bay. The watershed of the Susquehanna River at Marietta, Pennsylvania encompasses much of central Pennsylvania and parts of southcentral New York (Figure 1). Land use varies throughout the watershed with forest dominating the Allegheny Plateau in the upper portions and agriculture becoming more prevalent in the lower parts of the watershed. Overall, land use of the watershed at Marietta consists of 63% forest, 24% agriculture, 8% developed land, and 5% other natural features such as open water and wetlands. The designated aquatic life use of the Susquehanna River at Marietta is Warm Water Fishes (WWF).



Figure 1. Watershed of the Susquehanna River at the Marietta CIM location.

Data collected by Pennsylvania Department of Environmental Protection (DEP) staff in 2012 identified three distinct water quality zones in the Susquehanna River near Rockville, Pennsylvania, approximately 50 km upriver of Marietta location (Hoger 2019). These three water quality zones exist due to the incomplete mixing of the Juniata River, the West Branch Susquehanna River, and the mainstem Susquehanna River (Hoger 2019). The two Marietta continuous instream monitoring (CIM) sites described above

were positioned to determine the mixing patterns in the river downstream of the Rockville CIM sites (Figure 2).

In addition to the CIM site described above, a transect across the width of the river was established in 2013 according to DEP's *In-situ Field Meter and Transect Data Collection Protocol* (Hoger 2018b) to characterize the mixing pattern of the upstream influences in the river. Discrete water quality measurements were taken at 11 equidistant points (MAR1 to MAR11) across the transect starting at the right descending bank (Figure 2). The MAR4 location coincided with the Marietta West CIM site and the MAR9 location coincided with the Marietta East CIM site (Figure 2).

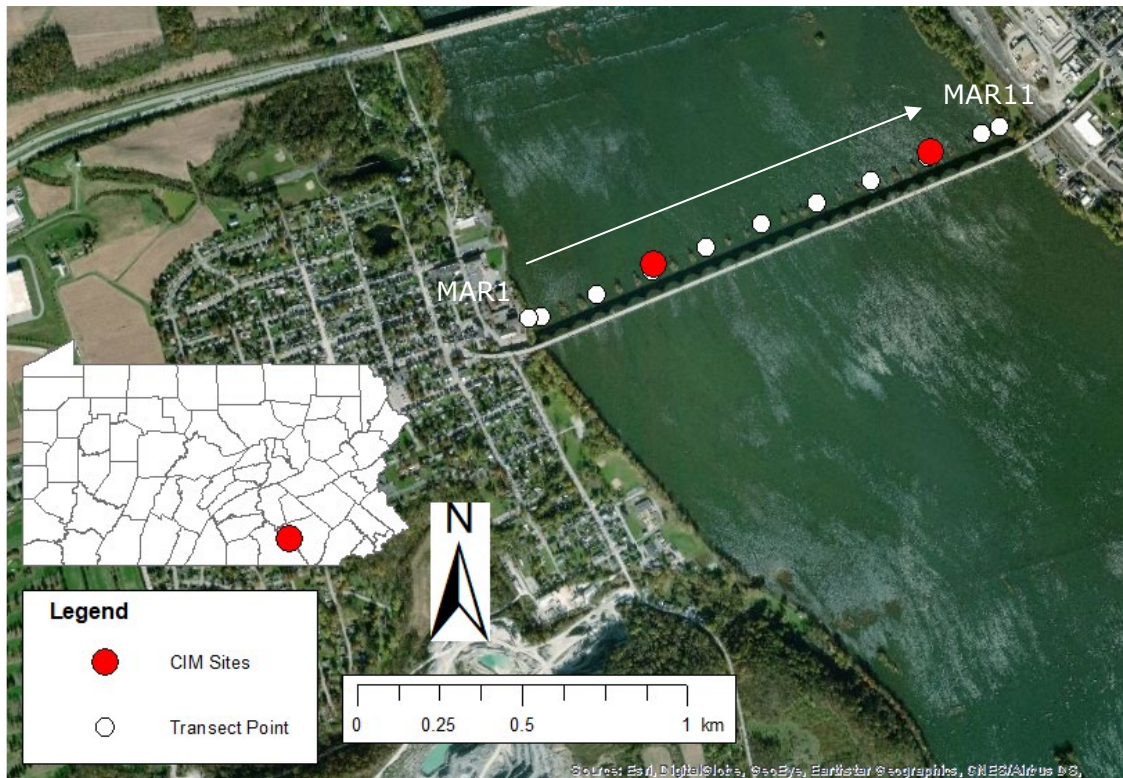


Figure 2. Map of the two Susquehanna River CIM sites and cross-sectional transect sampling locations at Marietta.

Water quality data at these sites were initially collected as part of the Susquehanna River Project investigating health and recruitment issues of smallmouth bass. These sites have since become long-term monitoring stations to inform ongoing studies and trends analyses. This report focuses only on the CIM data and chemical grab samples collected from 2013 to 2016. Other data collected at this location include benthic macroinvertebrate and fish community surveys, periphyton and algal analyses, and analyses of emerging contaminants in sediment and water.

PRIMARY OBJECTIVES

The primary objective of this report is to characterize temporal and spatial patterns in various physical and chemical water quality parameters in the Susquehanna River at Marietta.

WATER QUALITY PARAMETERS

Five water quality parameters were measured using CIM at the Marietta site (Table 1).

Table 1. Water quality parameters monitored by CIM.

Parameter	Units
Water Temperature	°C
Specific Conductance (@ 25°C)	µS/cm ^c
pH	Standard Units (SU)
Dissolved Oxygen (DO)	mg/L
Turbidity	Formazin Nephelometric Unit (FNU)

EQUIPMENT

Water quality sondes from Eureka and Yellow Springs Instruments (YSI) were used to collect CIM data at both sites in 2013 and 2014. In 2015, YSI 6920 V2s sondes were used. In 2016, YSI EXO2s sondes were used.

In 2013 and 2014, sondes were housed in a 24-inch length of 4-inch diameter schedule 80 PVC pipe with holes drilled to allow water to flow through the pipe. One end of the pipe was capped, and a notch was cut to accommodate the metal attachment bar on the top of the sondes. The attachment bars were clipped to an eye-bolt attached to rebar driven into the river bed. The attachment bars were also clipped to a cable attached to a second piece of rebar located just upstream of the first.

The west site deployment was changed in 2015 to improve accessibility of the sonde in variable flow conditions and to reduce equipment fouling. A 10-foot length of 4-inch diameter PVC pipe was anchored to large rocks that remain in the river bed from an abandoned bridge pier, creating a chute to slide the sonde into. Cables were attached to the sonde and then to pins driven into the river bed to facilitate retrieval of the sonde from the pipe.

PERIOD OF RECORD

Continuous data were recorded from late winter or spring until late fall near the time when the macroinvertebrate sample was collected in November or December each year, except in 2013 when the sonde was removed in September (Table 2). Sondes were deployed earlier each year to document changes in water quality near the beginning of each growing season. Each year, sondes were removed before winter to prevent damage from ice. The sonde was visited several times throughout each

deployment period to download data, to check calibration, and for cleaning. Each sonde recorded water quality parameter measurements once every 30 minutes. Turbidity was not recorded in 2013.

Table 2. Continuous data period of record.

Year	Deployment	Removal
2013	May 24	September 18
2014	April 30	December 15
2015	March 13	December 03
2016	March 07	November 17

DATA

Cross-Sectional Surveys

To monitor variations in the water quality across the river throughout the year, cross-sectional transect surveys were conducted several times each year at various flows. Cross-section survey data were analyzed by comparing each survey point to MAR5, one of the midpoints of the transect (Figure 3). MAR5 was selected as the reference site because, as a central point, it is least likely to be influenced by local tributaries. For temperature and pH, the difference in readings between MAR5 and each transect point was considered significant if the difference was greater than 0.5 units. For specific conductance, DO, and turbidity, this difference was considered significant if it was greater than 10% of MAR5. When transects were conducted when turbidity was low (less than 10 FNU), a difference of one FNU was equivalent to a 10% difference.

Continuous Monitoring

Continuous data were collected and evaluated following DEP’s *Continuous Physicochemical Data Collection Protocol* (Hoger et al. 2018). Grades and corrections were based on a combined evaluation of sensor fouling and calibration error. Gaps in the CIM data are attributable either to equipment or battery failure or to removal of data that did not meet usability standards due to excessive sensor fouling or calibration error. Annual CIM data at both sites are charted together to illustrate cross-sectional differences in water quality (Figures 4 to 22). Due to year-to-year differences in the timing of data collection and to data missing from one site but not the other, comparison of the summary CIM data should be made with caution.

River discharge data from the United States Geological Survey (USGS) station 01576000, Susquehanna River at Marietta, Pennsylvania are provided, in cubic feet per second (cfs), alongside the CIM data (Figures 4 to 22). This USGS gaging station is located approximately 3.1 river kilometers upstream of the Marietta CIM sites.

Discrete Water Chemistry Sampling

Grab samples were collected several times each year at each of the two Marietta CIM sites (Table 3) according to DEP’s *Discrete Water Chemistry Data Collection Protocol* (Shull 2013). Initial grab samples were analyzed using DEP’s standard analysis code (SAC) 612, which includes general chemistry parameters, dissolved and total nutrients,

and total metals. Beginning in 2014, dissolved metals were added to the suite of analytes for many grab samples. In 2016, the discrete samples were analyzed using the newly created SAC 087, which is SAC 612 plus the dissolved metals analytes. SAC 618 and SAC 779 were used to obtain concentrations of suspended sediment and acid-soluble aluminum, respectively. A complete list of grab sample analytes can be found in Table 3.

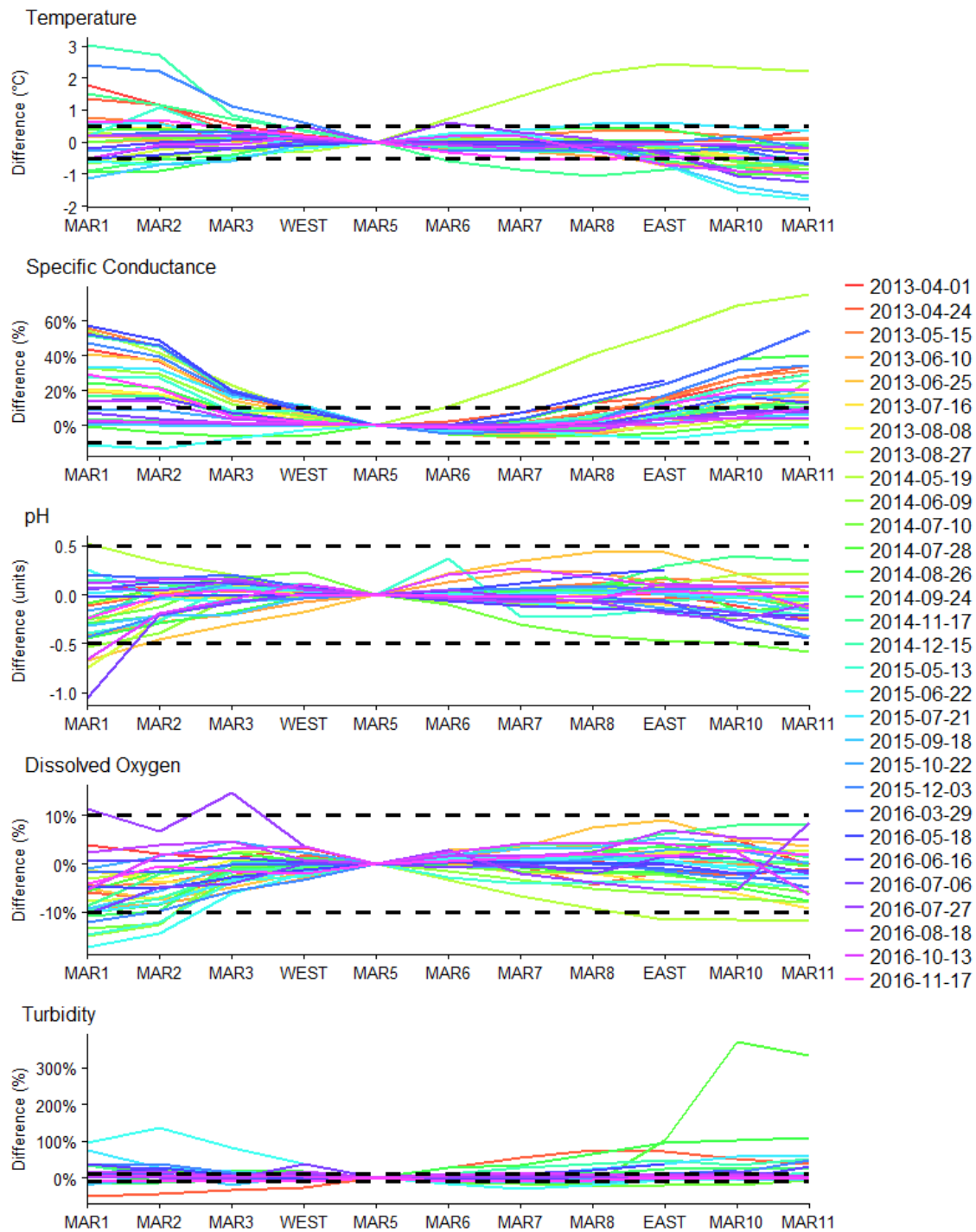


Figure 3. Cross-section surveys at Marietta showing relative difference in readings compared to MAR5 over four years. Dashed, black lines indicate thresholds of significance.

2013 Water Temperature:

<i>West</i>	Min: 16.24 °C	Average: 21.95 °C	Max: 32.78 °C
<i>East</i>	Min: 15.49 °C	Average: 21.35 °C	Max: 32.61 °C

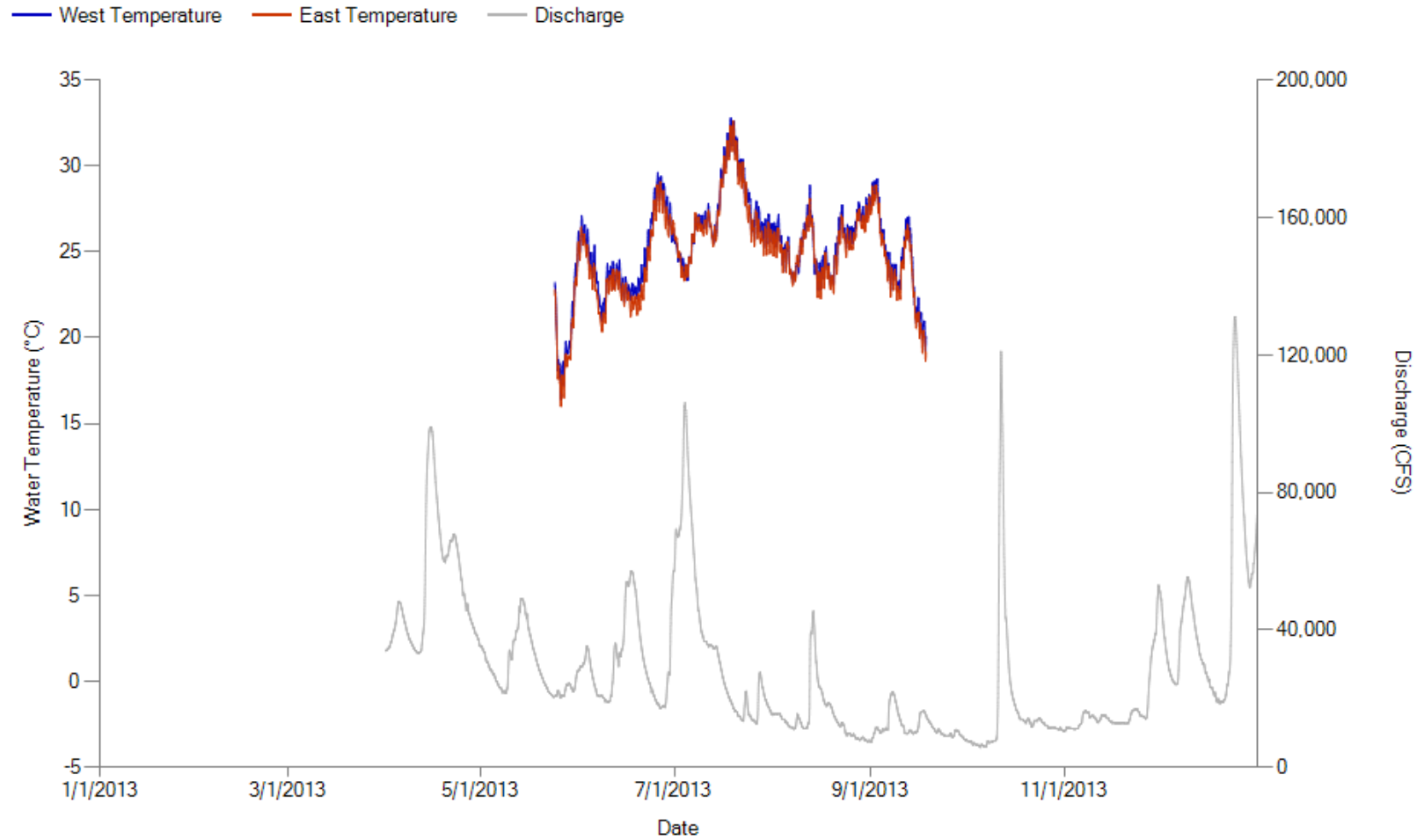


Figure 4. Continuous water temperature (°C) and discharge (cfs) at the two Marietta sites from May 24, 2013 to September 18, 2013.

2014 Water Temperature:

<i>West</i>	Min: 1.27 °C	Average: 16.50 °C	Max: 29.74 °C
<i>East</i>	Min: 0.49 °C	Average: 16.08 °C	Max: 29.69 °C

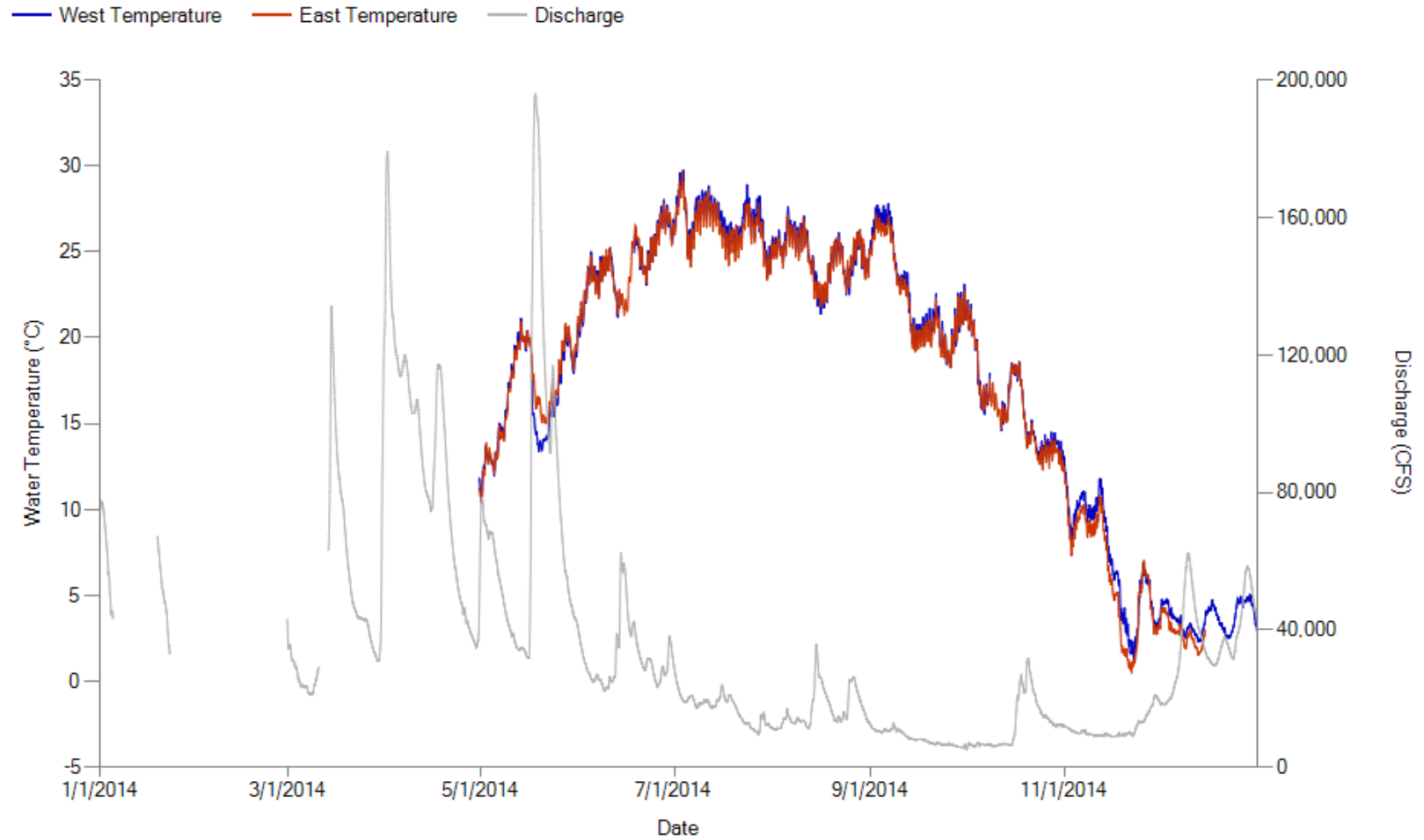


Figure 5. Continuous water temperature (°C) and discharge (cfs) at the two Marietta sites from April 30, 2014 to December 15, 2014.

2015 Water Temperature: *West* Min: -0.09 °C Average: 14.01 °C Max: 30.63 °C
 East Min: -0.03 °C Average: 13.98 °C Max: 30.33 °C

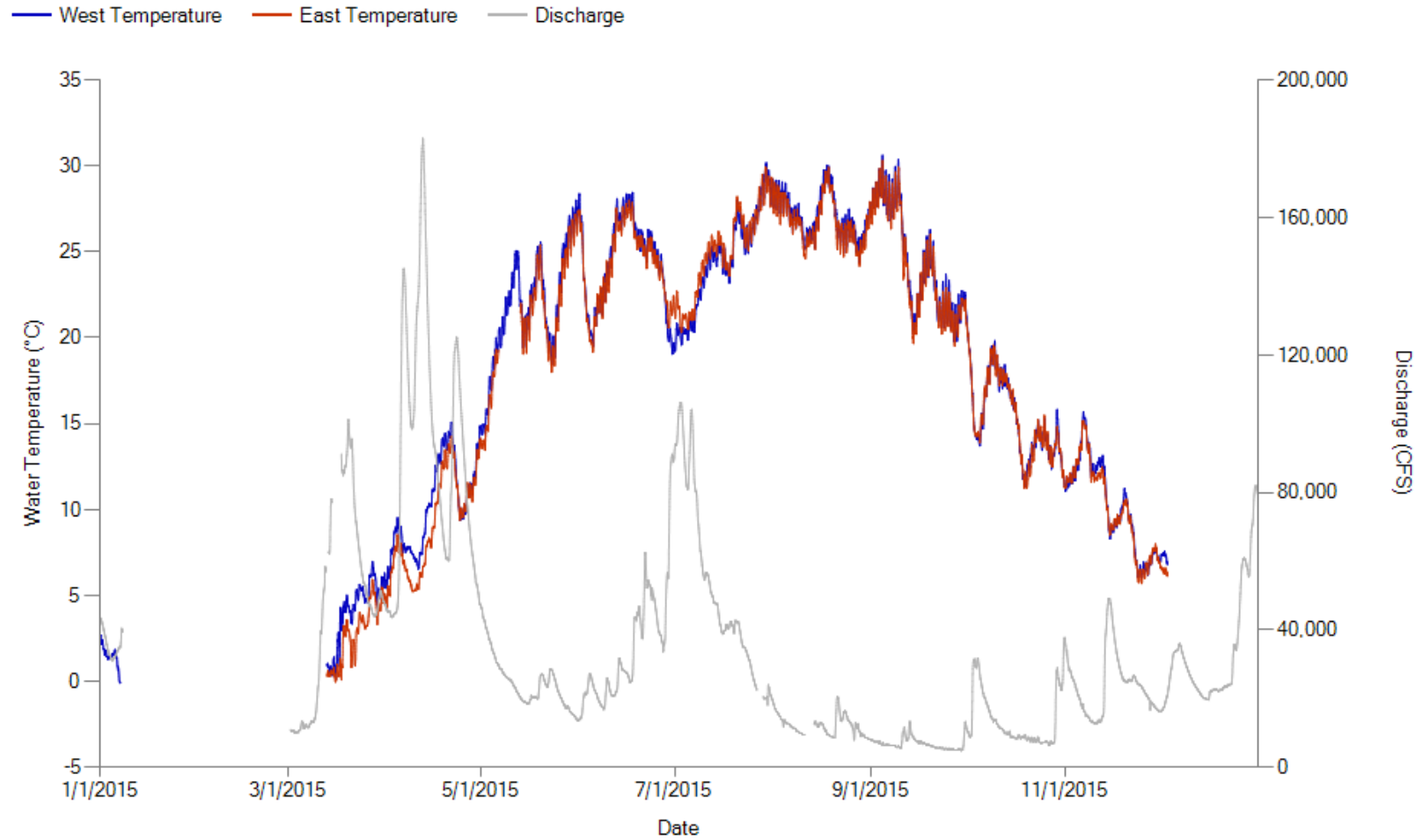


Figure 6. Continuous water temperature (°C) and discharge (cfs) at the two Marietta sites from March 13, 2015 to December 3, 2015.

2016 Water Temperature:

<i>West</i>	Min: 5.05 °C	Average: 16.07 °C	Max: 32.69 °C
<i>East</i>	Min: 4.94 °C	Average: 16.96 °C	Max: 32.23 °C

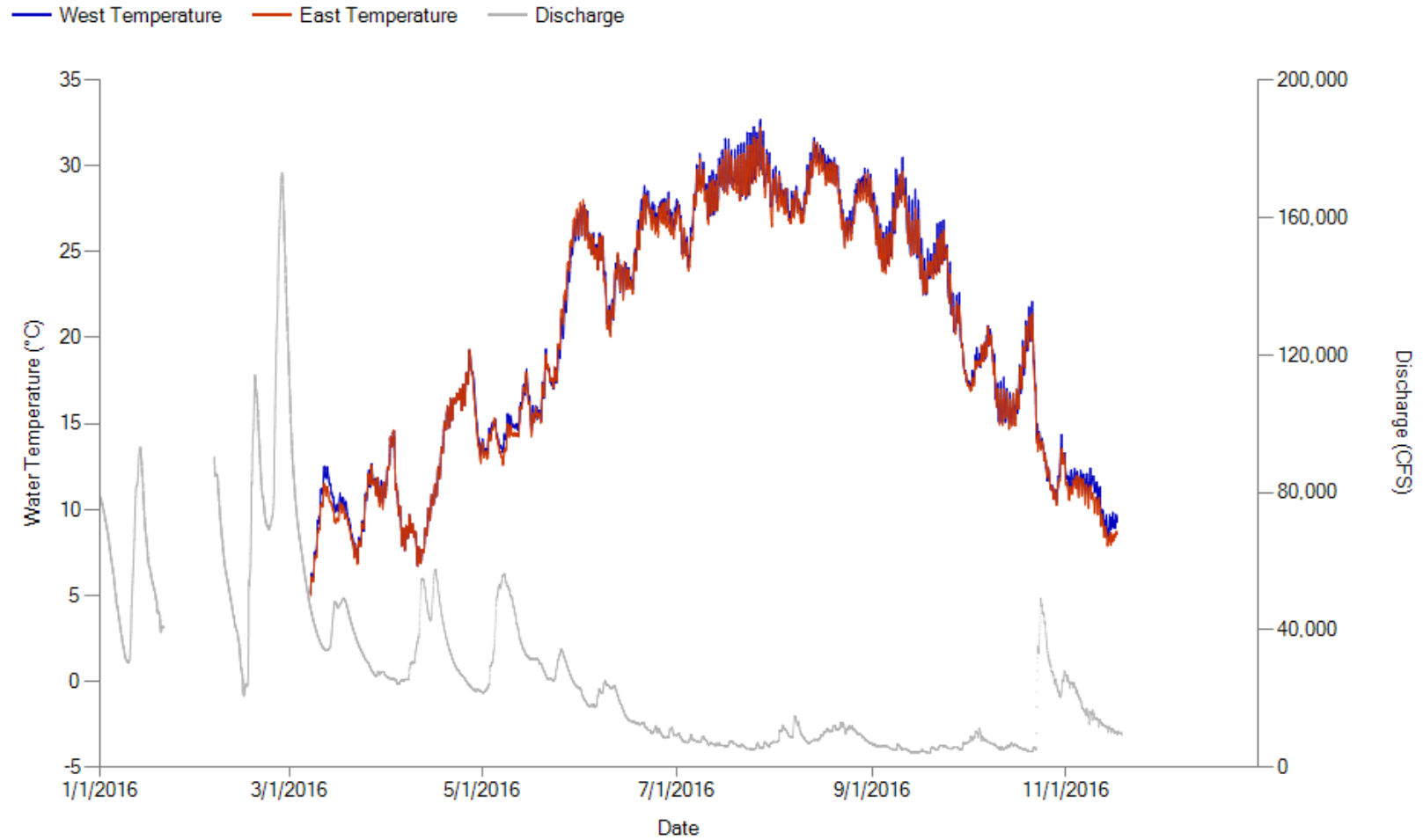


Figure 7. Continuous water temperature (°C) and discharge (cfs) at the two Marietta sites from March 7, 2016 to November 17, 2016.

2013 Specific Conductance: *West* Min: 157.1 $\mu\text{S}/\text{cm}^\circ$ Average: 260.4 $\mu\text{S}/\text{cm}^\circ$ Max: 333.9 $\mu\text{S}/\text{cm}^\circ$
East Min: 150.6 $\mu\text{S}/\text{cm}^\circ$ Average: 251.6 $\mu\text{S}/\text{cm}^\circ$ Max: 337.6 $\mu\text{S}/\text{cm}^\circ$

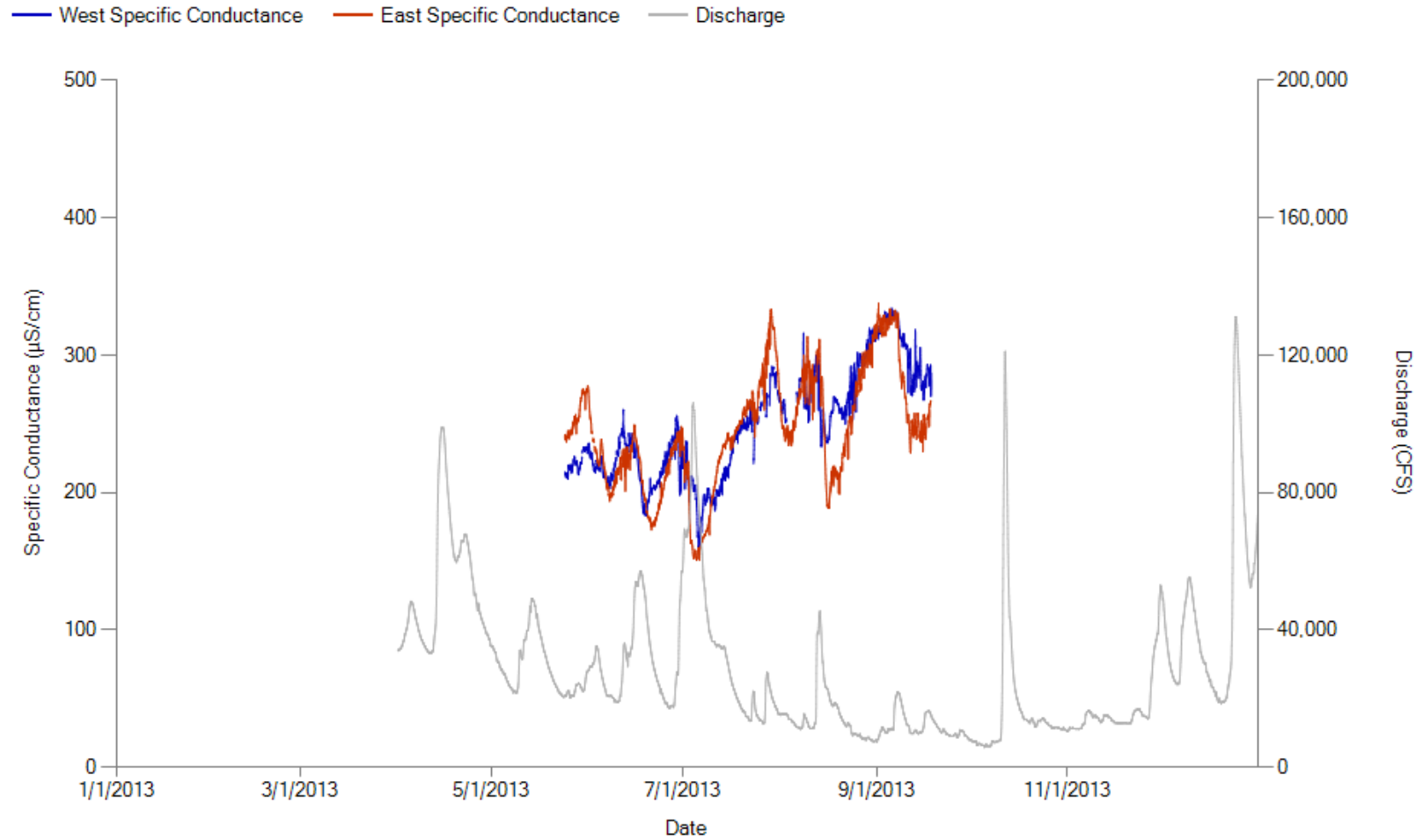


Figure 8. Continuous specific conductance ($\mu\text{S}/\text{cm}^\circ$) and discharge (cfs) at the two Marietta sites from May 24, 2013 to September 18, 2013.

2014 Specific Conductance: *West* Min: 116.3 $\mu\text{S}/\text{cm}^\circ$ Average: 262.4 $\mu\text{S}/\text{cm}^\circ$ Max: 387.9 $\mu\text{S}/\text{cm}^\circ$
East Min: 150.0 $\mu\text{S}/\text{cm}^\circ$ Average: 272.4 $\mu\text{S}/\text{cm}^\circ$ Max: 406.0 $\mu\text{S}/\text{cm}^\circ$

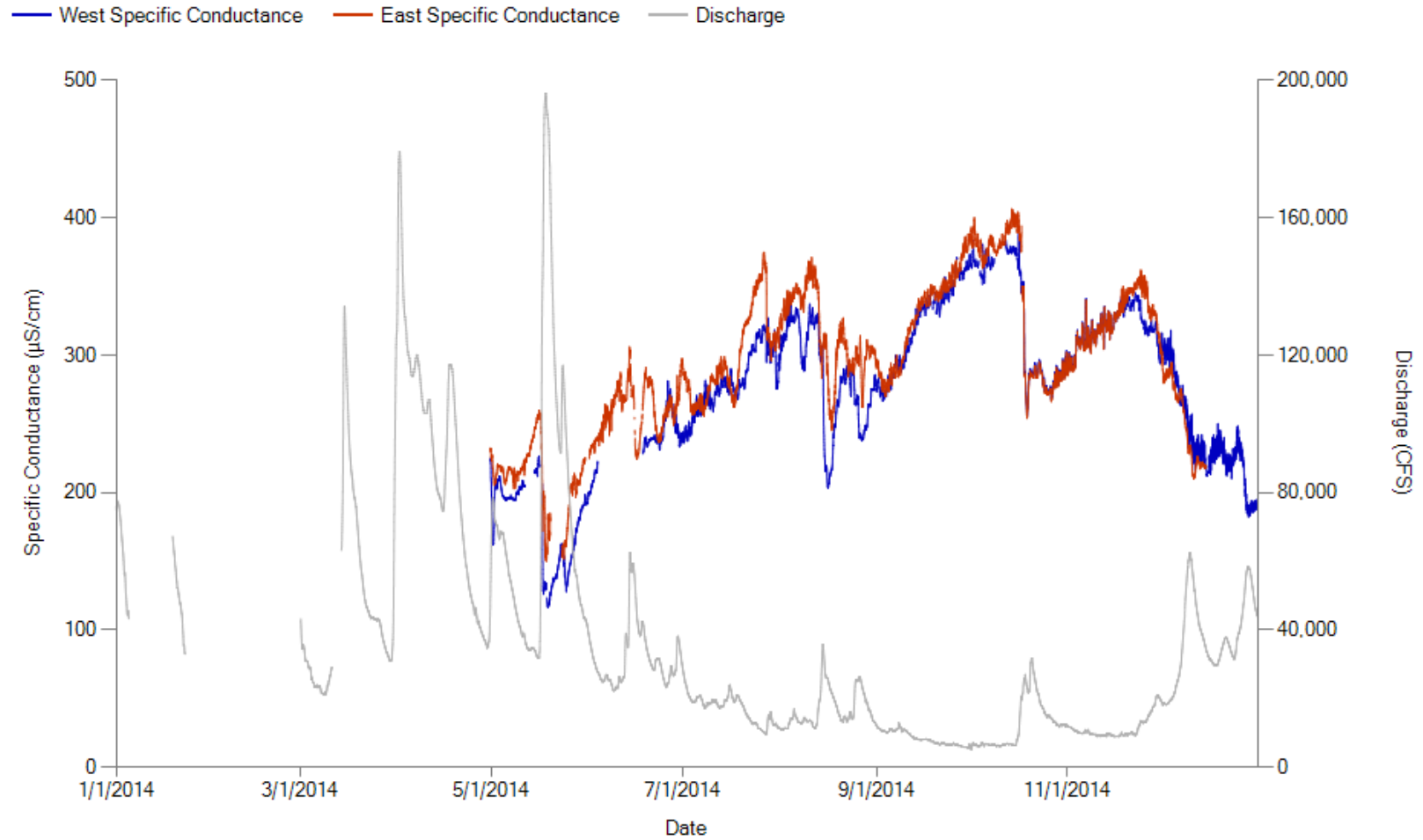


Figure 9. Continuous specific conductance ($\mu\text{S}/\text{cm}^\circ$) and discharge (cfs) at the two Marietta sites from April 30, 2014 to December 15, 2014.

2015 Specific Conductance: *West* Min: 117.1 $\mu\text{S}/\text{cm}^\circ$ Average: 258.3 $\mu\text{S}/\text{cm}^\circ$ Max: 457.6 $\mu\text{S}/\text{cm}^\circ$
East Min: 132.9 $\mu\text{S}/\text{cm}^\circ$ Average: 283.1 $\mu\text{S}/\text{cm}^\circ$ Max: 456.0 $\mu\text{S}/\text{cm}^\circ$

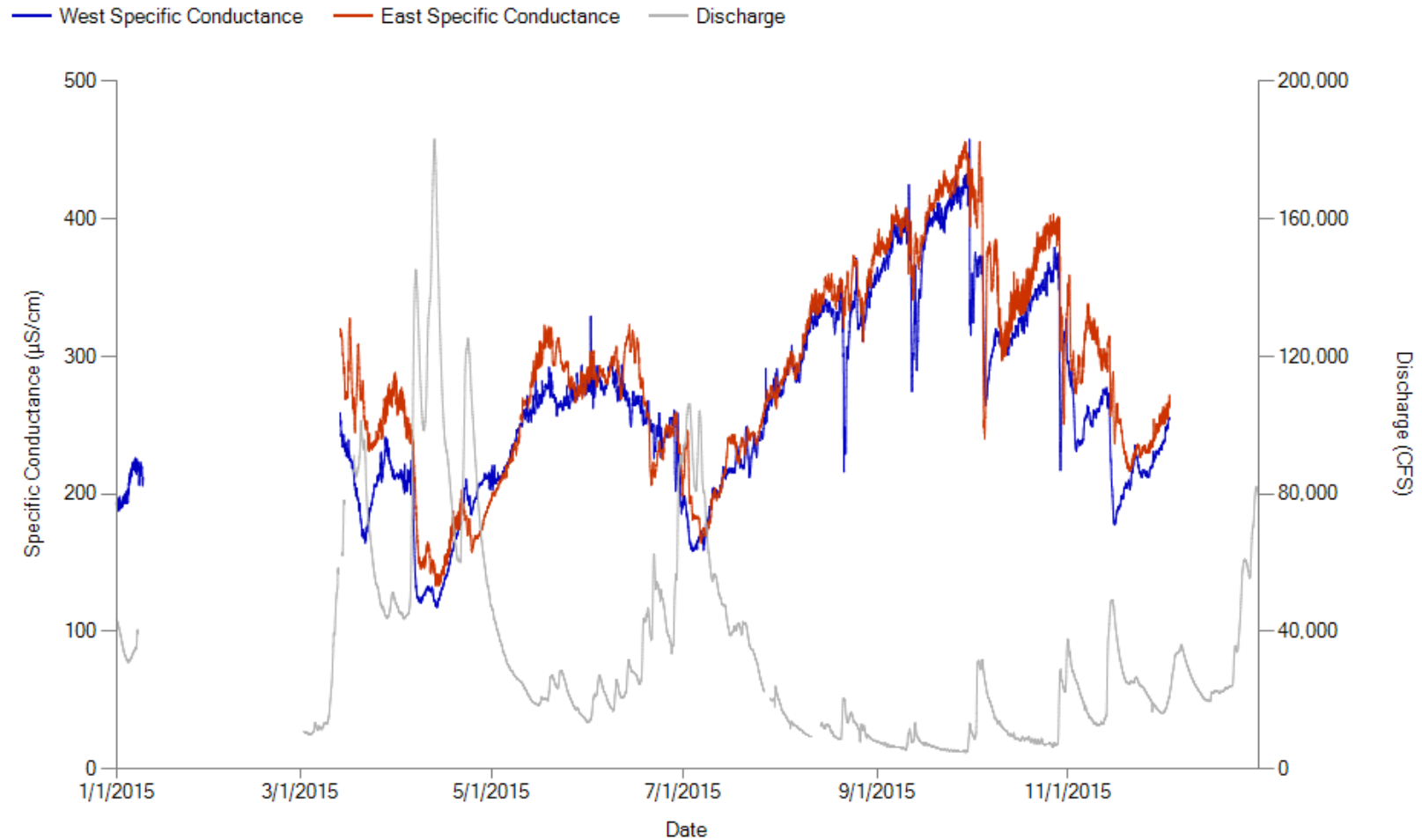


Figure 10. Continuous specific conductance ($\mu\text{S}/\text{cm}^\circ$) and discharge (cfs) at the two Marietta sites from March 13, 2015 to December 3, 2015.

2016 Specific Conductance: *West* Min: 171.1 $\mu\text{S}/\text{cm}^\circ$ Average: 258.3 $\mu\text{S}/\text{cm}^\circ$ Max: 439.5 $\mu\text{S}/\text{cm}^\circ$
East Min: 181.1 $\mu\text{S}/\text{cm}^\circ$ Average: 287.4 $\mu\text{S}/\text{cm}^\circ$ Max: 445.5 $\mu\text{S}/\text{cm}^\circ$

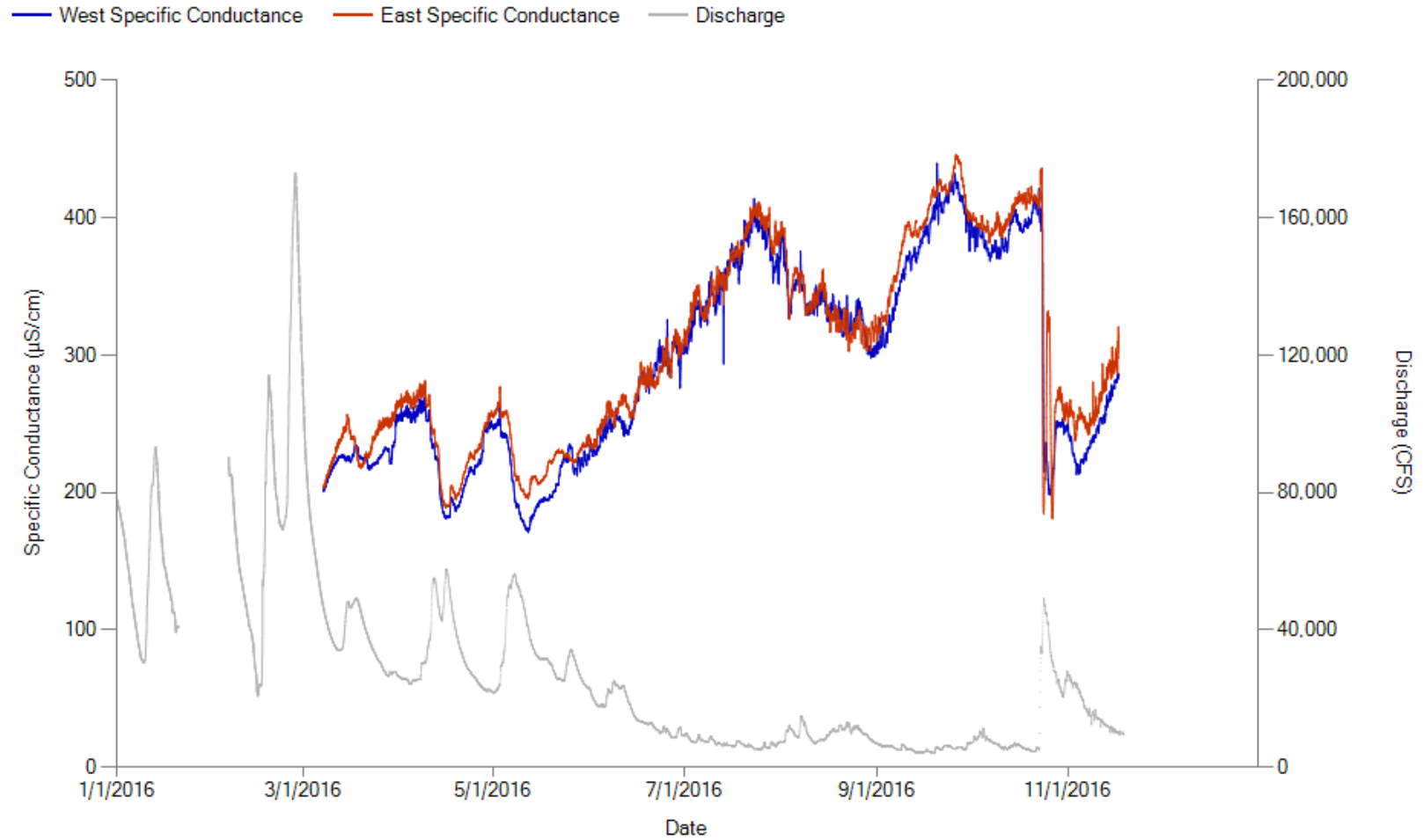


Figure 11. Continuous specific conductance ($\mu\text{S}/\text{cm}^\circ$) and discharge (cfs) at the two Marietta sites from March 7, 2016 to November 17, 2016.

2013 pH:

<i>West</i>	Min: 7.23 SU	Average: 8.04 SU	Max: 8.90 SU
<i>East</i>	Min: 7.09 SU	Average: 7.85 SU	Max: 8.99 SU

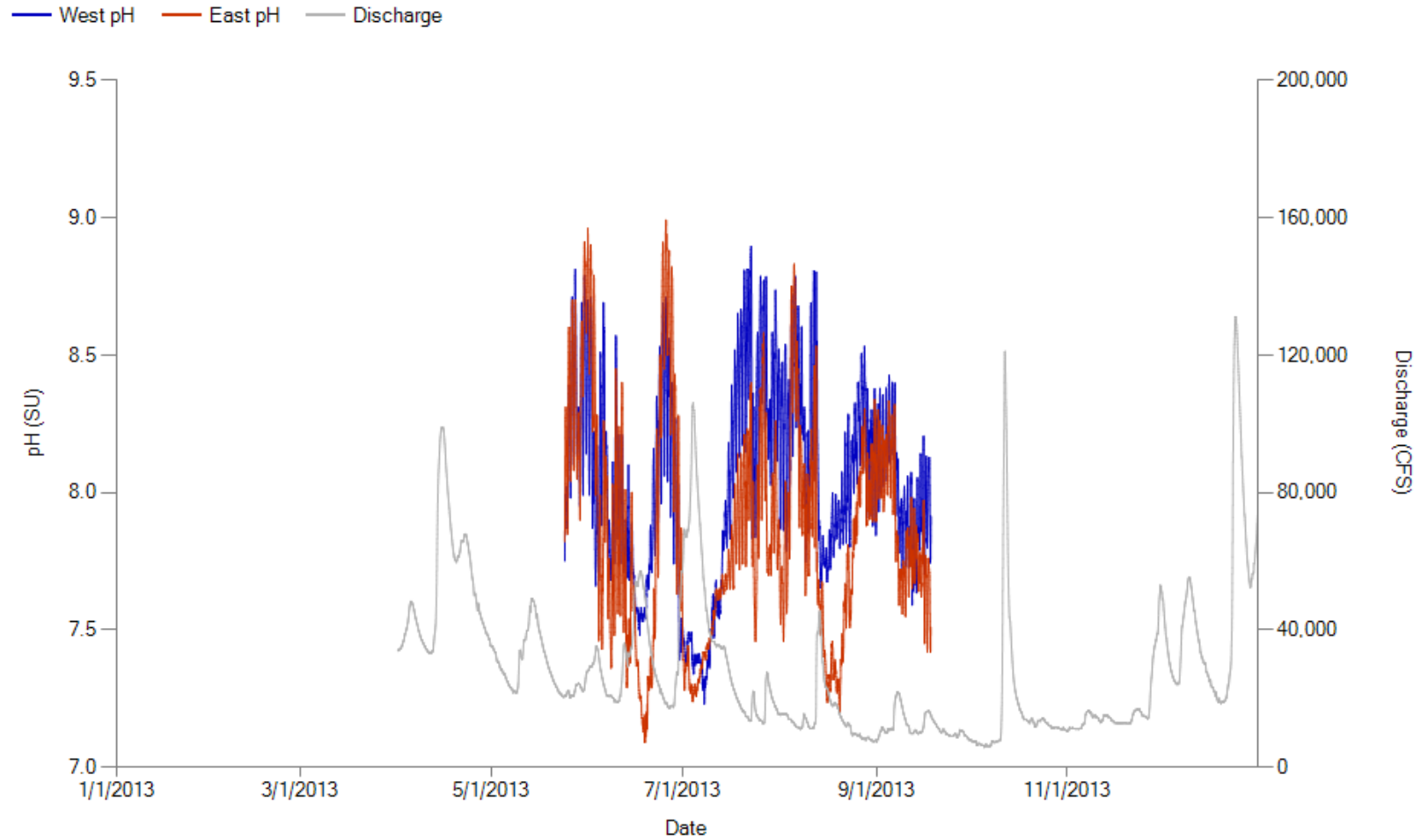


Figure 12. Continuous pH and discharge (cfs) at the two Marietta sites from May 24, 2013 to September 18, 2013.

2014 pH:

<i>West</i>	Min: 7.28 SU	Average: 8.36 SU	Max: 9.36 SU
<i>East</i>	Min: 7.28 SU	Average: 8.31 SU	Max: 9.17 SU

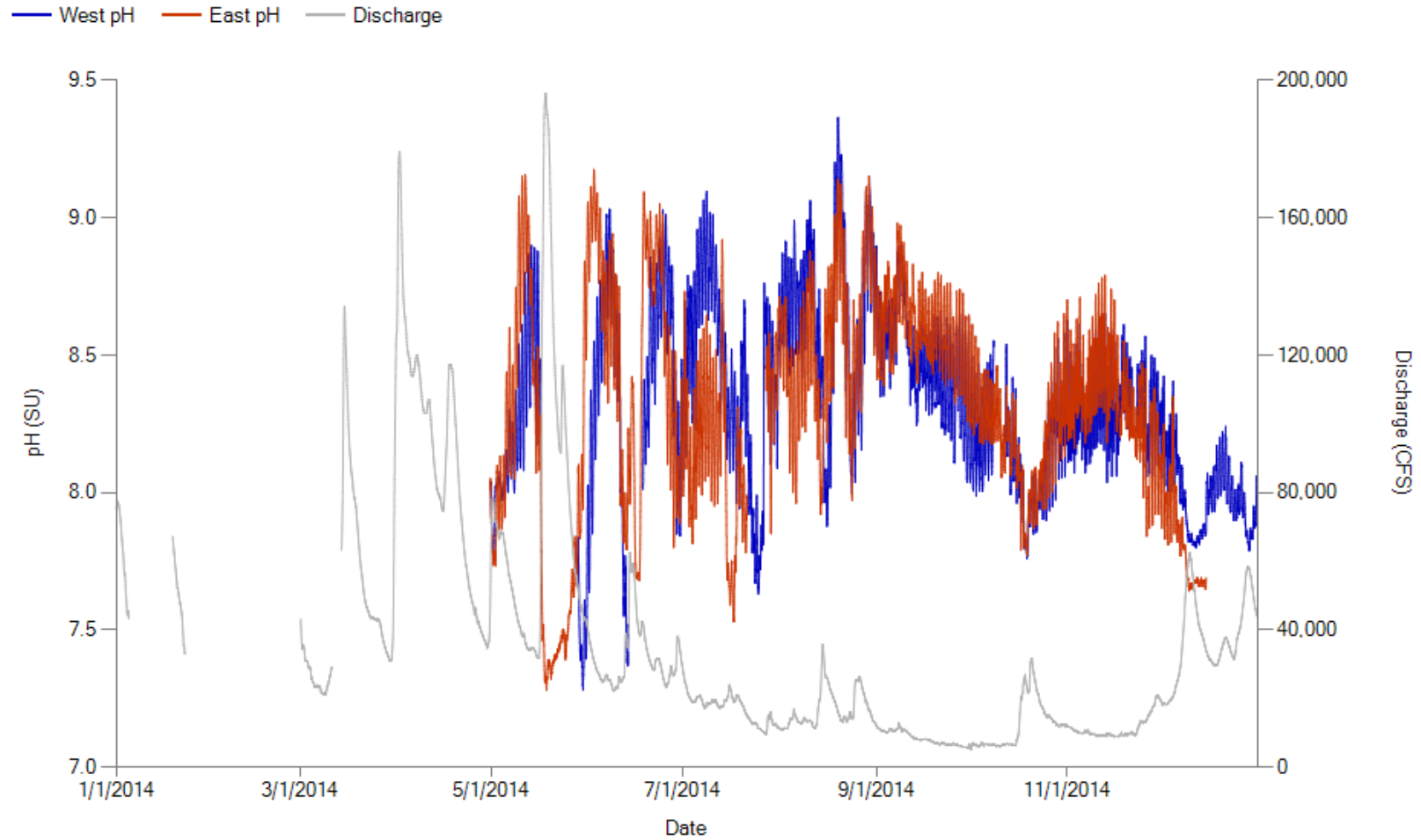


Figure 13. Continuous pH and discharge (cfs) at the two Marietta sites from April 30, 2014 to December 15, 2014.

2015 pH:

West
East

Min: 7.36 SU
Min: 7.35 SU

Average: 8.15 SU
Average: 8.09 SU

Max: 9.13 SU
Max: 9.15 SU

— West pH — East pH — Discharge

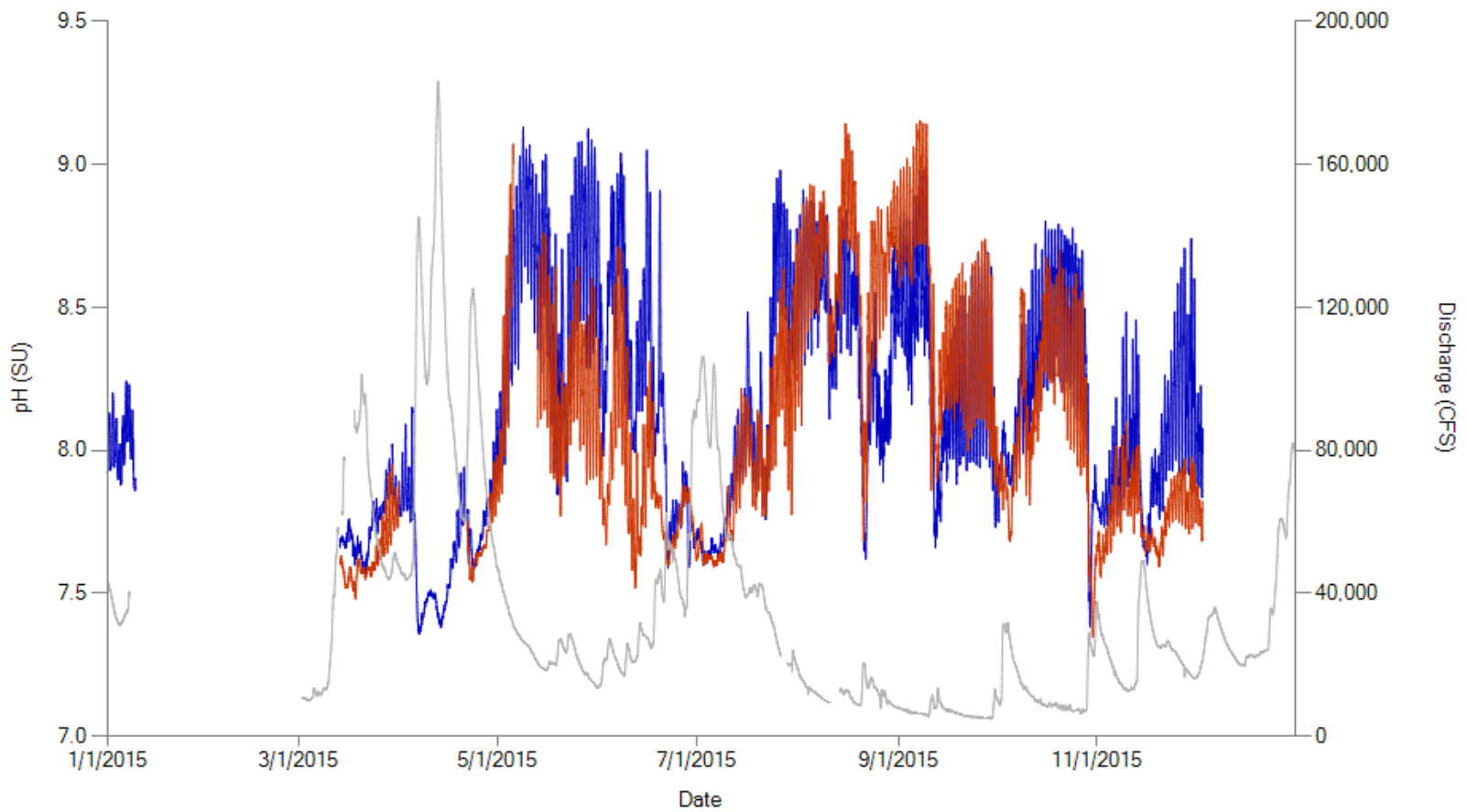


Figure 14. Continuous pH and discharge (cfs) at the two Marietta sites from March 13, 2015 to December 3, 2015.

2016 pH:

West
East

Min: 7.43 SU
Min: 7.36 SU

Average: 8.13 SU
Average: 8.13 SU

Max: 9.04 SU
Max: 8.95 SU

— West pH — East pH — Discharge

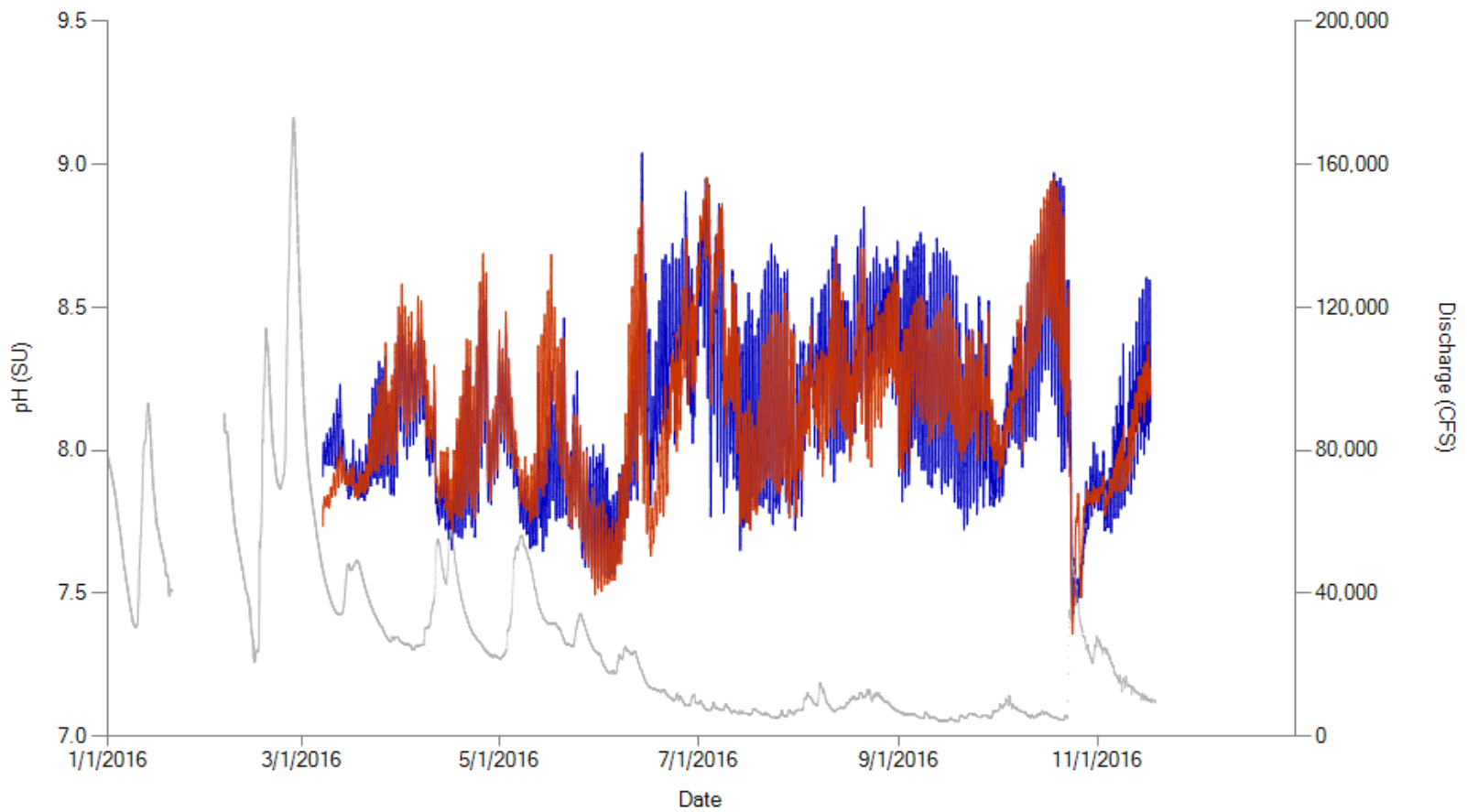


Figure 15. Continuous pH and discharge (cfs) at the two Marietta sites from March 7, 2016 to November 17, 2016

2013 Dissolved Oxygen:

<i>West</i>	Min: 6.12 mg/L	Average: 8.94 mg/L	Max: 11.06 mg/L
<i>East</i>	Min: 6.07 mg/L	Average: 8.98 mg/L	Max: 12.39 mg/L

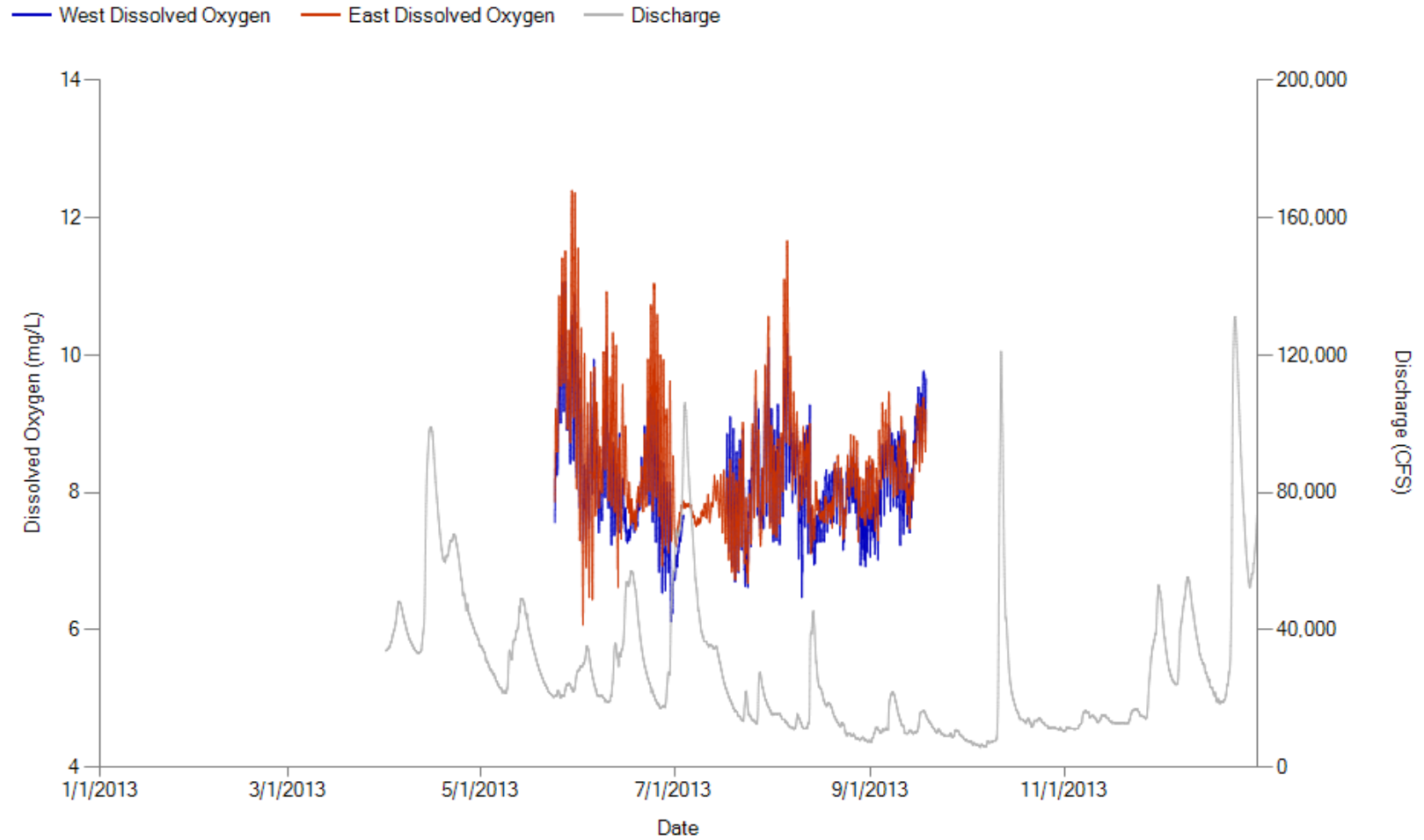


Figure 16. Continuous dissolved oxygen (mg/L) and discharge (cfs) at the two Marietta sites from May 24, 2013 to September 18, 2013.

2014 Dissolved Oxygen:

<i>West</i>	Min: 6.77 mg/L	Average: 10.26 mg/L	Max: 15.43 mg/L
<i>East</i>	Min: 6.62 mg/L	Average: 10.40 mg/L	Max: 15.17 mg/L

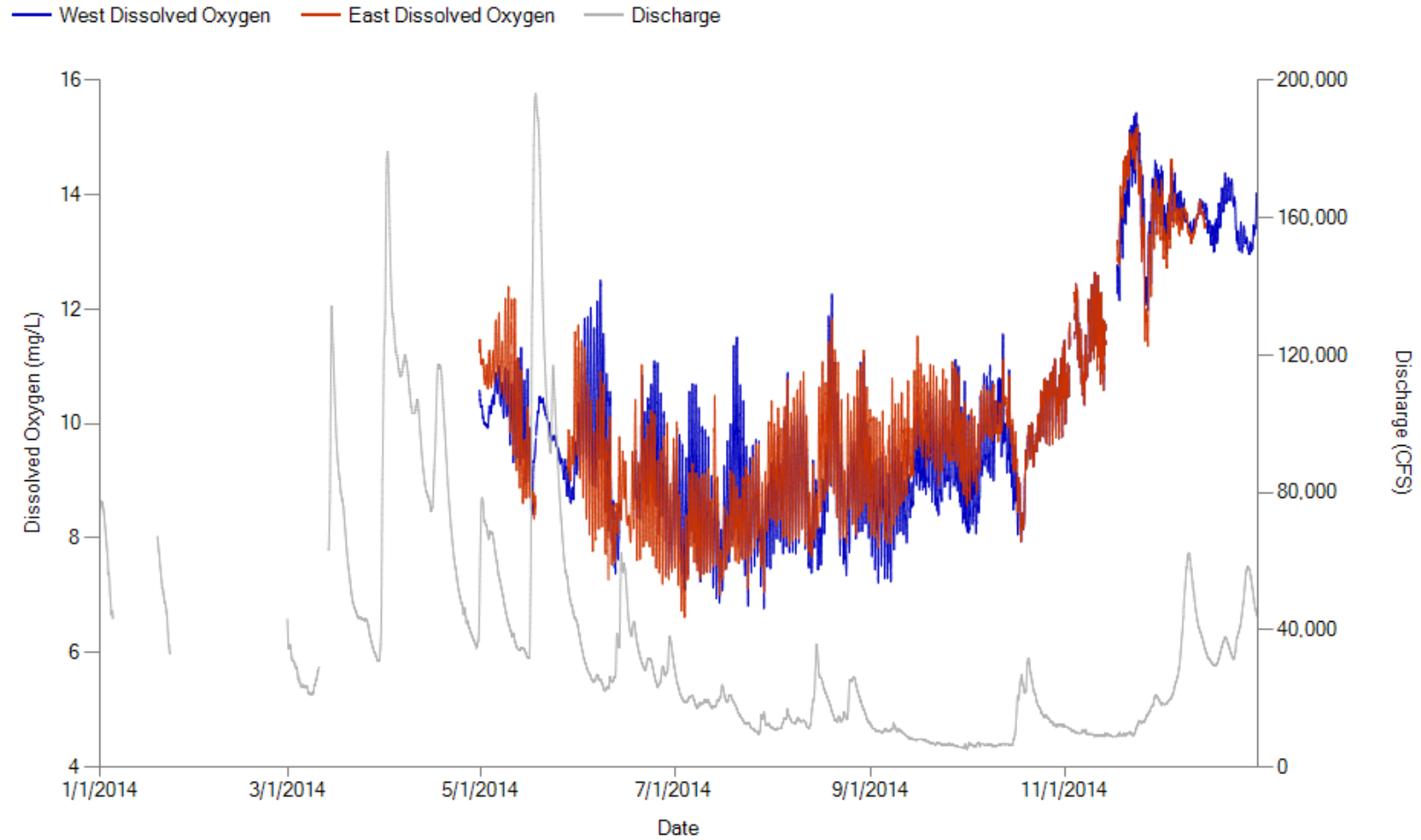


Figure 17. Continuous dissolved oxygen (mg/L) and discharge (cfs) at the two Marietta sites from April 30, 2014 to December 15, 2014.

2015 Dissolved Oxygen:

<i>West</i>	Min: 6.29 mg/L	Average: 10.78 mg/L	Max: 13.95 mg/L
<i>East</i>	Min: 6.96 mg/L	Average: 10.82 mg/L	Max: 13.58 mg/L

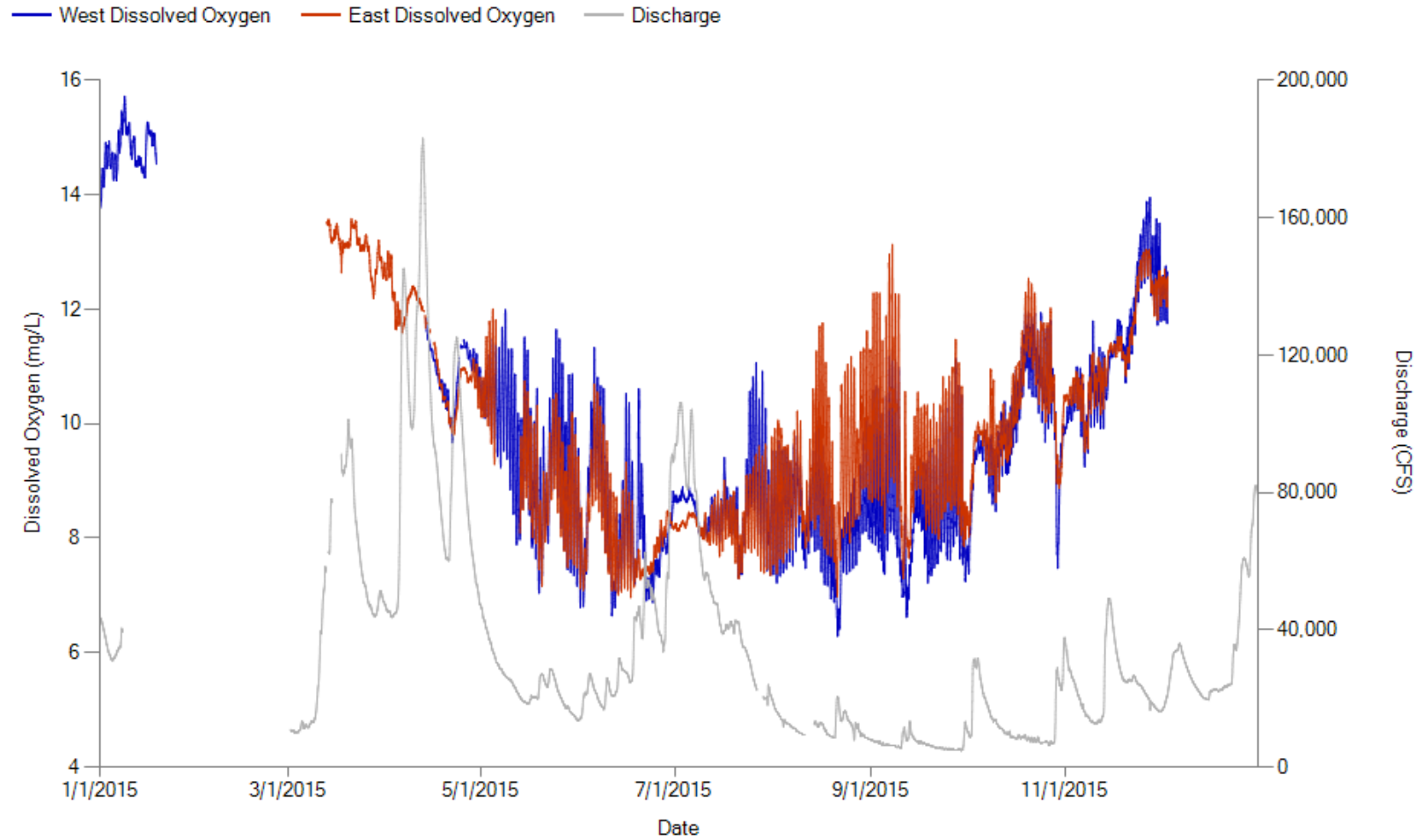


Figure 18. Continuous dissolved oxygen (mg/L) and discharge (cfs) at the two Marietta sites from March 13, 2015 to December 3, 2015.

2016 Dissolved Oxygen:

<i>West</i>	Min: 5.75 mg/L	Average: 10.34 mg/L	Max: 13.20 mg/L
<i>East</i>	Min: 6.40 mg/L	Average: 10.11 mg/L	Max: 13.00 mg/L

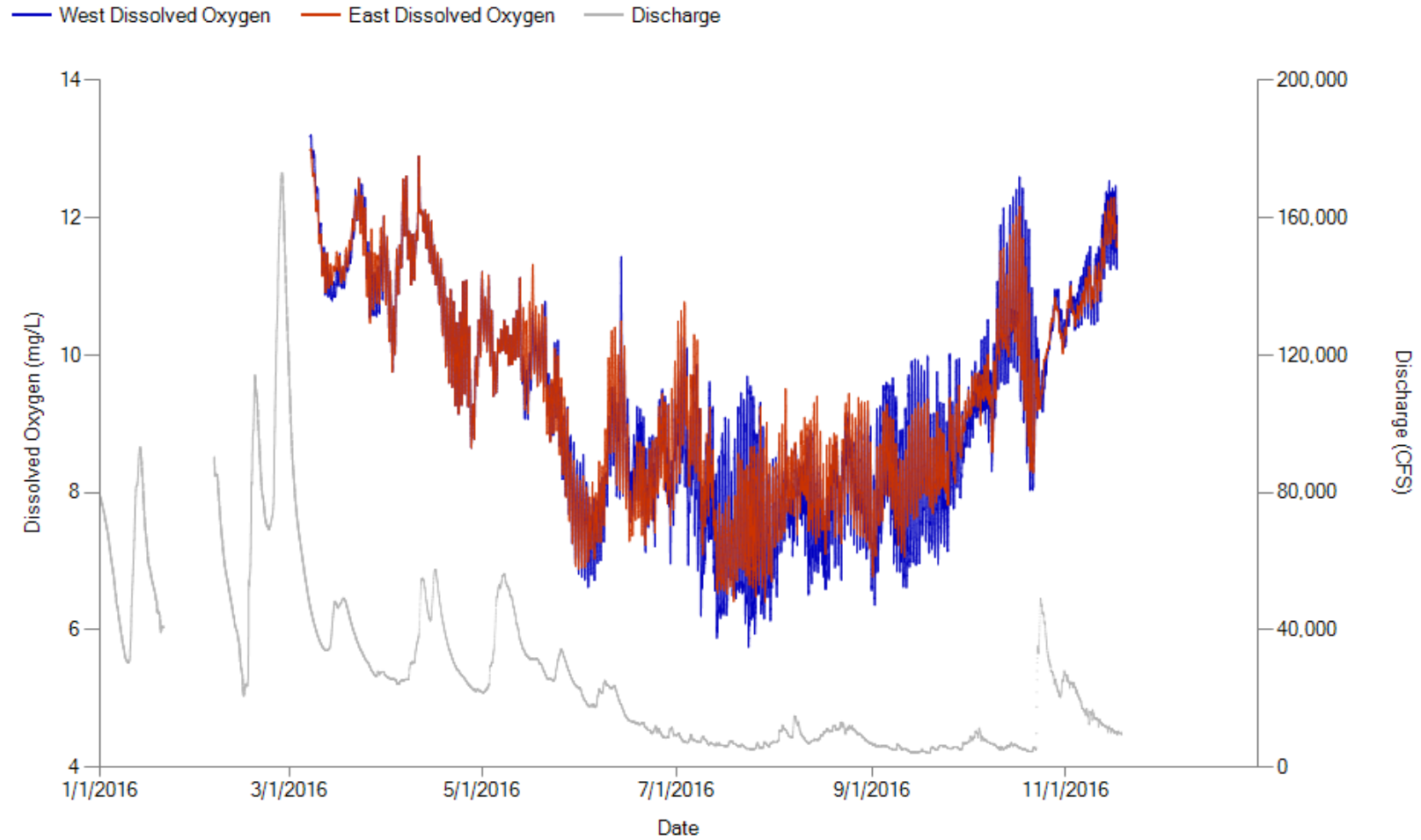


Figure 19. Continuous dissolved oxygen (mg/L) and discharge (cfs) at the two Marietta sites from March 7, 2016 to November 17, 2016.

2014 Turbidity:

West Min: 0.3 FNU
East Min: 0.1 FNU

Average: 6.7 FNU
Average: 8.2 FNU

Max: 50.2 FNU
Max: 51.2 FNU

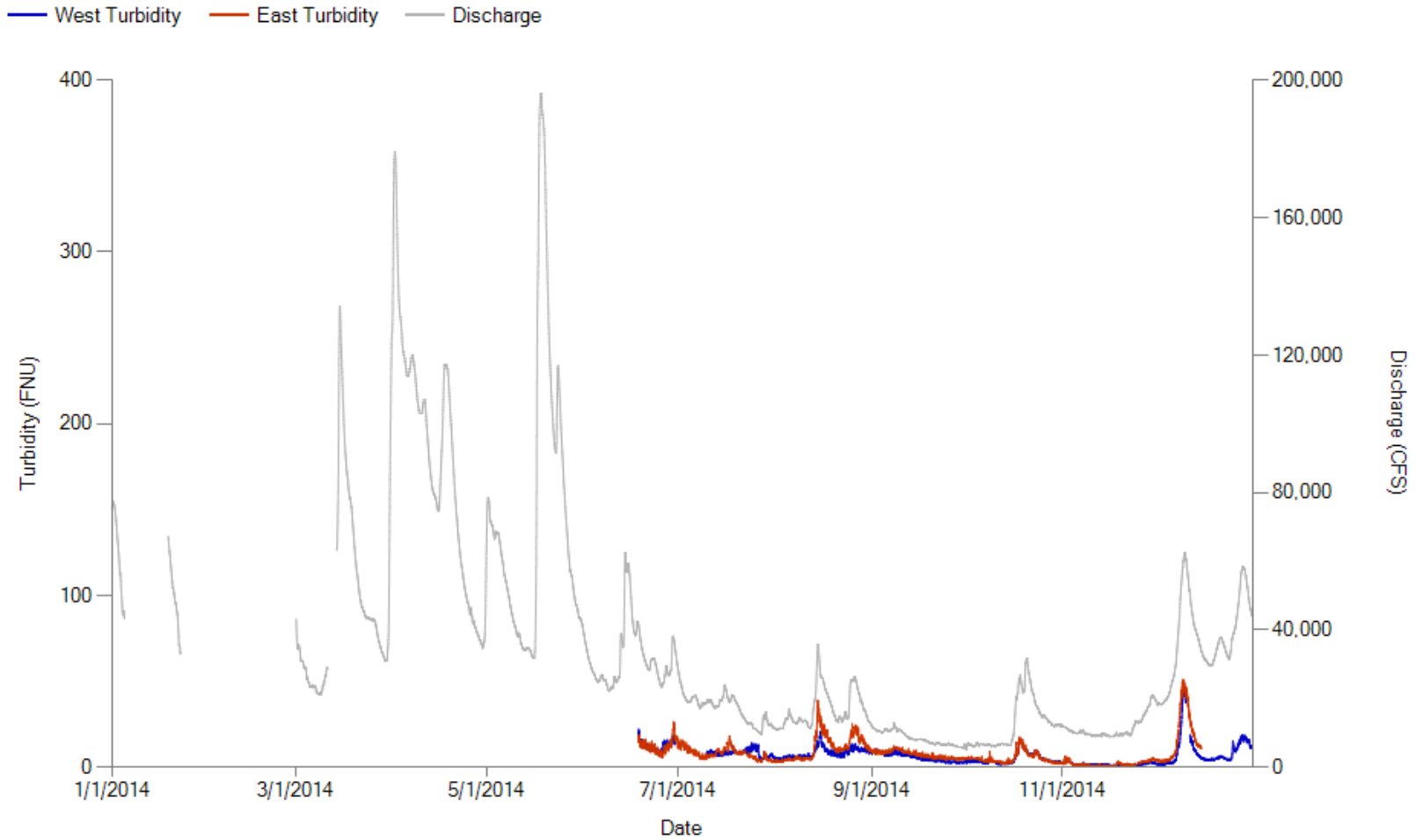


Figure 20. Continuous turbidity (FNU) and discharge (cfs) at the two Marietta sites from April 30, 2014 to December 15, 2014.

2015 Turbidity:

<i>West</i>	Min: 1.2 FNU	Average: 18.0 FNU	Max: 178.4 FNU
<i>East</i>	Min: 1.3 FNU	Average: 19.7 FNU	Max: 188.9 FNU

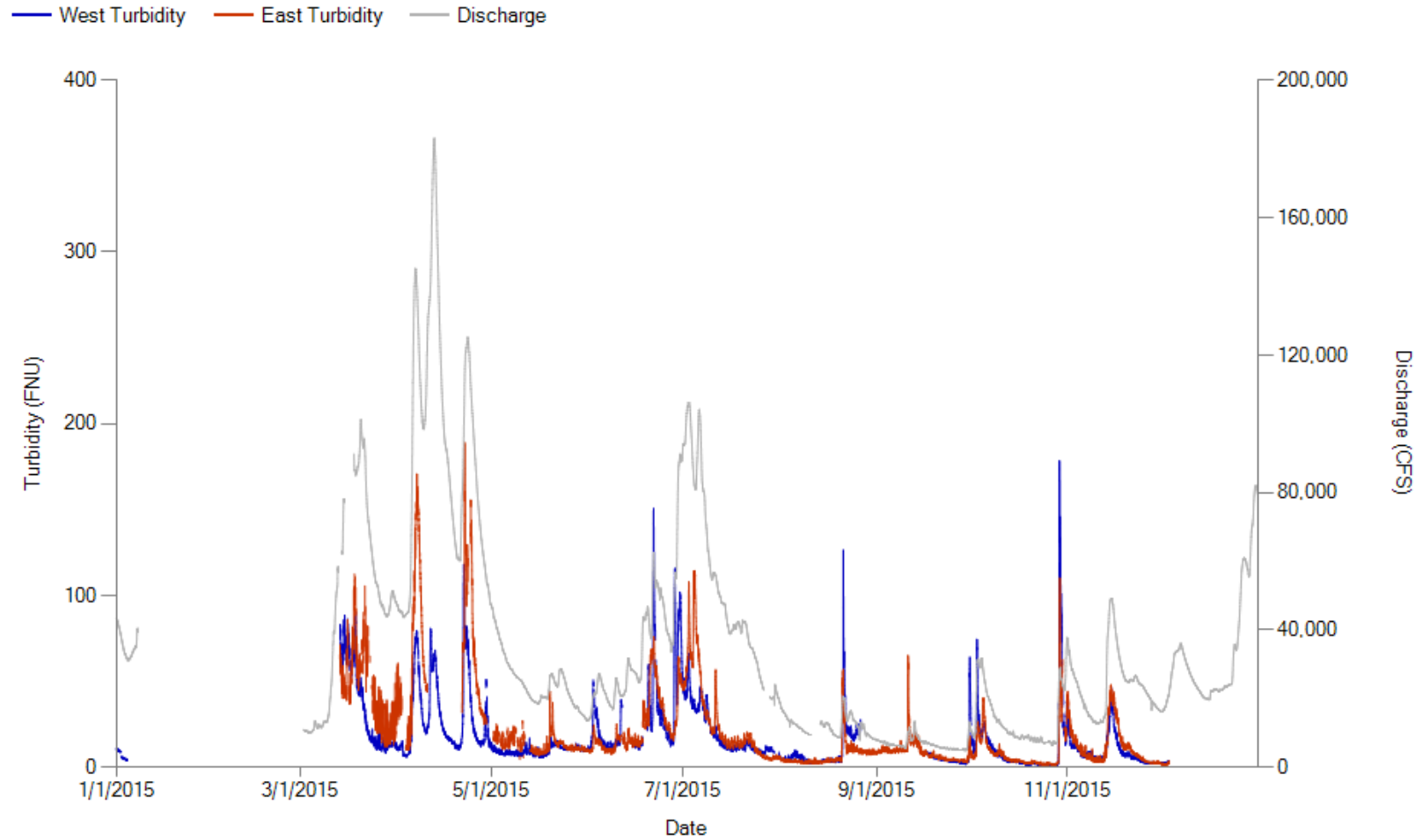


Figure 21. Continuous turbidity (FNU) and discharge (cfs) at the two Marietta sites from March 13, 2015 to December 3, 2015.

2016 Turbidity:

<i>West</i>	Min: 0.6 FNU	Average: 5.0 FNU	Max: 31.5 FNU
<i>East</i>	Min: 0.7 FNU	Average: 9.3 FNU	Max: 858.7 FNU

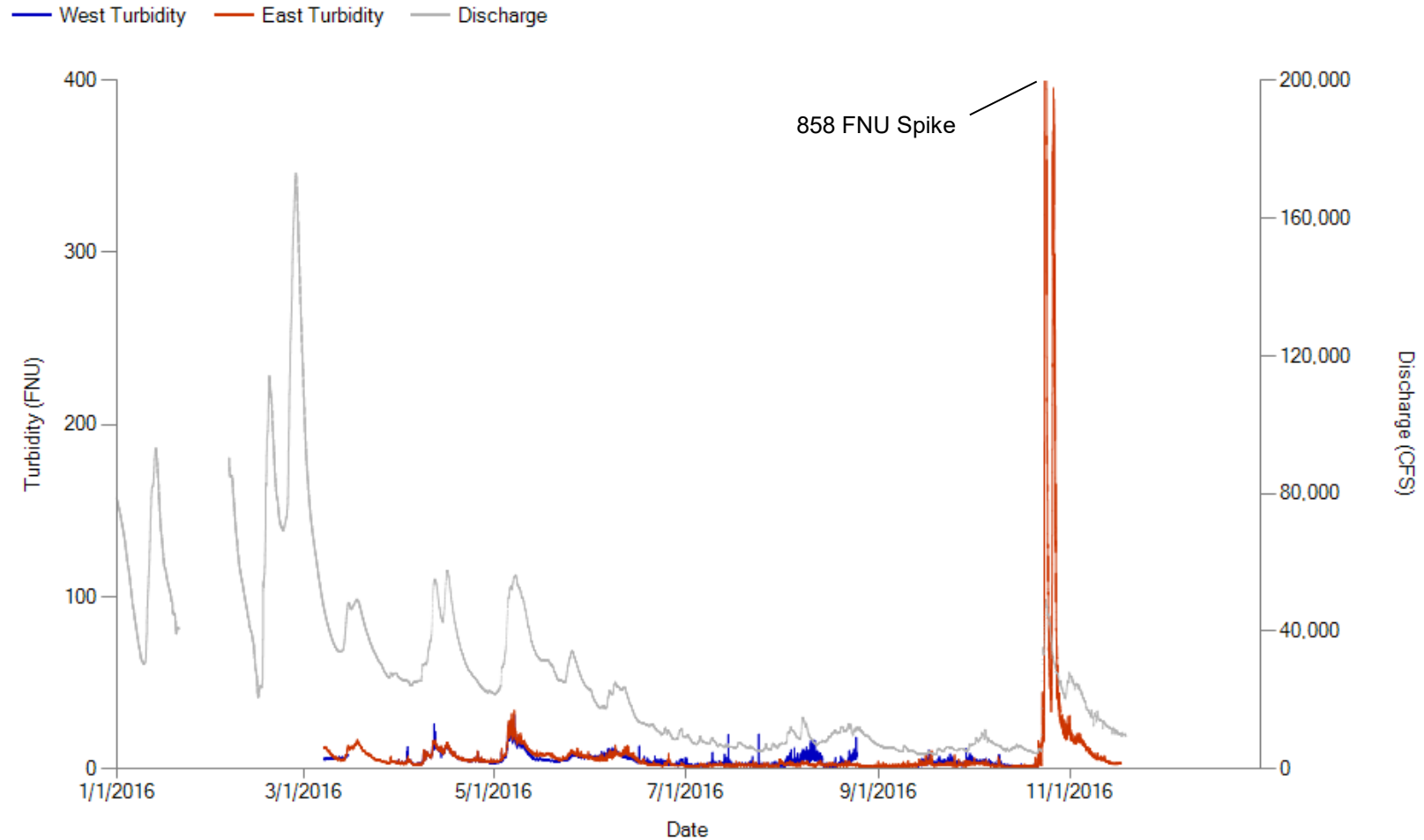


Figure 22. Continuous turbidity (FNU) and discharge (cfs) at the two Marietta sites from March 7, 2016 to November 17, 2016. A large spike on October 24 at the East site was cut off to maintain a consistent y-axis with other years that did not excessively compact other readings.

Table 3. Summary of discrete chemical sample results at the two Marietta CIM sites.

	PARAMETER	UNITS	WEST				EAST			
			n	nd	Mean	Median	n	nd	Mean	Median
METALS AND IONS	ACID SOLUBLE	µg/L	3	2	270	270	4	3	388	388
	ALUMINUM D	µg/L	20	7	19	18	20	8	18	19
	ALUMINUM T	µg/L	31	0	364	142	32	0	456	150
	BARIUM T	µg/L	31	0	36	35	36	1	33	31
	BORON T	µg/L	31	14	29	25	36	19	26	22
	BROMIDE	µg/L	31	7	45.53	30.57	36	7	37.18	27.62
	CADMIUM D	µg/L	9	9	NA	NA	12	12	NA	NA
	CALCIUM T	mg/L	31	0	27	27.2	36	1	26.6	26.3
	CHLORIDE T	mg/L	31	0	23	20	36	1	28	26
	COPPER D	µg/L	20	17	2.81	1.62	24	21	1.27	0.97
	COPPER T	µg/L	31	9	2.28	1.66	36	11	2.24	1.67
	IRON D	µg/L	20	6	30	26	24	9	47	32
	IRON T	µg/L	31	0	581	227	36	1	820	334
	LEAD D	µg/L	20	20	NA	NA	24	24	NA	NA
	LEAD T	µg/L	31	8	0.836	0.408	36	13	0.995	0.411
	LITHIUM D	µg/L	9	9	NA	NA	12	12	NA	NA
	LITHIUM T	µg/L	10	10	NA	NA	14	12	4	4
	MAGNESIUM T	mg/L	31	0	8.1	7.8	36	1	7.6	7.4
	MANGANESE D	µg/L	20	8	16	17	24	13	26	25
	MANGANESE T	µg/L	31	0	71	52	36	1	96	63
	NICKEL D	µg/L	9	9	NA	NA	12	12	NA	NA
	NICKEL T	µg/L	31	31	NA	NA	36	36	NA	NA
	POTASSIUM T	mg/L	14	0	2.226	2.245	17	1	2.082	2.164
SELENIUM T	µg/L	31	25	0.872	0.583	36	29	0.738	0.595	
SODIUM T	mg/L	31	0	13.928	11.95	36	1	16.837	16.1	
STRONTIUM T	µg/L	31	0	182	185	36	1	126	118	
SULFATE T	mg/L	31	0	35.816	34.91	36	1	34.297	31.81	
ZINC D	µg/L	20	13	11	10	24	15	12	11	
ZINC T	µg/L	31	8	11	9	36	9	13	10	
NUTRIENTS	AMMONIA D	mg/L	31	9	0.039	0.025	36	9	0.048	0.04
	AMMONIA T	mg/L	31	9	0.042	0.027	36	8	0.046	0.03
	NITRATE & NITRITE D	mg/L	31	0	0.719	0.66	36	1	0.65	0.62
	NITRATE & NITRITE T	mg/L	31	0	0.704	0.659	36	1	0.644	0.613
	NITROGEN D	mg/L	22	0	1.062	1.011	24	0	0.987	0.907
	NITROGEN T	mg/L	31	0	1.037	0.919	36	1	0.981	0.891
	ORTHO PHOSPHORUS	mg/L	31	2	0.015	0.009	36	8	0.014	0.011
	ORTHO PHOSPHORUS	mg/L	31	3	0.015	0.012	36	6	0.017	0.013
	PHOSPHORUS D	mg/L	31	1	0.018	0.013	36	3	0.017	0.015
	PHOSPHORUS T	mg/L	31	0	0.042	0.027	36	1	0.041	0.029
PHYSICAL/OTHER	ALKALINITY	mg/L	31	0	64.2	65.6	36	0	58.8	59.6
	GLYPHOSATE	µg/L	7	0	9	10	8	0	9	10
	HARDNESS T	mg/L	31	0	101	98	36	0	95	95
	OSMOTIC PRESSURE	mOsm	17	2	4	3	22	3	3	3
	pH	SU	31	0	8.16	8.2	36	0	8.06	8.1
	SPECIFIC COND	µS/cm ^c	31	0	276.8	261	36	0	276.7	276.5
	SSC - TOTAL	PPM	16	0	23.5	7.3	21	0	22.7	9.9
	SSC-COARSE	PPM	16	0	4.2	0.8	21	0	3.5	1.2
	SSC-FINE	PPM	16	0	19.3	6.5	21	0	19.2	7.5
	TDS	mg/L	31	0	170	172	36	0	170	175
	TOC	mg/L	31	0	2.605	2.485	36	1	2.713	2.54
TSS	mg/L	31	9	25	9	36	12	29	13	

Means and medians were calculated from measurements greater than the relevant detection limit.

n = number of samples. nd = number of non-detects. NA = mean/median not available, all data were non-detect

EVALUATION

The evaluation of CIM data incorporates water quality criteria from 25 Pa. Code § 93.7 and the 99% frequency rule from 25 Pa. Code § 96.3(c) as described in Hoger 2018a. Each reading represents a period of time equal to the recording interval. Because the sondes at this site recorded measurements every 30 minutes, 176 exceedances measured over a 365-day period constitutes a percentage greater than 1% ($176 \times 30 \text{ minutes} = 5,280 \text{ minutes}$ or 1.004% of a year). The evaluations in this report include 99% frequency rule calculations but do not include protected use assessment determinations.

Annual Variation and Critical Conditions

A major determinant of variation in water quality is the amount, timing, and location of precipitation in the watershed upstream of a site. Elevated precipitation will result in increased surface water discharge, which can moderate some instream conditions stressful for certain forms of aquatic life. In past surveys, DEP has documented that elevated discharge can reduce the magnitudes of daily fluctuations of DO, pH, and temperature, and can increase daily minimum DO and decrease daily maximum pH and temperature.

Figure 24 shows the large variation in stream discharge of the Susquehanna River at Marietta during the four summers covered by this report. These data demonstrate the difficulty in accurately assessing water quality in complex river systems with a temporally limited dataset. Compared with 2016 flows which remained relatively low throughout the summer and early fall, flows in 2013, 2014, and 2015 were much more variable during the same seasons.

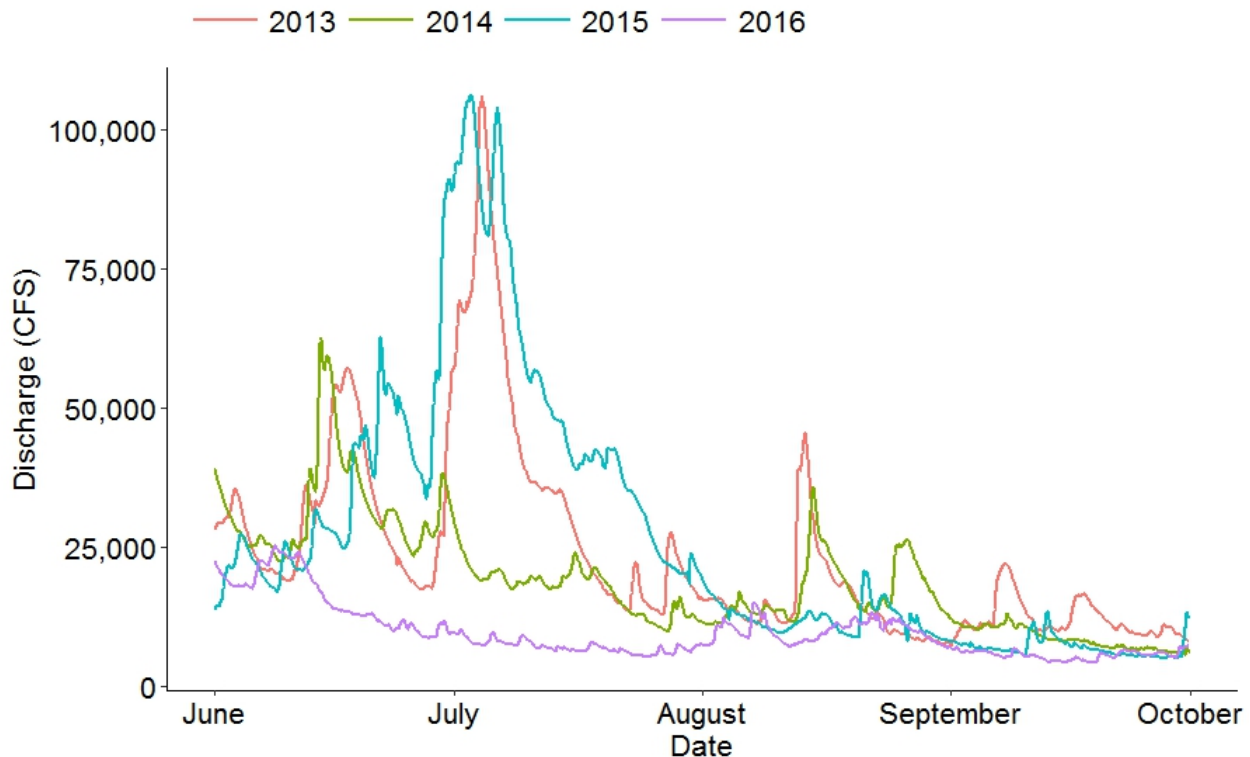


Figure 24. Discharge data from USGS station 01576000, Susquehanna River at Marietta, for the summer and early fall of 2013 to 2016.

Cross-Sectional Surveys

Temperature, specific conductance, and turbidity transects show significant differences in water quality along either bank, with effects extending out as much as a quarter of the river's width (Figure 3). Most often, readings for these three parameters along the banks were higher than central transect points, differences attributable to the influence of local tributaries with significantly different water quality. The spatial effect of these tributaries on water quality at the Marietta site varied depending on the amount and timing of rainfall locally and in the upper portions of the watershed. DO and pH data showed less variability across the width of the river, with differences only reaching significant levels on a few occasions, and only just along the banks (Figure 3). Relative to MAR5, MAR1 showed significantly lower DO and pH in the early morning during summer collections (Figure 3), which is due to the formation of more stagnant water along that bank and increased respiration overnight.

CIM, Temperature

Temperature varied only slightly between the two Marietta CIM sites. Deviations in temperature readings between the two sites were observed mostly during higher-flow events. Temperature minima, maxima, and averages were similar across survey years, with differences less than 1°C. Maximum temperatures exceeded 29.5°C at both CIM sites all four years and exceeded 32°C at both sites in 2013 and 2016 (Figures 4 to 7).

CIM, Specific Conductance

Specific conductance was slightly higher in most years at the East CIM site, except in 2013 where the mean specific conductance was higher at the West site. At both CIM sites, specific conductance exhibited negative correlation with river discharge each year, with specific conductance increasing as river flows dropped and specific conductance decreasing during periods of higher flows (Figures 8 to 11).

CIM, pH

Exceedances of the maximum pH water quality criterion of 9.0 units occurred at both Marietta CIM sites in 2014 and 2015, and at the West site in 2016 (Figures 13 to 15, Table 4). In 2014, the number of exceedances of the maximum pH criterion at both Marietta CIM sites was greater than 1% of the year. Although individual readings exceeded the maximum pH criterion in 2015 and 2016, the number of exceedances did not reach the 1% threshold. The maximum number of pH criterion exceedances in a 365-day period during these four years was 327 (1.87%) at the West site and 302 (1.72%) at the East site. The greatest number of exceedances in any rolling 365-day period at Marietta was determined to be May 31, 2014 to May 20, 2015 for the West site and May 6, 2014 to May 5, 2015 for the East site. No maximum pH criterion exceedances were observed during 2013 (Table 4), and no exceedances of the minimum criterion were measured during the study.

Table 4. Annual exceedances of pH water quality criteria.

Year	Marietta West		Marietta East	
	No.	%	No.	%
2013	0	0.00	0	0.00
2014	223	1.27	295	1.68
2015	112	0.63	151	0.86
2016	5	0.02	0	0.00
rolling year	327	1.87	302	1.72

Percent calculations are percentages of each year.

Red text indicates > 1% exceedance frequency.

The timing of pH criterion exceedances was not consistent between years or between sites. In 2014 at the West site, the most and highest exceedances were observed in mid- to late August with a few exceedances observed in late spring and early summer (Figure 13). In 2014 at the East site, however, pH criterion exceedances were mostly observed in May and June with only a few exceedances observed in August (Figure 13). In 2015, a distinctly different pattern was observed: at the West site, almost all pH criterion exceedances were observed in May with no exceedances observed after June 15, while at the East site only a couple exceedances were observed in May with the majority of exceedances observed in August and early September (Figure 14). In the summer and fall of 2016, smaller diel pH swings were observed at the East site than at the West site (Figure 15).

CIM, Dissolved Oxygen

Neither of the Marietta CIM sites exceeded the WWF minimum DO criterion of 5.0 mg/L at any point during the study period (Figures 16 to 19). Average DO each year was

very similar between sites (Figures 16 to 19). The largest difference in annual DO averages between sites was in 2016 when the annual DO average was 0.23 mg/L higher at the West site than the East site (Figure 19). Dissolved oxygen readings at Marietta did not fall below the WWF minimum DO criterion in 2016 as DEP staff expected based on the prolonged period of low-flow conditions (Figure 19) coupled with field observations and measurements in other areas of the Susquehanna River watershed that did exceed the criterion during the same time frame. During the late summer and early fall of 2015, the magnitudes of diel DO swings were higher at the East site than at the West site (Figure 18) whereas the magnitudes of diel DO swings were higher at the West site than at the East site during the same time of year in 2016 (Figure 19).

CIM, Turbidity

Through the three years of turbidity data collection, the Marietta West site tended to have lower turbidity readings than the Marietta East site (Figures 20 to 22). Spikes in turbidity readings were evident at both sites during high flows (Figures 20 to 22). Due to the variable timing, location, duration, and intensity of precipitation events in the watershed, the turbidity spikes at Marietta did not always directly correlate with river discharge. Due to sensor fouling, and subsequent removal of data from the record, during some high-flow events, caution should be used when comparing turbidity data between years or sites. For instance, during a high-flow event in late October of 2016, sensor fouling rendered the data from the West site unusable, but the sensor at the East site recorded very high turbidity (Figure 22). Due to these data being lost from the West site, average turbidity at the East site was almost double that of the West site in 2016, and the maximum turbidity at the East site was over 25 times greater than that of the West in 2016 (Figure 22). In contrast, the average and maximum turbidity between the two sites was more comparable in 2014 and 2015 when the datasets were more complete at both sites (Figures 20 and 21).

Discrete Water Chemistry Sampling

Results from chemical analyses of the grab samples vary between the two Marietta CIM sites but the means and medians of many of the parameters are very similar at both sites (Table 3) consistent with the CIM data showing generally similar water quality at both sites (Figures 4 to 22). In particular, all of the nutrient parameters had very comparable means and medians at both sites (Table 3). Notably higher results for acid-soluble aluminum, total aluminum, and total iron were observed at the East site than at the West site (Table 3). Total strontium was the only other parameter from the discrete sampling for which a notably different mean and median was observed between the two Marietta CIM sites, with notably higher results at the West site than at the East site (Table 3).

SUMMARY

The data collected at Marietta indicate that the river is more completely mixed at Marietta compared to 50 km upriver at Rockville where the river is characterized by three distinct, incompletely mixed water quality zones (Hoger 2019). Physiochemical differences in water quality between the two CIM sites at Marietta were much smaller

and less conspicuous than the cross-sectional differences in water quality documented upstream at Rockville. During higher-flow events, more notable variations in water quality were observed between the East and West CIM sites at Marietta, but conditions at both sites were more comparable during baseflow conditions. Basic annual statistics (i.e., minima, maxima, and means) of the CIM data were similar at the two sites, but notable differences were observed for some parameters in the timing of criterion exceedances during some years and occasionally in the magnitude and timing of diel swings.

Maximum pH criterion exceedances greater than 1% of the year were documented in the 2014 CIM data at both Marietta sites. Measurements above the 9.0 maximum pH criterion were observed in 2015 and 2016, but represented less than 1% of each of those years, and no pH values above 9.0 were recorded in 2013. DEP will continue collecting and analyzing data from the Marietta East and West sites as long-term monitoring stations.

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